Common Lisp Object System Specification

2. Functions in the Programmer Interface

Authors: Daniel G. Bobrow, Linda G. DeMichiel, Richard P. Gabriel, Sonya E. Keene, Gregor Kiczales, and David A. Moon.

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“The X3J13 Committee hereby accepts chapters 1 and 2 of the Common Lisp Object System, as defined in document 88-002R, for inclusion in the Common Lisp language being specified by this committee. Subsequent changes will be handled through the usual editorial and cleanup processes.”
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This chapter describes the functions, macros, special forms, and generic functions provided by the Common Lisp Object System Programmer Interface. The Programmer Interface comprises the functions and macros that are sufficient for writing most object-oriented programs.

This chapter is reference material that requires an understanding of the basic concepts of the Common Lisp Object System. The functions are arranged in alphabetical order for convenient reference.

The description of each function, macro, special form, and generic function includes its purpose, its syntax, the semantics of its arguments and returned values, and often an example and cross-references to related functions.

The syntax description for a function, macro, or special form describes its parameters. The following is an example of the format for the syntax description of a function:

**Syntax:**

```lisp
F x y &optional z &key k
```

This description indicates that the generic function `F` has two required parameters, `x` and `y`. In addition, there is an optional parameter `z` and a keyword parameter `k`.

The generic functions described in this chapter are all standard generic functions. They all use standard method combination.

The description of a generic function includes descriptions of the methods that are defined on that generic function by the Common Lisp Object System. A **method signature** is used to describe the parameters and parameter specializers for each method. The following is an example of the format for a method signature:

**Method Signature:**

```lisp
F (x class) (y t) &optional z &key k
```

This signature indicates that this method on the generic function `F` has two required parameters, `x`, which must be an instance of the class `class`, and `y`, which can be any object. In addition, there is an optional parameter `z` and a keyword parameter `k`. This signature also indicates that this method on `F` is a primary method and has no qualifiers.

The syntax description for a generic function describes the lambda-list of the generic function itself, while the method signatures describe the lambda-lists of the defined methods.

Any implementation of the Common Lisp Object System is allowed to provide additional methods on the generic functions described in this chapter.
It is useful to categorize the functions and macros according to their role in this standard:

- **Tools used for simple object-oriented programming**
  
  These tools allow for defining new classes, methods, and generic functions, and for making instances. Some tools used within method bodies are also listed here. Some of the macros listed here have a corresponding function that performs the same task at a lower level of abstraction.

  - `call-next-method`
  - `change-class`
  - `defclass`
  - `defgeneric`
  - `defmethod`
  - `generic-flet`
  - `generic-function`
  - `generic-labels`
  - `initialize-instance`
  - `make-instance`
  - `next-method-p`
  - `slot-boundp`
  - `slot-value`
  - `with-accessors`
  - `with-added-methods`
  - `with-slots`

- **Functions underlying the commonly used macros**

  - `add-method`
  - `class-name`
  - `compute-applicable-methods`
  - `ensure-generic-function`
  - `find-class`
  - `find-method`
  - `function-keywords`
  - `make-instances-obsolete`
  - `no-applicable-method`
  - `no-next-method`
  - `reinitialize-instance`
  - `remove-method`
  - `shared-initialize`
  - `slot-exists-p`
  - `slot-makunbound`
  - `slot-missing`
  - `slot-unbound`
  - `update-instance-for-different-class`
update-instance-for-redefined-class

- Tools for declarative method combination
  
  call-method
  define-method-combination
  invalid-method-error
  method-combination-error
  method-qualifiers

- General Common Lisp support tools
  
  class-of
  describe
  documentation
  print-object
  symbol-macrolet
Notation

This specification uses an extended Backus Normal Form (BNF) to describe the syntax of the Object System. This section discusses the syntax of BNF expressions. The primary extension used is the following:

\[ [O] \]

An expression of this form will appear whenever a list of elements is to be spliced into a larger structure and the elements can appear in any order. The symbol \( O \) represents a description of the syntax of some number of syntactic elements to be spliced; that description must be of the form

\[ O_1 \mid \ldots \mid O_N \]

where each \( O_i \) can be either of the form \( S \) or of the form \( S^* \). The expression \([O]\) means that a list of the form

\[ (O_{i_1} \ldots O_{i_j}) \quad 1 \leq j \]

is spliced into the enclosing expression, such that if \( n \neq m \) and \( 1 \leq n, m \leq j \), then either \( O_{i_n} \neq O_{i_m} \) or \( O_{i_n} = O_{i_m} = Q_k \), where for some \( 1 \leq k \leq N \), \( O_k \) is of the form \( Q_k^* \).

For example, the expression

\[(x [A \mid B^* \mid C] y)\]

means that at most one \( A \), any number of \( B \)'s, and at most one \( C \) can occur in any order. It is a description of any of these:

\[(x y)\]
\[(x B A C y)\]
\[(x A B B B B B C y)\]
\[(x C B A B B B y)\]

but not any of these:

\[(x B B A A C C y)\]
\[(x C B C y)\]

In the first case, both \( A \) and \( C \) appear too often, and in the second case \( C \) appears too often.
A simple indirection extension is introduced in order to make this new syntax more readable:

\[ \downarrow O \]

If \( O \) is a non-terminal symbol, the right-hand side of its definition is substituted for the entire expression \( \downarrow O \). For example, the following BNF is equivalent to the BNF in the previous example:

\[
(x \ [ \downarrow O \ ] \ y) \\
O ::= A \mid B* \mid C
\]
add-method  

Purpose:

The generic function add-method adds a method to a generic function. It destructively modifies the generic function and returns the modified generic function as its result.

Syntax:

add-method generic-function method

Method Signatures:

add-method (generic-function standard-generic-function)

Arguments:

The generic-function argument is a generic function object.

The method argument is a method object. The lambda-list of the method function must be congruent with the lambda-list of the generic function, or an error is signaled.

Values:

The modified generic function is returned. The result of add-method is eq to the generic-function argument.

Remarks:

If the given method agrees with an existing method of the generic function on parameter specializers and qualifiers, the existing method is replaced. See the section “Agreement on Parameter Specializers and Qualifiers” for a definition of agreement in this context.

If the method object is a method object of another generic function, an error is signaled.

See Also:

“Agreement on Parameter Specializers and Qualifiers”

defmethod
defgeneric
find-method
remove-method

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call-method

Macro

Purpose:

The macro `call-method` is used in method combination. It hides the implementation-dependent details of how methods are called. The macro `call-method` has lexical scope and can only be used within an effective method form.

The macro `call-method` invokes the specified method, supplying it with arguments and with definitions for `call-next-method` and for `next-method-p`. The arguments are the arguments that were supplied to the effective method form containing the invocation of `call-method`. The definitions of `call-next-method` and `next-method-p` rely on the list of method objects given as the second argument to `call-method`.

The `call-next-method` function available to the method that is the first subform will call the first method in the list that is the second subform. The `call-next-method` function available in that method, in turn, will call the second method in the list that is the second subform, and so on, until the list of next methods is exhausted.

Syntax:

```
call-method  method  next-method-list
```  

[Macro]

Arguments:

The `method` argument is a method object; the `next-method-list` argument is a list of method objects.

A list whose first element is the symbol `make-method` and whose second element is a Lisp form can be used instead of a method object as the first subform of `call-method` or as an element of the second subform of `call-method`. Such a list specifies a method object whose method function has a body that is the given form.

Values:

The result of `call-method` is the value or values returned by the method invocation.

See Also:

- `call-next-method`
- `define-method-combination`
- `next-method-p`
call-next-method

Purpose:

The function call-next-method can be used within the body of a method defined by a method-defining form to call the next method.

The function call-next-method returns the value or values returned by the method it calls. If there is no next method, the generic function no-next-method is called.

The type of method combination used determines which methods can invoke call-next-method. The standard method combination type allows call-next-method to be used within primary methods and :around methods. The standard method combination type defines the next method as follows:

- If call-next-method is used in an :around method, the next method is the next most specific :around method, if one is applicable.
- If there are no :around methods at all or if call-next-method is called by the least specific :around method, other methods are called as follows:
  - All the :before methods are called, in most-specific-first order. The function call-next-method cannot be used in :before methods.
  - The most specific primary method is called. Inside the body of a primary method, call-next-method may be used to pass control to the next most specific primary method. The generic function no-next-method is called if call-next-method is used and there are no more primary methods.
  - All the :after methods are called in most-specific-last order. The function call-next-method cannot be used in :after methods.

For further discussion of call-next-method, see the sections “Standard Method Combination” and “Built-in Method Combination Types.”

Syntax:

\[ \text{call-next-method \&rest \textit{args}} \]

Arguments:

When call-next-method is called with no arguments, it passes the current method’s original arguments to the next method. Neither argument defaulting, nor using setq, nor rebinding variables with the same names as parameters of the method affects the values call-next-method passes to the method it calls.
call-next-method

When `call-next-method` is called with arguments, the next method is called with those arguments. When providing arguments to `call-next-method`, the following rule must be satisfied or an error is signaled: The ordered set of methods applicable for a changed set of arguments for `call-next-method` must be the same as the ordered set of applicable methods for the original arguments to the generic function. Optimizations of the error checking are possible, but they must not change the semantics of `call-next-method`.

If `call-next-method` is called with arguments but omits optional arguments, the next method called defaults those arguments.

Values:

The function `call-next-method` returns the value or values returned by the method it calls.

Remarks:

Further computation is possible after `call-next-method` returns.

The function `call-next-method` has lexical scope and indefinite extent.

For generic functions using a type of method combination defined by the short form of `define-method-combination`, `call-next-method` can be used in `:around` methods only.

The function `next-method-p` can be used to test whether there is a next method.

If `call-next-method` is used in methods that do not support it, an error is signaled.

See Also:

“Method Selection and Combination”
“Standard Method Combination”
“Built-in Method Combination Types”
`define-method-combination`
`next-method-p`
`no-next-method`

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change-class

Standard Generic Function

Purpose:

The generic function change-class changes the class of an instance to a new class. It destructively modifies and returns the instance.

If in the old class there is any slot of the same name as a local slot in the new class, the value of that slot is retained. This means that if the slot has a value, the value returned by slot-value after change-class is invoked is eql to the value returned by slot-value before change-class is invoked. Similarly, if the slot was unbound, it remains unbound. The other slots are initialized as described in the section “Changing the Class of an Instance.”

Syntax:

change-class instance new-class

[Generic Function]

Method Signatures:

change-class (instance standard-object) (new-class standard-class)

[Primary Method]

change-class (instance t) (new-class symbol)

[Primary Method]

Arguments:

The instance argument is a Lisp object.

The new-class argument is a class object or a symbol that names a class.

If the second of the above methods is selected, that method invokes change-class on instance and (find-class new-class).

Values:

The modified instance is returned. The result of change-class is eq to the instance argument.

Examples:

(defclass position () ())

(defclass x-y-position (position)
  ((x :initform 0 :initarg :x)
   (y :initform 0 :initarg :y)))
(defclass rho-theta-position (position)
  ((rho :initform 0)
   (theta :initform 0)))

(defmethod update-instance-for-different-class :before ((old x-y-position)
  (new rho-theta-position)
  &key)
  ;; Copy the position information from old to new to make new
  ;; be a rho-theta-position at the same position as old.
  (let ((x (slot-value old 'x))
        (y (slot-value old 'y)))
    (setf (slot-value new 'rho) (sqrt (+ (* x x) (* y y)))
          (slot-value new 'theta) (atan y x))))

;; At this point an instance of the class x-y-position can be
;; changed to be an instance of the class rho-theta-position using
;; change-class:
(setq p1 (make-instance 'x-y-position :x 2 :y 0))
(change-class p1 'rho-theta-position)

;; The result is that the instance bound to p1 is now an instance of
;; the class rho-theta-position. The update-instance-for-different-class
;; method performed the initialization of the rho and theta slots based
;; on the value of the x and y slots, which were maintained by
;; the old instance.

Remarks:

After completing all other actions, change-class invokes the generic function update-instance-for-different-class. The generic function update-instance-for-different-class can be used to assign values to slots in the transformed instance.

The generic function change-class has several semantic difficulties. First, it performs a destructive operation that can be invoked within a method on an instance that was used to select that method. When multiple methods are involved because methods are being combined, the methods currently executing or about to be executed may no longer be applicable. Second, some implementations might use compiler optimizations of slot access, and when the class of an instance is changed the assumptions the compiler made might be violated. This implies that a programmer must not use change-class inside a method if any methods for that generic function access any slots, or the results are undefined.
change-class

See Also:

“Changing the Class of an Instance”

update-instance-for-different-class
class-name, (setf class-name)  

*Standard Generic Function*

Purpose:

The generic function `class-name` takes a class object and returns its name.

The generic function `(setf class-name)` takes a class object and sets its name.

Syntax:

```
class-name class                      [Generic Function]
(setf class-name) new-value class     [Generic Function]
```

Method Signatures:

```
class-name (class class)              [Primary Method]
(setf class-name) new-value (class class) [Primary Method]
```

Arguments:

The `class` argument is a class object.

The `new-value` argument is any object.

Values:

The name of the given class is returned.

Remarks:

The name of an anonymous class is `nil`.

If `S` is a symbol such that `S = (class-name C)` and `C = (find-class S)`, then `S` is the proper name of `C`. For further discussion, see the section “Classes.”

See Also:

“Classes”

`find-class`
class-of

Purpose:
The function class-of returns the class of which the given object is an instance.

Syntax:

```lisp
class-of object
```

Arguments:
The argument to class-of may be any Common Lisp object.

Values:
The function class-of returns the class of which the argument is an instance.
compute-applicable-methods

Function

Purpose:

Given a generic function and a set of arguments, the function `compute-applicable-methods` returns the set of methods that are applicable for those arguments. The methods are sorted according to precedence order. See the section “Method Selection and Combination.”

Syntax:

```
compute-applicable-methods generic-function function-arguments
```

Arguments:

The `generic-function` argument is a generic function object. The `function-arguments` argument is a list of the arguments to that generic function.

Values:

The result is a list of the applicable methods in order of precedence.

See Also:

“Method Selection and Combination”
defclass

Purpose:

The macro defclass defines a new named class. It returns the new class object as its result.

The syntax of defclass provides options for specifying initialization arguments for slots, for specifying default initialization values for slots, and for requesting that methods on specified generic functions be automatically generated for reading and writing the values of slots. No reader or writer functions are defined by default; their generation must be explicitly requested.

Defining a new class also causes a type of the same name to be defined. The predicate (typep object class-name) returns true if the class of the given object is class-name itself or a subclass of the class class-name. A class object can be used as a type specifier. Thus (typep object class) returns true if the class of the object is class itself or a subclass of class.
Syntax:

```lisp
defclass class-name ({superclass-name}*) ({slot-specifier}*) ([class-option])

class-name::= symbol
superclass-name::= symbol
slot-specifier::= slot-name | (slot-name [slot-option])
slot-name::= symbol
slot-option::= { :reader reader-function-name }* | { :writer writer-function-name }* | { :accessor reader-function-name }* | { :allocation allocation-type } | { :initarg initarg-name }* | { :initform form } | { :type type-specifier } | { :documentation string } 
reader-function-name::= symbol
writer-function-name::= function-specifier
function-specifier::= { symbol | (setf symbol) }
initarg-name::= symbol
allocation-type::= :instance | :class
class-option::= (:default-initargs initarg-list) | (:documentation string) | (:metaclass class-name)
initarg-list::= { initarg-name default-initial-value-form }*
```

Figure 2–1. Syntax for defclass
defclass

Arguments:

The class-name argument is a non-nil symbol. It becomes the proper name of the new class. If a class with the same proper name already exists and that class is an instance of standard-class, and if the defclass form for the definition of the new class specifies a class of class standard-class, the definition of the existing class is replaced.

Each superclass-name argument is a non-nil symbol that specifies a direct superclass of the new class. The new class will inherit slots and methods from each of its direct superclasses, from their direct superclasses, and so on. See the section “Inheritance” for a discussion of how slots and methods are inherited.

Each slot-specifier argument is the name of the slot or a list consisting of the slot name followed by zero or more slot options. The slot-name argument is a symbol that is syntactically valid for use as a Common Lisp variable name. If there are any duplicate slot names, an error is signaled.

The following slot options are available:

- The :reader slot option specifies that an unqualified method is to be defined on the generic function named reader-function-name to read the value of the given slot. The reader-function-name argument is a non-nil symbol. The :reader slot option may be specified more than once for a given slot.

- The :writer slot option specifies that an unqualified method is to be defined on the generic function named writer-function-name to write the value of the slot. The writer-function-name argument is a function specifier. The :writer slot option may be specified more than once for a given slot.

- The :accessor slot option specifies that an unqualified method is to be defined on the generic function named reader-function-name to read the value of the given slot and that an unqualified method is to be defined on the generic function named (setf reader-function-name) to be used with setf to modify the value of the slot. The reader-function-name argument is a non-nil symbol. The :accessor slot option may be specified more than once for a given slot.

- The :allocation slot option is used to specify where storage is to be allocated for the given slot. Storage for a slot may be located in each instance or in the class object itself. The value of the allocation-type argument can be either the keyword :instance or the keyword :class. The :allocation slot option may be specified once at most for a given slot. If the :allocation slot option is not specified, the effect is the same as specifying :allocation :instance.

  - If allocation-type is :instance, a local slot of the given name is allocated in each instance of the class.

  - If allocation-type is :class, a shared slot of the given name is allocated in the class object created by this defclass form. The value of the slot is shared by all instances of the class. If a class \( C_1 \) defines such a shared slot, any subclass \( C_2 \) of \( C_1 \) will share this single slot unless the defclass form for \( C_2 \) specifies a slot of the same name or there is a superclass
of $C_2$ that precedes $C_1$ in the class precedence list of $C_2$ and that defines a slot of the same name.

- The `:initform` slot option is used to provide a default initial value form to be used in the initialization of the slot. The `:initform` slot option may be specified once at most for a given slot. This form is evaluated every time it is used to initialize the slot. The lexical environment in which this form is evaluated is the lexical environment in which the `defclass` form was evaluated. Note that the lexical environment refers both to variables and to functions. For local slots, the dynamic environment is the dynamic environment in which `make-instance` was called; for shared slots, the dynamic environment is the dynamic environment in which the `defclass` form was evaluated. See the section “Object Creation and Initialization.”

No implementation is permitted to extend the syntax of `defclass` to allow `(slot-name form)` as an abbreviation for `(slot-name :initform form)`.

- The `:initarg` slot option declares an initialization argument named `initarg-name` and specifies that this initialization argument initializes the given slot. If the initialization argument has a value in the call to `initialize-instance`, the value will be stored into the given slot, and the slot’s `:initform` slot option, if any, is not evaluated. If none of the initialization arguments specified for a given slot has a value, the slot is initialized according to the `:initform` slot option, if specified. The `:initarg` slot option can be specified more than once for a given slot. The `initarg-name` argument can be any symbol.

- The `:type` slot option specifies that the contents of the slot will always be of the specified data type. It effectively declares the result type of the reader generic function when applied to an object of this class. The result of attempting to store in a slot a value that does not satisfy the type of the slot is undefined. The `:type` slot option may be specified once at most for a given slot. The `:type` slot option is further discussed in the section “Inheritance of Slots and Slot Options.”

- The `:documentation` slot option provides a documentation string for the slot.

Each class option is an option that refers to the class as a whole or to all class slots. The following class options are available:

- The `:default-initargs` class option is followed by a list of alternating initialization argument names and default initial value forms. If any of these initialization arguments does not appear in the initialization argument list supplied to `make-instance`, the corresponding default initial value form is evaluated, and the initialization argument name and the form’s value are added to the end of the initialization argument list before the instance is created (see the section “Object Creation and Initialization”). The default initial value form is evaluated each time it is used. The lexical environment in which this form is evaluated is the lexical environment in which the `defclass` form was evaluated. The dynamic environment is the dynamic environment in which `make-instance` was called. If an initialization argument name appears more than once in a `:default-initargs` class option, an error is signaled. The `:default-initargs` class option may be specified at most once.
defclass

- The :documentation class option causes a documentation string to be attached to the class name. The documentation type for this string is type. The form (documentation class-name 'type) may be used to retrieve the documentation string. The :documentation class option may be specified once at most.

- The :metaclass class option is used to specify that instances of the class being defined are to have a different metaclass than the default provided by the system (the class standard-class). The class-name argument is the name of the desired metaclass. The :metaclass class option may be specified once at most.

Values:

The new class object is returned as the result.

Remarks:

If a class with the same proper name already exists and that class is an instance of standard-class, and if the defclass form for the definition of the new class specifies a class of class standard-class, the existing class is redefined, and instances of it (and its subclasses) are updated to the new definition at the time that they are next accessed. For details, see “Redefining Classes.”

Note the following rules of defclass for standard classes:

- It is not required that the superclasses of a class be defined before the defclass form for that class is evaluated.

- All the superclasses of a class must be defined before an instance of the class can be made.

- A class must be defined before it can be used as a parameter specializer in a defmethod form.

The Object System may be extended to cover situations where these rules are not obeyed.

Some slot options are inherited by a class from its superclasses, and some can be shadowed or altered by providing a local slot description. No class options except :default-initargs are inherited. For a detailed description of how slots and slot options are inherited, see the section “Inheritance of Slots and Slot Options.”

The options to defclass can be extended. It is required that all implementations signal an error if they observe a class option or a slot option that is not implemented locally.

It is valid to specify more than one reader, writer, accessor, or initialization argument for a slot. No other slot option may appear more than once in a single slot description, or an error is signaled.

If no reader, writer, or accessor is specified for a slot, the slot can only be accessed by the function slot-value.
See Also:

“Classes”
“Inheritance”
“Redefining Classes”
“Determining the Class Precedence List”
“Object Creation and Initialization”

`slot-value`
`make-instance`
`initialize-instance`
defgeneric  

Macro

Purpose:

The macro `defgeneric` is used to define a generic function or to specify options and declarations that pertain to a generic function as a whole.

If `(fboundp function-specifier)` is `nil`, a new generic function is created. If `(symbol-function function-specifier)` is a generic function, that generic function is modified. If `function-specifier` names a non-generic function, a macro, or a special form, an error is signaled.

Each `method-description` defines a method on the generic function. The lambda-list of each method must be congruent with the lambda-list specified by the `lambda-list` option. If this condition does not hold, an error is signaled. See the section “Congruent Lambda-Lists for All Methods of a Generic Function” for a definition of congruence in this context.

The macro `defgeneric` returns the generic function object as its result.

Syntax:

```
defgeneric function-specifier lambda-list [ | option | method-description* ]  
function-specifier::= { symbol | (setf symbol) }  
lambda-list::= ( { var } [ &optional { var | ( var ) )* ] 
[ &rest var ] 
[ &key { var | ( var | keyword var ) } ] [ &allow-other-keys ] )  
option::= (:argument-precedence-order { parameter-name } ) [ 
( declare { declaration } )* ]  
( :documentation string ) |  
( :method-combination symbol { arg } )* |  
( :generic-function-class class-name ) |  
( :method-class class-name ) 

method-description::= (:method { method-qualifier }* specialized-lambda-list  
{ declaration | documentation }* { form }* )  

method-qualifier::= non-nil-atom
```

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defgeneric

specialized-lambda-list::= ({{var | (var parameter-specializer-name)}}*)
    [optional {var | (var [initform [supplied-p-parameter] ])}*]
    [&rest var]
    [&key {var | ([var | (keyword var)] [initform [supplied-p-parameter] ])}*]
    [&aux {var | (var [initform] )}]*)

parameter-specializer-name::= symbol | (eql eql-specializer-form)

Arguments:

The function-specifier argument is a non-nil symbol or a list of the form (setf symbol).

The lambda-list argument is an ordinary function lambda-list with these exceptions:

- The use of &aux is not allowed.
- Optional and keyword arguments may not have default initial value forms nor use supplied-p parameters. The generic function passes to the method all the argument values passed to it, and only those; default values are not supported. Note that optional and keyword arguments in method definitions, however, can have default initial value forms and can use supplied-p parameters.

The following options are provided. A given option may occur only once, or an error is signaled.

- The :argument-precedence-order option is used to specify the order in which the required arguments in a call to the generic function are tested for specificity when selecting a particular method. Each required argument, as specified in the lambda-list argument, must be included exactly once as a parameter-name so that the full and unambiguous precedence order is supplied. If this condition is not met, an error is signaled.
- The declare option is used to specify declarations that pertain to the generic function. The following standard Common Lisp declaration is allowed:

  - An optimize declaration specifies whether method selection should be optimized for speed or space, but it has no effect on methods. To control how a method is optimized, an optimize declaration must be placed directly in the defmethod form or method description. The optimization qualities speed and space are the only qualities this standard requires, but an implementation can extend the Common Lisp Object System to recognize other qualities. A simple implementation that has only one method selection technique and ignores the optimize declaration is valid.

The special, ftype, function, inline, notinline, and declaration declarations are not permitted. Individual implementations can extend the declare option to support additional declarations. If an implementation notices a declaration that it does not support and that has not been proclaimed as a non-standard declaration name in a declaration proclamation, it should issue a warning.

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defgeneric

- The :documentation argument associates a documentation string with the generic function. The documentation type for this string is function. The form (documentation function-specifier 'function) may be used to retrieve this string.

- The :generic-function-class option may be used to specify that the generic function is to have a different class than the default provided by the system (the class standard-generic-function). The class-name argument is the name of a class that can be the class of a generic function. If function-specifier specifies an existing generic function that has a different value for the :generic-function-class argument and the new generic function class is compatible with the old, change-class is called to change the class of the generic function; otherwise an error is signaled.

- The :method-class option is used to specify that all methods on this generic function are to have a different class from the default provided by the system (the class standard-method). The class-name argument is the name of a class that is capable of being the class of a method.

- The :method-combination option is followed by a symbol that names a type of method combination. The arguments (if any) that follow that symbol depend on the type of method combination. Note that the standard method combination type does not support any arguments. However, all types of method combination defined by the short form of define-method-combination accept an optional argument named order, defaulting to :most-specific-first, where a value of :most-specific-last reverses the order of the primary methods without affecting the order of the auxiliary methods.

The method-description arguments define methods that will be associated with the generic function. The method-qualifier and specialized-lambda-list arguments in a method description are the same as for defmethod.

The form arguments specify the method body. The body of the method is enclosed in an implicit block. If function-specifier is a symbol, this block bears the same name as the generic function. If function-specifier is a list of the form (setf symbol), the name of the block is symbol.

Values:

The generic function object is returned as the result.

Remarks:

The effect of the defgeneric macro is as if the following three steps were performed: first, methods defined by previous defgeneric forms are removed; second, ensure-generic-function is called; and finally, methods specified by the current defgeneric form are added to the generic function.

If no method descriptions are specified and a generic function of the same name does not already exist, a generic function with no methods is created.
The lambda-list argument of `defgeneric` specifies the shape of lambda-lists for the methods on this generic function. All methods on the resulting generic function must have lambda-lists that are congruent with this shape. If a `defgeneric` form is evaluated and some methods for that generic function have lambda-lists that are not congruent with that given in the `defgeneric` form, an error is signaled. For further details on method congruence, see “Congruent Lambda-Lists for All Methods of a Generic Function”

Implementations can extend `defgeneric` to include other options. It is required that an implementation signal an error if it observes an option that is not implemented locally.

See Also:

“Congruent Lambda-Lists for All Methods of a Generic Function”

`defmethod`

`ensure-generic-function`

`generic-function`
define-method-combination  

Purpose:

The macro define-method-combination is used to define new types of method combination.

There are two forms of define-method-combination. The short form is a simple facility for the cases that are expected to be most commonly needed. The long form is more powerful but more verbose. It resembles defmacro in that the body is an expression, usually using backquote, that computes a Lisp form. Thus arbitrary control structures can be implemented. The long form also allows arbitrary processing of method qualifiers.

Syntax:

```
define-method-combination name [↓ short-form-option ]  [Macro]
short-form-option::= :documentation string | :identity-with-one-argument boolean | :operator operator |

define-method-combination name lambda-list  [Macro]
  { method-group-specifier }*  
  [:arguments . lambda-list ]  
  [:generic-function generic-function-symbol ]  
  { declaration | doc-string }*  
  { form }*  

method-group-specifier::= (variable {{ qualifier-pattern }+ | predicate }  
  [↓ long-form-option ]  

long-form-option::= :description format-string | :order order | :required boolean
```

Arguments:

In both the short and long forms, name is a symbol. By convention, non-keyword, non-nil symbols are usually used.
define-method-combination

Arguments of the Short Form:

The short form syntax of **define-method-combination** is recognized when the second subform is a non-**nil** symbol or is not present. When the short form is used, **name** is defined as a type of method combination that produces a Lisp form (**operator** method-call method-call ...). The **operator** is a symbol that can be the name of a function, macro, or special form. The **operator** can be specified by a keyword option; it defaults to **name**.

Keyword options for the short form are the following:

- The **:documentation** option is used to document the method-combination type.
- The **:identity-with-one-argument** option enables an optimization when boolean is true (the default is false). If there is exactly one applicable method and it is a primary method, that method serves as the effective method and **operator** is not called. This optimization avoids the need to create a new effective method and avoids the overhead of a function call. This option is designed to be used with operators such as **progn**, **and**, +, and **max**.
- The **:operator** option specifies the name of the operator. The **operator** argument is a symbol that can be the name of a function, macro, or special form. By convention, **name** and **operator** are often the same symbol. This is the default, but it is not required.

None of the subforms is evaluated.

These types of method combination require exactly one qualifier per method. An error is signaled if there are applicable methods with no qualifiers or with qualifiers that are not supported by the method combination type.

A method combination procedure defined in this way recognizes two roles for methods. A method whose one qualifier is the symbol naming this type of method combination is defined to be a primary method. At least one primary method must be applicable or an error is signaled. A method with **:around** as its one qualifier is an auxiliary method that behaves the same as a **:around** method in standard method combination. The function **call-next-method** can only be used in **:around** methods; it cannot be used in primary methods defined by the short form of the **define-method-combination** macro.

A method combination procedure defined in this way accepts an optional argument named **order**, which defaults to **:most-specific-first**. A value of **:most-specific-last** reverses the order of the primary methods without affecting the order of the auxiliary methods.

The short form automatically includes error checking and support for **:around** methods.

For a discussion of built-in method combination types, see the section “Built-in Method Combination Types.”
define-method-combination

Arguments of the Long Form:

The long form syntax of `define-method-combination` is recognized when the second subform is a list.

The `lambda-list` argument is an ordinary lambda-list. It receives any arguments provided after the name of the method combination type in the `method-combination` option to `defgeneric`.

A list of method group specifiers follows. Each specifier selects a subset of the applicable methods to play a particular role, either by matching their qualifiers against some patterns or by testing their qualifiers with a predicate. These method group specifiers define all method qualifiers that can be used with this type of method combination. If an applicable method does not fall into any method group, the system signals the error that the method is invalid for the kind of method combination in use.

Each method group specifier names a variable. During the execution of the forms in the body of `define-method-combination`, this variable is bound to a list of the methods in the method group. The methods in this list occur in most-specific-first order.

A qualifier pattern is a list or the symbol `*`. A method matches a qualifier pattern if the method’s list of qualifiers is `equal` to the qualifier pattern (except that the symbol `*` in a qualifier pattern matches anything). Thus a qualifier pattern can be one of the following: the empty list `()`, which matches unqualified methods; the symbol `*`, which matches all methods; a true list, which matches methods with the same number of qualifiers as the length of the list when each qualifier matches the corresponding list element; or a dotted list that ends in the symbol `*` (the `*` matches any number of additional qualifiers).

Each applicable method is tested against the qualifier patterns and predicates in left-to-right order. As soon as a qualifier pattern matches or a predicate returns true, the method becomes a member of the corresponding method group and no further tests are made. Thus if a method could be a member of more than one method group, it joins only the first such group. If a method group has more than one qualifier pattern, a method need only satisfy one of the qualifier patterns to be a member of the group.

The name of a predicate function can appear instead of qualifier patterns in a method group specifier. The predicate is called for each method that has not been assigned to an earlier method group; it is called with one argument, the method’s qualifier list. The predicate should return true if the method is to be a member of the method group. A predicate can be distinguished from a qualifier pattern because it is a symbol other than `nil` or `*`.

If there is an applicable method whose qualifiers are not valid for the method combination type, the function `invalid-method-error` is called.

Method group specifiers can have keyword options following the qualifier patterns or predicate. Keyword options can be distinguished from additional qualifier patterns because they are neither lists nor the symbol `*`. The keyword options are as follows:

- The `:description` option is used to provide a description of the role of methods in the
method group. Programming environment tools use (apply #'format stream format-string
(method-qualifiers method)) to print this description, which is expected to be concise.
This keyword option allows the description of a method qualifier to be defined in the same
module that defines the meaning of the method qualifier. In most cases, format-string will
not contain any format directives, but they are available for generality. If :description
is not specified, a default description is generated based on the variable name and the qualifier
patterns and on whether this method group includes the unqualified methods. The argument
format-string is not evaluated.

- The :order option specifies the order of methods. The order argument is a form that evalu-
ates to :most-specific-first or :most-specific-last. If it evaluates to any other value,
an error is signaled. This keyword option is a convenience and does not add any expressive
power. If :order is not specified, it defaults to :most-specific-first.

- The :required option specifies whether at least one method in this method group is required.
If the boolean argument is non-nil and the method group is empty (that is, no applicable
methods match the qualifier patterns or satisfy the predicate), an error is signaled. This
keyword option is a convenience and does not add any expressive power. If :required is not
specified, it defaults to nil. The boolean argument is not evaluated.

The use of method group specifiers provides a convenient syntax to select methods, to divide
them among the possible roles, and to perform the necessary error checking. It is possible to
perform further filtering of methods in the body forms by using normal list-processing operations
and the functions method-qualifiers and invalid-method-error. It is permissible to use setq
on the variables named in the method group specifiers and to bind additional variables. It is also
possible to bypass the method group specifier mechanism and do everything in the body forms.
This is accomplished by writing a single method group with * as its only qualifier pattern; the
variable is then bound to a list of all of the applicable methods, in most-specific-first order.

The body forms compute and return the Lisp form that specifies how the methods are combined,
that is, the effective method. The effective method uses the macro call-method. This macro
has lexical scope and is available only in an effective method form. Given a method object in one
of the lists produced by the method group specifiers and a list of next methods, the macro call-
method will invoke the method such that call-next-method has available the next methods.

When an effective method has no effect other than to call a single method, some implementa-
tions employ an optimization that uses the single method directly as the effective method, thus
avoiding the need to create a new effective method. This optimization is active when the effective
method form consists entirely of an invocation of the call-method macro whose first subform is
a method object and whose second subform is nil. Each define-method-combination body is
responsible for stripping off redundant invocations of progn, and, multiple-value-progl, and
the like, if this optimization is desired.
The list (:arguments . lambda-list) can appear before any declarations or documentation string. This form is useful when the method combination type performs some specific behavior as part of the combined method and that behavior needs access to the arguments to the generic function. Each parameter variable defined by lambda-list is bound to a form that can be inserted into the effective method. When this form is evaluated during execution of the effective method, its value is the corresponding argument to the generic function. If lambda-list is not congruent to the generic function’s lambda-list, additional ignored parameters are automatically inserted until it is congruent. Thus it is permissible for lambda-list to receive fewer arguments than the number that the generic function expects.

Erroneous conditions detected by the body should be reported with method-combination-error or invalid-method-error; these functions add any necessary contextual information to the error message and will signal the appropriate error.

The body forms are evaluated inside of the bindings created by the lambda-list and method group specifiers. Declarations at the head of the body are positioned directly inside of bindings created by the lambda-list and outside of the bindings of the method group variables. Thus method group variables cannot be declared.

Within the body forms, generic-function-symbol is bound to the generic function object.

If a doc-string argument is present, it provides the documentation for the method-combination type.

The functions method-combination-error and invalid-method-error can be called from the body forms or from functions called by the body forms. The actions of these two functions can depend on implementation-dependent dynamic variables automatically bound before the generic function compute-effective-method is called.

Note that two methods with identical specializers, but with different qualifiers, are not ordered by the algorithm described in Step 2 of the method selection and combination process described in the section “Method Selection and Combination.” Normally the two methods play different roles in the effective method because they have different qualifiers, and no matter how they are ordered in the result of Step 2, the effective method is the same. If the two methods play the same role and their order matters, an error is signaled. This happens as part of the qualifier pattern matching in define-method-combination.

Values:

The value returned by the define-method-combination macro is the new method combination object.
Examples:

Most examples of the long form of **define-method-combination** also illustrate the use of the related functions that are provided as part of the declarative method combination facility.

;;; Examples of the short form of define-method-combination

```
(define-method-combination and :identity-with-one-argument t)
```

(define-method func and ((x class1) y) ...)

;;; The equivalent of this example in the long form is:

```
(define-method-combination and
  (&optional (order ':most-specific-first))
  ((around (:around))
   (primary (and) :order order :required t))
  (let ((form (if (rest primary)
               '...(call-method ...)
               'call-method ...)))))
```
define-method-combination

('(call-method ,(first primary) ()))))

(if around
  '(call-method ,(first around)
    ,(,@(rest around)
      (make-method ,form)))
  form)))

; A simple way to try several methods until one returns non-nil
(define-method-combination or ()
  ((methods (or)))
  '(or ,,@(mapcar #'(lambda (method)
        '(call-method ,method ())
      methods)))

; A more complete version of the preceding
(define-method-combination or
  (&optional (order ':most-specific-first))
  ((around (:around))
   (primary (or)))
  ;; Process the order argument
  (case order
    (:most-specific-first)
    (:most-specific-last (setq primary (reverse primary)))
    (otherwise (method-combination-error ""S is an invalid order."@ 
      :most-specific-first and :most-specific-last are the possible values." @
      order)))
  ;; Must have a primary method
  (unless primary
    (method-combination-error "A primary method is required.")))
  ;; Construct the form that calls the primary methods
  (let ((form (if (rest primary)
      '(or ,,@(mapcar #'(lambda (method)
        '(call-method ,method ())
      primary))
      '(call-method ,(first primary) ()))))
  ;; Wrap the around methods around that form
  (if around
    '(call-method ,(first around)
      ,(,@(rest around)
        (make-method ,form)))
    form)))

; The same thing, using the :order and :required keyword options
(define-method-combination or
  (&optional (order ':most-specific-first)

(define-method-combination

  ((around (:around))
   (primary (or) :order order :required t))

  (let ((form (if (rest primary)
                '(or ,@ (mapcar #'(lambda (method)
                               '(call-method ,method ()))
                     primary))
                '(call-method ,(first primary) ()))))

  (if around
      '(call-method ,(first around)
                    ,(,@ (rest around)
                        (make-method ,form)))
      form)))

;This short-form call is behaviorally identical to the preceding
(define-method-combination or :identity-with-one-argument t)

;Order methods by positive integer qualifiers
;:around methods are disallowed to keep the example small
(define-method-combination example-method-combination ()
  ((methods positive-integer-qualifier-p))
  '(progn ,@ (mapcar #'(lambda (method)
                        'call-method ,method ())
                     (stable-sort methods #'<
                      :key #'(lambda (method) (first (method-qualifiers method)))))))

(defun positive-integer-qualifier-p (method-qualifiers)
  (and (= (length method-qualifiers) 1)
       (typep (first method-qualifiers) '(integer 0 *))))

;;; Example of the use of :arguments
(define-method-combination progn-with-lock ()
  ((methods ()))
  (:arguments object)
  '(unwind-protect
     (progn (lock (object-lock ,object))
            ,@ (mapcar #'(lambda (method)
                          'call-method ,method ())
                    methods))
     (unlock (object-lock ,object))))

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define-method-combination

Remarks:

The :method-combination option of defgeneric is used to specify that a generic function should use a particular method combination type. The argument to the :method-combination option is the name of a method combination type.

See Also:

“Method Selection and Combination”
“Built-in Method Combination Types”
call-method
method-qualifiers
method-combination-error
invalid-method-error
defgeneric
defmethod  

**Purpose:**

The macro `defmethod` defines a method on a generic function.

If `(fboundp function-specifier)` is `nil`, a generic function is created with default values for the argument precedence order (each argument is more specific than the arguments to its right in the argument list), for the generic function class (the class `standard-generic-function`), for the method class (the class `standard-method`), and for the method combination type (the standard method combination type). The lambda-list of the generic function is congruent with the lambda-list of the method being defined; if the `defmethod` form mentions keyword arguments, the lambda-list of the generic function will mention `&key` (but no keyword arguments). If `function-specifier` names a non-generic function, a macro, or a special form, an error is signaled.

If a generic function is currently named by `function-specifier`, where `function-specifier` is a symbol or a list of the form `(setf symbol)`, the lambda-list of the method must be congruent with the lambda-list of the generic function. If this condition does not hold, an error is signaled. See the section “Congruent Lambda-Lists for All Methods of a Generic Function” for a definition of congruence in this context.

**Syntax:**

```
defmethod function-specifier {method-qualifier}* specialized-lambda-list
                          {declaration | documentation}* {form}*                      [Macro]

function-specifier::= {symbol | (setf symbol)}
method-qualifier::= non-nil-atom
specialized-lambda-list::= ({var | (var parameter-specializer-name)}*
                              [koptional {var | (var [initform [supplied-p-parameter] 1])}*]
                              [krest var]
                              [kkey {var | ({var | (keyword var)} [initform [supplied-p-parameter] 1])]*
                              [kallow-other-keys]
                              [kaux {var | (var [initform] )}*] )

parameter-specializer-name::= symbol | (eql eql-specializer-form)
```

Functions in the Programmer Interface  2–39
defmethod

Arguments:

The function-specifier argument is a non-nil symbol or a list of the form (setf symbol). It names the generic function on which the method is defined.

Each method-qualifier argument is an object that is used by method combination to identify the given method. A method qualifier is a non-nil atom. The method combination type may further restrict what a method qualifier may be. The standard method combination type allows for unqualified methods or methods whose sole qualifier is the keyword :before, the keyword :after, or the keyword :around.

The specialized-lambda-list argument is like an ordinary function lambda-list except that the names of required parameters can be replaced by specialized parameters. A specialized parameter is a list of the form (variable-name parameter-specializer-name). Only required parameters may be specialized. A parameter specializer name is a symbol that names a class or (eql eql-specializer-form). The parameter specializer name (eql eql-specializer-form) indicates that the corresponding argument must be eql to the object that is the value of eql-specializer-form for the method to be applicable. If no parameter specializer name is specified for a given required parameter, the parameter specializer defaults to the class named t. See the section “Introduction to Methods” for further discussion.

The form arguments specify the method body. The body of the method is enclosed in an implicit block. If function-specifier is a symbol, this block bears the same name as the generic function. If function-specifier is a list of the form (setf symbol), the name of the block is symbol.

Values:

The result of defmethod is the method object.

Remarks:

The class of the method object that is created is that given by the method class option of the generic function on which the method is defined.

If the generic function already has a method that agrees with the method being defined on parameter specializers and qualifiers, defmethod replaces the existing method with the one now being defined. See the section “Agreement on Parameter Specializers and Qualifiers” for a definition of agreement in this context.

The parameter specializers are derived from the parameter specializer names as described in the section “Introduction to Methods.”

The expansion of the defmethod macro “refers to” each specialized parameter (see the description of ignore in Common Lisp: The Language, p. 160). This includes parameters that have an explicit parameter specializer name of t. This means that a compiler warning does not occur if the body of the method does not refer to a specialized parameter. Note that a parameter that specializes on t is not synonymous with an unspecialized parameter in this context.
See Also:

“Introduction to Methods”
“Congruent Lambda-Lists for All Methods of a Generic Function”
“Agreement on Parameter Specializers and Qualifiers”
describe

Standard Generic Function

Purpose:

The Common Lisp function \texttt{describe} is replaced by a generic function. The generic function \texttt{describe} prints information about a given object on the standard output.

Each implementation is required to provide a method on the class \texttt{standard-object} and methods on enough other classes so as to ensure that there is always an applicable method. Implementations are free to add methods for other classes. Users can write methods for \texttt{describe} for their own classes if they do not wish to inherit an implementation-supplied method. These methods must conform to the definition of \texttt{describe} as specified in \textit{Common Lisp: The Language}.

Syntax:

\begin{verbatim}
describe object \[Generic Function]\end{verbatim}

Method Signatures:

\begin{verbatim}
describe (object standard-object) \[Primary Method]\end{verbatim}

Arguments:

The \textit{object} argument may be any Common Lisp object.

Values:

The generic function \texttt{describe} returns no values.
documentation, (setf documentation)  

`Standard Generic Function`

**Purpose:**

The Common Lisp function `documentation` is replaced by a generic function. The generic function `documentation` returns the documentation string associated with the given object if it is available; otherwise it returns `nil`.

The generic function `(setf documentation)` is used to update the documentation.

**Syntax:**

```
documentation  x &optional  doc-type
(setf documentation) new-value  x &optional  doc-type
```

`[Generic Function]`

**Method Signatures:**

```
documentation  (method  standard-method) &optional  doc-type
(setf documentation) new-value  (method  standard-method)
&optional  doc-type

documentation  (generic-function  standard-generic-function)
&optional  doc-type
(setf documentation) new-value
  (generic-function  standard-generic-function)
&optional  doc-type

documentation  (class  standard-class) &optional  doc-type
(setf documentation) new-value  (class  standard-class)
&optional  doc-type

documentation  (method-combination  method-combination)
&optional  doc-type
(setf documentation) new-value
  (method-combination  method-combination)
&optional  doc-type
```

`[Primary Method]`

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documentation, (setf documentation)

\[
\text{documentation} \ (\text{slot-description} \ \text{standard-slot-description}) \\
&\text{optional doc-type}
\]

\[
\text{(setf documentation)} \ \text{new-value} \\
\ (\text{slot-description} \ \text{standard-slot-description}) \\
&\text{optional doc-type}
\]

\[
\text{documentation} \ (\text{symbol} \ \text{symbol}) \\
&\text{optional doc-type}
\]

\[
\text{(setf documentation)} \ \text{new-value} \ (\text{symbol} \ \text{symbol}) \\
&\text{optional doc-type}
\]

\[
\text{documentation} \ (\text{list} \ \text{list}) \\
&\text{optional doc-type}
\]

\[
\text{(setf documentation)} \ \text{new-value} \ (\text{list} \ \text{list}) \\
&\text{optional doc-type}
\]

Arguments:

The first argument of documentation is either a symbol, a function specifier list of the form (setf symbol), a method object, a class object, a generic function object, a method combination object, or a slot description object.

- If the first argument is a method object, a class object, a generic function object, a method combination object, or a slot description object, the second argument must not be supplied, or an error is signaled.
- If the first argument is a symbol or a list of the form (setf symbol), the second argument must be supplied.
  - The forms (documentation symbol 'function) and (documentation '(setf symbol) 'function) return the documentation string of the function, generic function, special form, or macro named by the symbol or list.
  - The form (documentation symbol 'variable) returns the documentation string of the special variable or constant named by the symbol.
  - The form (documentation symbol 'structure) returns the documentation string of the defstruct structure named by the symbol.
  - The form (documentation symbol 'type) returns the documentation string of the class object named by the symbol, if there is such a class. If there is no such class, it returns the documentation string of the type specifier named by the symbol.
  - The form (documentation symbol 'setf) returns the documentation string of the defsetf
documentation, (setf documentation)

or define-setf-method definition associated with the symbol.

- The form (documentation symbol 'method-combination) returns the documentation string of the method combination type named by the symbol.

An implementation may extend the set of symbols that are acceptable as the second argument. If a symbol is not recognized as an acceptable argument by the implementation, an error must be signaled.

Values:

The documentation string associated with the given object is returned unless none is available, in which case documentation returns nil.
Purpose:

The function `ensure-generic-function` is used to define a globally named generic function with no methods or to specify or modify options and declarations that pertain to a globally named generic function as a whole.

If `(fboundp function-specifier)` is `nil`, a new generic function is created. If `(symbol-function function-specifier)` is a non-generic function, a macro, or a special form, an error is signaled.

If `function-specifier` specifies a generic function that has a different value for any of the following arguments, the generic function is modified to have the new value: `:argument-precedence-order`, `:declare`, `:documentation`, `:method-combination`.

If `function-specifier` specifies a generic function that has a different value for the `:lambda-list` argument, and the new value is congruent with the lambda-lists of all existing methods or there are no methods, the value is changed; otherwise an error is signaled.

If `function-specifier` specifies a generic function that has a different value for the `:generic-function-class` argument and if the new generic function class is compatible with the old, `change-class` is called to change the class of the generic function; otherwise an error is signaled.

If `function-specifier` specifies a generic function that has a different value for the `:method-class` argument, the value is changed, but any existing methods are not changed.

Syntax:

```
ensure-generic-function function-specifier &key :lambda-list          [Function]
  :argument-precedence-order
  :declare
  :documentation
  :generic-function-class
  :method-combination
  :method-class
  :environment

function-specifier::= { symbol | (setf symbol) }
```

Arguments:

The `function-specifier` argument is a symbol or a list of the form `(setf symbol)`.

The keyword arguments correspond to the option arguments of `defgeneric`, except that the `:method-class` and `:generic-function-class` arguments can be class objects as well as names.
ensure-generic-function

The :environment argument is the same as the &environment argument to macro expansion functions. It is typically used to distinguish between compile-time and run-time environments.

The :method-combination argument is a method combination object.

Values:

The generic function object is returned.

See Also:

defgeneric
find-class

Function

Purpose:

The function `find-class` returns the class object named by the given symbol in the given environment.

Syntax:

```
find-class symbol &optional errorp environment
```

Arguments:

The first argument to `find-class` is a symbol.

If there is no such class and the `errorp` argument is not supplied or is non-nil, `find-class` signals an error. If there is no such class and the `errorp` argument is nil, `find-class` returns `nil`. The default value of `errorp` is `t`.

The optional `environment` argument is the same as the `&environment` argument to macro expansion functions. It is typically used to distinguish between compile-time and run-time environments.

Values:

The result of `find-class` is the class object named by the given symbol.

Remarks:

The class associated with a particular symbol can be changed by using `setf` with `find-class`. The results are undefined if the user attempts to change the class associated with a symbol that is defined as a type specifier by `Common Lisp: The Language`. See the section “Integrating Types and Classes.”
find-method

Purpose:
The generic function find-method takes a generic function and returns the method object that agrees on method qualifiers and parameter specializers with the method-qualifiers and specializers arguments of find-method. See the section “Agreement on Parameter Specializers and Qualifiers” for a definition of agreement in this context.

Syntax:

find-method generic-function method-qualifiers specializers &optional errorp [Generic Function]

Method Signatures:

find-method (generic-function standard-generic-function) method-qualifiers specializers &optional errorp [Primary Method]

Arguments:
The generic-function argument is a generic function.

The method-qualifiers argument is a list of the method qualifiers for the method. The order of the method qualifiers is significant.

The specializers argument is a list of the parameter specializers for the method. It must correspond in length to the number of required arguments of the generic function, or an error is signaled. This means that to obtain the default method on a given generic function, a list whose elements are the class named t must be given.

If there is no such method and the errorp argument is not supplied or is non-nil, find-method signals an error. If there is no such method and the errorp argument is nil, find-method returns nil. The default value of errorp is t.

Values:
The result of find-method is the method object with the given method qualifiers and parameter specializers.

See Also:

“Agreement on Parameter Specializers and Qualifiers”
function-keywords

Standard Generic Function

Purpose:
The generic function function-keywords is used to return the keyword parameter specifiers for a given method.

Syntax:

function-keywords method

[Generic Function]

Method Signatures:

function-keywords (method standard-method)

[Primary Method]

Arguments:
The method argument is a method object.

Values:
The generic function function-keywords returns two values: a list of the explicitly named keywords and a boolean that states whether &allow-other-keys had been specified in the method definition.
special form

Purpose:
The generic-flet special form is analogous to the Common Lisp flet special form. It produces new generic functions and establishes new lexical function definition bindings. Each generic function is created with the set of methods specified by its method descriptions.

The special form generic-flet is used to define functions whose names are meaningful only locally and to execute a series of forms with these function definition bindings. Any number of such local generic functions may be defined.

The names of functions defined by generic-flet have lexical scope; they retain their local definitions only within the body of the generic-flet. Any references within the body of the generic-flet to functions whose names are the same as those defined within the generic-flet are thus references to the local functions instead of to any global functions of the same names. The scope of these generic function definition bindings, however, includes only the body of generic-flet, not the definitions themselves. Within the method bodies, local function names that match those being defined refer to global functions defined outside the generic-flet. It is thus not possible to define recursive functions with generic-flet.

Syntax:

```
generic-flet  (((function-specifier lambda-list [| option | method-description* []])*) [Special Form] {form}*)

function-specifier::= {symbol | (setf symbol)}
lambda-list::= ({var}* [&optional {var | (var)}*] [&rest var] [&key {var | (keyword var)}*] [&allow-other-keys] )
option::= (:argument-precedence-order {parameter-name}+ ) |
          (declare {declaration}+ ) |
          (:documentation string) |
          (:method-combination symbol {arg}*) |
          (:generic-function-class class-name) |
          (:method-class class-name)
```
generic-flet

method-description::= (:method {method-qualifier}* specialized-lambda-list
{declaration | documentation}* {form}*)

Arguments:

The function-specifier, lambda-list, option, method-qualifier, and specialized-lambda-list arguments are the same as for defgeneric.

A generic-flet local method definition is identical in form to the method definition part of a defmethod.

The body of each method is enclosed in an implicit block. If function-specifier is a symbol, this block bears the same name as the generic function. If function-specifier is a list of the form (setf symbol), the name of the block is symbol.

Values:

The result returned by generic-flet is the value or values returned by the last form executed. If no forms are specified, generic-flet returns nil.

See Also:

generic-labels
defmethod
defgeneric
generic-function
generic-function

Purpose:
The generic-function macro creates an anonymous generic function. The generic function is created with the set of methods specified by its method descriptions.

Syntax:
\[
generic-function \quad \text{lambda-list} \quad \left[ \downarrow \text{option} \mid \text{method-description}^* \right]
\]

\[
\text{lambda-list} ::= \{{\text{var}}^* \backslash \{\text{optional} \quad \{\text{var} \mid (\text{var})^*\}\backslash \{\text{rest} \quad \text{var}\} \backslash \{\text{key} \quad \{\text{var} \mid \{(\text{var} \mid \text{keyword} \quad \text{var})\}^* \backslash \{\text{allow-other-keys}\} \}\}
\]

\[
\text{option} ::= (:\text{argument-precedence-order} \quad \{\text{parameter-name}\}^+) \mid \\
(\text{declare} \quad \{\text{declaration}\}^+) \mid \\
(\text{:documentation} \quad \text{string}) \mid \\
(\text{:method-combination} \quad \text{symbol} \quad \{\text{arg}\}^+) \mid \\
(\text{:generic-function-class} \quad \text{class-name}) \mid \\
(\text{:method-class} \quad \text{class-name})
\]

\[
\text{method-description} ::= (:\text{method} \quad \{\text{method-qualifier}\}^* \quad \text{specialized-lambda-list} \quad \{\text{declaration} \mid \text{documentation}\}^* \quad \{\text{form}\}^*)
\]

Arguments:
The option, method-qualifier, and specialized-lambda-list arguments are the same as for def-generic.

Values:
The generic function object is returned as the result.

Remarks:
If no method descriptions are specified, an anonymous generic function with no methods is created.
generic-function

See Also:

defgeneric
generic-flet
generic-labels
defmethod
generic-labels

Purpose:

The `generic-labels` special form is analogous to the Common Lisp `labels` special form. It produces new generic functions and establishes new lexical function definition bindings. Each generic function is created with the set of methods specified by its method descriptions.

The special form `generic-labels` is used to define functions whose names are meaningful only locally and to execute a series of forms with these function definition bindings. Any number of such local functions may be defined.

The names of functions defined by `generic-labels` have lexical scope; they retain their local definitions only within the body of the `generic-labels` construct. Any references within the body of the `generic-labels` construct to functions whose names are the same as those defined within the `generic-labels` form are thus references to the local functions instead of to any global functions of the same names. The scope of these generic function definition bindings includes the method bodies themselves as well as the body of the `generic-labels` construct.

Syntax:

```
generic-labels ({{function-specifier lambda-list
                    [[↑ option | method-description*]]}*}
                    {form}*)

function-specifier::= {symbol | (setf symbol)}

lambda-list::= ({{var}* [&optional {var | (var)}*]
                   [&rest var]
                   [&key {var | ((var | keyword var)})*]
                   [&allow-other-keys]})

option::= (:argument-precedence-order {parameter-name}+)
          (declare {declaration}+)
          (:documentation string)
          (:method-combination symbol {arg}*)
          (:generic-function-class class-name)
          (:method-class class-name)

method-description::= (:method {method-qualifier}* specialized-lambda-list
                             {declaration | documentation}* {form}*)
```

Functions in the Programmer Interface  2–55
generic-labels

Arguments:

The function-specifier, lambda-list, option, method-qualifier, and specialized-lambda-list arguments are the same as for defgeneric.

A generic-labels local method definition is identical in form to the method definition part of a defmethod.

The body of each method is enclosed in an implicit block. If function-specifier is a symbol, this block bears the same name as the generic function. If function-specifier is a list of the form (setf symbol), the name of the block is symbol.

Values:

The result returned by generic-labels is the value or values returned by the last form executed. If no forms are specified, generic-labels returns nil.

See Also:

generic-flet
defmethod
defgeneric
generic-function
initialize-instance

Purpose:
The generic function initialize-instance is called by make-instance to initialize a newly created instance. The generic function initialize-instance is called with the new instance and the defaulted initialization arguments.

The system-supplied primary method on initialize-instance initializes the slots of the instance with values according to the initialization arguments and the :initform forms of the slots. It does this by calling the generic function shared-initialize with the following arguments: the instance, t (this indicates that all slots for which no initialization arguments are provided should be initialized according to their :initform forms), and the defaulted initialization arguments.

Syntax:
initialize-instance instance &rest initargs [Generic Function]

Method Signatures:
initialize-instance (instance standard-object) &rest initargs [Primary Method]

Arguments:
The instance argument is the object to be initialized.
The initargs argument consists of alternating initialization argument names and values.

Values:
The modified instance is returned as the result.

Remarks:
Programmers can define methods for initialize-instance to specify actions to be taken when an instance is initialized. If only :after methods are defined, they will be run after the system-supplied primary method for initialization and therefore will not interfere with the default behavior of initialize-instance.

See Also:
“Object Creation and Initialization”
“Rules for Initialization Arguments”
“Declaring the Validity of Initialization Arguments”
initialize-instance

shared-initialize
make-instance
slot-boundp
slot-makunbound
invalid-method-error

Function

Purpose:
The function invalid-method-error is used to signal an error when there is an applicable method whose qualifiers are not valid for the method combination type. The error message is constructed by using a format string and any arguments to it. Because an implementation may need to add additional contextual information to the error message, invalid-method-error should be called only within the dynamic extent of a method combination function.

The function invalid-method-error is called automatically when a method fails to satisfy every qualifier pattern and predicate in a define-method-combination form. A method combination function that imposes additional restrictions should call invalid-method-error explicitly if it encounters a method it cannot accept.

Syntax:
invalid-method-error method format-string &rest args

Arguments:
The method argument is the invalid method object.

The format-string argument is a control string that can be given to format, and args are any arguments required by that string.

Remarks:
Whether invalid-method-error returns to its caller or exits via throw is implementation dependent.

See Also:
define-method-combination
make-instance  

*Standard Generic Function*

**Purpose:**

The generic function `make-instance` creates and returns a new instance of the given class.

The generic function `make-instance` may be used as described in the section “Object Creation and Initialization.”

**Syntax:**

```lisp
make-instance class &rest initargs
```

**Method Signatures:**

- `make-instance (class standard-class) &rest initargs` [Primary Method]
- `make-instance (class symbol) &rest initargs` [Primary Method]

**Arguments:**

The `class` argument is a class object or a symbol that names a class. The remaining arguments form a list of alternating initialization argument names and values.

If the second of the above methods is selected, that method invokes `make-instance` on the arguments `find-class class` and `initargs`.

The initialization arguments are checked within `make-instance`. See the section “Object Creation and Initialization.”

**Values:**

The new instance is returned.

**Remarks:**

The meta-object protocol can be used to define new methods on `make-instance` to replace the object-creation protocol.

**See Also:**

“Object Creation and Initialization”

defclass

initialize-instance

class-of

2–60  Common Lisp Object System Specification
make-instances-obsolete  

*Standard Generic Function*

**Purpose:**

The generic function `make-instances-obsolete` is invoked automatically by the system when `defclass` has been used to redefine an existing standard class and the set of local slots accessible in an instance is changed or the order of slots in storage is changed. It can also be explicitly invoked by the user.

The function `make-instances-obsolete` has the effect of initiating the process of updating the instances of the class. During updating, the generic function `update-instance-for-redefined-class` will be invoked.

**Syntax:**

```
make-instances-obsolete class
```

**Method Signatures:**

```
make-instances-obsolete (class standard-class)
```

**Arguments:**

The `class` argument is a class object or a symbol that names the class whose instances are to be made obsolete.

If the second of the above methods is selected, that method invokes `make-instances-obsolete` on `(find-class class)`.

**Values:**

The modified class is returned. The result of `make-instances-obsolete` is `eq` to the `class` argument supplied to the first of the above methods.

**See Also:**

“Redefining Classes”

`update-instance-for-redefined-class`

Functions in the Programmer Interface  2–61
method-combination-error

Function

Purpose:
The function `method-combination-error` is used to signal an error in method combination. The error message is constructed by using a format string and any arguments to it. Because an implementation may need to add additional contextual information to the error message, `method-combination-error` should be called only within the dynamic extent of a method combination function.

Syntax:

```
method-combination-error format-string &rest args
```

Arguments:
The `format-string` argument is a control string that can be given to `format`, and `args` are any arguments required by that string.

Remarks:

Whether `method-combination-error` returns to its caller or exits via `throw` is implementation dependent.

See Also:

`define-method-combination`
method-qualifiers  

*Standard Generic Function*

**Purpose:**

The generic function `method-qualifiers` returns a list of the qualifiers of the given method.

**Syntax:**

```lisp
method-qualifiers method
```

*Generic Function*

**Method Signatures:**

```lisp
method-qualifiers (method standard-method)
```

*Primary Method*

**Arguments:**

The `method` argument is a method object.

**Values:**

A list of the qualifiers of the given method is returned.

**Examples:**

```lisp
(setq methods (remove-duplicates methods :from-end t :key #'method-qualifiers :test #'equal))
```

**See Also:**

`define-method-combination`
next-method-p

Purpose:
The locally defined function next-method-p can be used within the body of a method defined by a method-defining form to determine whether a next method exists.

Syntax:

    next-method-p

Arguments:
The function next-method-p takes no arguments.

Values:
The function next-method-p returns true or false.

Remarks:
Like call-next-method, the function next-method-p has lexical scope and indefinite extent.

See Also:
call-next-method
Purpose:

The generic function **no-applicable-method** is called when a generic function of the class **standard-generic-function** is invoked and no method on that generic function is applicable. The default method signals an error.

The generic function **no-applicable-method** is not intended to be called by programmers. Programmers may write methods for it.

Syntax:

```
no-applicable-method generic-function &rest function-arguments
```

Method Signatures:

```
no-applicable-method (generic-function t) &rest function-arguments
```

Arguments:

The **generic-function** argument of **no-applicable-method** is the generic function object on which no applicable method was found.

The **function-arguments** argument is a list of the arguments to that generic function.
no-next-method

Standard Generic Function

Purpose:

The generic function **no-next-method** is called by **call-next-method** when there is no next method. The system-supplied method on **no-next-method** signals an error.

The generic function **no-next-method** is not intended to be called by programmers. Programmers may write methods for it.

Syntax:

```
no-next-method  generic-function  method  &rest  args
```

Method Signatures:

```
(no-next-method  (generic-function  standard-generic-function)
  (method  standard-method)
  &rest  args)
```

Arguments:

The **generic-function** argument is the generic function object to which the method that is the second argument belongs.

The **method** argument is the method that contained the call to **call-next-method** for which there is no next method.

The **args** argument is a list of the arguments to **call-next-method**.

See Also:

- **call-next-method**

2-66 Common Lisp Object System Specification
**print-object**

*Standard Generic Function*

**Purpose:**
The generic function **print-object** writes the printed representation of an object to a stream. The function **print-object** is called by the print system; it should not be called by the user.

Each implementation is required to provide a method on the class **standard-object** and methods on enough other classes so as to ensure that there is always an applicable method. Implementations are free to add methods for other classes. Users can write methods for **print-object** for their own classes if they do not wish to inherit an implementation-supplied method.

**Syntax:**

```
print-object object stream
```

**Method Signatures:**

```
print-object (object standard-object) stream
```

**Arguments:**
The first argument is any Lisp object. The second argument is a stream; it cannot be `t` or `nil`.

**Values:**
The function **print-object** returns its first argument, the object.

**Remarks:**
Methods on **print-object** must obey the print control special variables described in *Common Lisp: The Language*. The specific details are the following:

- Each method must implement **print-escape**.
- The **print.pretty** control variable can be ignored by most methods other than the one for lists.
- The **print-circle** control variable is handled by the printer and can be ignored by methods.
- The printer takes care of **print-level** automatically, provided that each method handles exactly one level of structure and calls **write** (or an equivalent function) recursively if there are more structural levels. The printer's decision of whether an object has components (and therefore should not be printed when the printing depth is not less than **print-level**) is implementation dependent. In some implementations its **print-object** method is not called; in others the method is called, and the determination that the object has components is
Methods that produce output of indefinite length must obey *print-length*, but most methods other than the one for lists can ignore it.

- The *print-base*, *print-radix*, *print-case*, *print-gensym*, and *print-array* control variables apply to specific types of objects and are handled by the methods for those objects.

If these rules are not obeyed, the results are undefined.

In general, the printer and the print-object methods should not rebind the print control variables as they operate recursively through the structure, but this is implementation dependent.

In some implementations the stream argument passed to a print-object method is not the original stream, but is an intermediate stream that implements part of the printer. Methods should therefore not depend on the identity of this stream.

All of the existing printing functions (write, prin1, print, princ, pprint, write-to-string, prin1-to-string, princ-to-string, the ~S and ~A format operations, and the ~B, ~D, ~E, ~F, ~G, ~$, ~O, ~R, and ~X format operations when they encounter a non-numeric value) are required to be changed to go through the print-object generic function. Each implementation is required to replace its former implementation of printing with one or more print-object methods. Exactly which classes have methods for print-object is not specified; it would be valid for an implementation to have one default method that is inherited by all system-defined classes.
reinitialize-instance

Standard Generic Function

Purpose:
The generic function reinitialize-instance can be used to change the values of local slots according to initialization arguments. This generic function is called by the Meta-Object Protocol. It can also be called by users.

The system-supplied primary method for reinitialize-instance checks the validity of initialization arguments and signals an error if an initialization argument is supplied that is not declared as valid. The method then calls the generic function shared-initialize with the following arguments: the instance, nil (which means no slots should be initialized according to their initforms), and the initialization arguments it received.

Syntax:

reinitialize-instance instance &rest initargs

Method Signatures:

reinitialize-instance (instance standard-object) &rest initargs

Arguments:
The instance argument is the object to be initialized.
The initargs argument consists of alternating initialization argument names and values.

Values:
The modified instance is returned as the result.

Remarks:
Initialization arguments are declared as valid by using the :initarg option to defclass, or by defining methods for reinitialize-instance or shared-initialize. The keyword name of each keyword parameter specifier in the lambda-list of any method defined on reinitialize-instance or shared-initialize is declared as a valid initialization argument name for all classes for which that method is applicable.

See Also:
“Reinitializing an Instance”
“Rules for Initialization Arguments”
“Declaring the Validity of Initialization Arguments”
reinitialize-instance

initialize-instance
shared-initialize
update-instance-for-redefined-class
update-instance-for-different-class
slot-boundp
slot-makunbound
remove-method

Purpose:
The generic function remove-method removes a method from a generic function. It destructively modifies the specified generic function and returns the modified generic function as its result.

Syntax:

remove-method generic-function method

Method Signatures:

remove-method (generic-function standard-generic-function) method

Arguments:
The generic-function argument is a generic function object.
The method argument is a method object. The function remove-method does not signal an error if the method is not one of the methods on the generic function.

Values:
The modified generic function is returned. The result of remove-method is eq to the generic-function argument.

See Also:

find-method
Purpose:

The generic function `shared-initialize` is used to fill the slots of an instance using initialization arguments and `:initform` forms. It is called when an instance is created, when an instance is re-initialized, when an instance is updated to conform to a redefined class, and when an instance is updated to conform to a different class. The generic function `shared-initialize` is called by the system-supplied primary method for `initialize-instance`, `reinitialize-instance`, `update-instance-for-redefined-class`, and `update-instance-for-different-class`.

The generic function `shared-initialize` takes the following arguments: the instance to be initialized, a specification of a set of names of slots accessible in that instance, and any number of initialization arguments. The arguments after the first two must form an initialization argument list. The system-supplied primary method on `shared-initialize` initializes the slots with values according to the initialization arguments and specified `:initform` forms. The second argument indicates which slots should be initialized according to their `:initform` forms if no initialization arguments are provided for those slots.

The system-supplied primary method behaves as follows, regardless of whether the slots are local or shared:

- If an initialization argument in the initialization argument list specifies a value for that slot, that value is stored into the slot, even if a value has already been stored in the slot before the method is run.
- Any slots indicated by the second argument that are still unbound at this point are initialized according to their `:initform` forms. For any such slot that has an `:initform` form, that form is evaluated in the lexical environment of its defining `defclass` form and the result is stored into the slot. For example, if a `:before` method stores a value in the slot, the `:initform` form will not be used to supply a value for the slot.
- The rules mentioned in the section “Rules for Initialization Arguments” are obeyed.

Syntax:

```lisp
shared-initialize  instance  slot-names  &rest  initargs
```

[Generic Function]

Method Signatures:

```lisp
shared-initialize  (instance  standard-object)  slot-names  &rest  initargs
```

[Primary Method]

Arguments:

The `instance` argument is the object to be initialized.
shared-initialize

The slots-names argument specifies the slots that are to be initialized according to their :initform forms if no initialization arguments apply. It is supplied in one of three forms as follows:

- It can be list of slot names, which specifies the set of those slot names.
- It can be nil, which specifies the empty set of slot names.
- It can be the symbol t, which specifies the set of all of the slots.

The initargs argument consists of alternating initialization argument names and values.

Values:

The modified instance is returned as the result.

Remarks:

Initialization arguments are declared as valid by using the :initarg option to defclass, or by defining methods for shared-initialize. The keyword name of each keyword parameter specifier in the lambda-list of any method defined on shared-initialize is declared as a valid initialization argument name for all classes for which that method is applicable.

Implementations are permitted to optimize :initform forms that neither produce nor depend on side effects, by evaluating these forms and storing them into slots before running any initialize-instance methods, rather than by handling them in the primary initialize-instance method.

(This optimization might be implemented by having the allocate-instance method copy a prototype instance.)

Implementations are permitted to optimize default initial value forms for initialization arguments associated with slots by not actually creating the complete initialization argument list when the only method that would receive the complete list is the method on standard-object. In this case default initial value forms can be treated like :initform forms. This optimization has no visible effects other than a performance improvement.

See Also:

“Object Creation and Initialization”
“Rules for Initialization Arguments”
“Declaring the Validity of Initialization Arguments”
initialize-instance
reinitialize-instance
update-instance-for-redefined-class
update-instance-for-different-class

Functions in the Programmer Interface 2–73
shared-initialize

slot-boundp
slot-makunbound
Function

slot-boundp

Purpose:
The function slot-boundp tests whether a specific slot in an instance is bound.

Syntax:

\[
\text{slot-boundp} \quad \text{instance} \quad \text{slot-name}
\]

Arguments:
The arguments are the instance and the name of the slot.

Values:
The function slot-boundp returns true or false.

Remarks:
The function slot-boundp allows for writing :after methods on initialize-instance in order to initialize only those slots that have not already been bound.

If no slot of the given name exists in the instance, slot-missing is called as follows:

\[
\text{(slot-missing (class-of instance) instance slot-name 'slot-boundp)}
\]

The function slot-boundp is implemented using slot-boundp-using-class.

See Also:

slot-missing
Function

slot-exists-p

Purpose:
The function slot-exists-p tests whether the specified object has a slot of the given name.

Syntax:

slot-exists-p object slot-name

Arguments:
The object argument is any object. The slot-name argument is a symbol.

Values:
The function slot-exists-p returns true or false.

Remarks:
The function slot-exists-p is implemented using slot-exists-p-using-class.
Function

slot-makunbound

Purpose:
The function slot-makunbound restores a slot in an instance to the unbound state.

Syntax:

    slot-makunbound instance slot-name

Arguments:
The arguments to slot-makunbound are the instance and the name of the slot.

Values:
The instance is returned as the result.

Remarks:
If no slot of the given name exists in the instance, slot-missing is called as follows:

    (slot-missing (class-of instance) instance slot-name 'slot-makunbound)

The function slot-makunbound is implemented using slot-makunbound-using-class.

See Also:
slot-missing
slot-missing

**Purpose:**

The generic function `slot-missing` is invoked when an attempt is made to access a slot in an object whose metaclass is `standard-class` and the name of the slot provided is not a name of a slot in that class. The default method signals an error.

The generic function `slot-missing` is not intended to be called by programmers. Programmers may write methods for it.

**Syntax:**

```
slot-missing class object slot-name operation &optional new-value
```

**Method Signatures:**

```
slot-missing (class t) object slot-name operation &optional new-value
```

**Arguments:**

The required arguments to `slot-missing` are the class of the object that is being accessed, the object, the slot name, and a symbol that indicates the operation that caused `slot-missing` to be invoked. The optional argument to `slot-missing` is used when the operation is attempting to set the value of the slot.

**Values:**

If a method written for `slot-missing` returns values, these values get returned as the values of the original function invocation.

**Remarks:**

The generic function `slot-missing` may be called during evaluation of `slot-value`, `(setf slot-value)`, `slot-boundp`, and `slot-makunbound`. For each of these operations the corresponding symbol for the `operation` argument is `slot-value`, `setf`, `slot-boundp`, and `slot-makunbound` respectively.

The set of arguments (including the class of the instance) facilitates defining methods on the metaclass for `slot-missing`. 
Slot-Unbound

Purpose:
The generic function `slot-unbound` is called when an unbound slot is read in an instance whose metaclass is `standard-class`. The default method signals an error.

The generic function `slot-unbound` is not intended to be called by programmers. Programmers may write methods for it. The function `slot-unbound` is called only by the function `slot-value-using-class` and thus indirectly by `slot-value`.

Syntax:
```
slot-unbound class instance slot-name
```

Method Signatures:
```
slot-unbound (class t) instance slot-name
```

Arguments:
The arguments to `slot-unbound` are the class of the instance whose slot was accessed, the instance itself, and the name of the slot.

Values:
If a method written for `slot-unbound` returns values, these values get returned as the values of the original function invocation.

Remarks:
An unbound slot may occur if no :initform form was specified for the slot and the slot value has not been set, or if `slot-makunbound` has been called on the slot.

See Also:
```
slot-makunbound
```

Functions in the Programmer Interface 2–79
slot-value  

Function

Purpose:

The function slot-value returns the value contained in the slot slot-name of the given object. If there is no slot with that name, slot-missing is called. If the slot is unbound, slot-unbound is called.

The macro setf can be used with slot-value to change the value of a slot.

Syntax:

slot-value object slot-name

Arguments:

The arguments are the object and the name of the given slot.

Values:

The result is the value contained in the given slot.

Remarks:

If an attempt is made to read a slot and no slot of the given name exists in the instance, slot-missing is called as follows: (slot-missing (class-of instance) instance slot-name 'slot-value)

If an attempt is made to write a slot and no slot of the given name exists in the instance, slot-missing is called as follows: (slot-missing (class-of instance) instance slot-name 'setf new-value)

The function slot-value is implemented using slot-value-using-class.

Implementations may optimize slot-value by compiling it inline.

See Also:

slot-missing
slot-unbound
symbol-macrolet

Purpose:
The macro symbol-macrolet provides a mechanism for the substitution of forms for variable names within a lexical scope.

Syntax:
symbol-macrolet ((symbol expansion)*) &body body

Arguments:
The symbol argument specifies the symbol with which the form specified by the expansion argument is to be associated.

Values:
The result returned is that obtained by executing the forms specified by the body argument.

Examples:

(symbol-macrolet ((x 'foo))
 (list x (let ((x 'bar)) x)))

;;; The result is (foo bar), not (foo foo).
;;; The expansion is (list 'foo (let ((x 'bar)) x)),
;;; not (list 'foo (let (('foo 'bar)) 'foo)).

(symbol-macrolet ((x (1+ x)))
 (print x))

;;; The expansion is (print (1+ x)),
;;; not (print (1+ (1+ (1+ ....

Remarks:
The lexical scope of symbol-macrolet is body; it does not include expansion.

Each reference to symbol as a variable within the lexical scope of symbol-macrolet is replaced by expansion (not the result of evaluating expansion).

The use of symbol-macrolet can be shadowed by let. In other words, symbol-macrolet only substitutes for occurrences of symbol that would be in the scope of a lexical binding of symbol surrounding the body.

Functions in the Programmer Interface 2–81
symbol-macrolet

The macro symbol-macrolet is the basic mechanism that is used to implement with-slots.

When the body of the symbol-macrolet form is expanded, any use of setq to set the value of one of the specified variables is converted to a use of setf.

See Also:

with-slots
update-instance-for-different-class  

Standard Generic Function

Purpose:

The generic function `update-instance-for-different-class` is not intended to be called by programmers. Programmers may write methods for it. The function `update-instance-for-different-class` is called only by the function `change-class`.

The system-supplied primary method on `update-instance-for-different-class` checks the validity of initialization arguments and signals an error if an initialization argument is supplied that is not declared as valid. This method then initializes slots with values according to the initialization arguments, and initializes the newly added slots with values according to their :initform forms. It does this by calling the generic function `shared-initialize` with the following arguments: the instance, a list of names of the newly added slots, and the initialization arguments it received. Newly added slots are those local slots for which no slot of the same name exists in the previous class.

Methods for `update-instance-for-different-class` can be defined to specify actions to be taken when an instance is updated. If only :after methods for `update-instance-for-different-class` are defined, they will be run after the system-supplied primary method for initialization and therefore will not interfere with the default behavior of `update-instance-for-different-class`.

Syntax:

```
update-instance-for-different-class  previous  current  &rest initargs  
```

[Generic Function]

Method Signatures:

```
update-instance-for-different-class  (previous  standard-object)  
        (current  standard-object)  
        &rest initargs  
```

[Primary Method]

Arguments:

The arguments to `update-instance-for-different-class` are computed by `change-class`. When `change-class` is invoked on an instance, a copy of that instance is made; `change-class` then destructively alters the original instance. The first argument to `update-instance-for-different-class`, `previous`, is that copy; it holds the old slot values temporarily. This argument has dynamic extent within `change-class`; if it is referenced in any way once `update-instance-for-different-class` returns, the results are undefined. The second argument to `update-instance-for-different-class`, `current`, is the altered original instance.
update-instance-for-different-class

The intended use of previous is to extract old slot values by using slot-value or with-slots or by invoking a reader generic function, or to run other methods that were applicable to instances of the original class.

The initargs argument consists of alternating initialization argument names and values.

Values:

The value returned by update-instance-for-different-class is ignored by change-class.

Examples:

See the example for the function change-class.

Remarks:

Initialization arguments are declared as valid by using the :initarg option to defclass, or by defining methods for update-instance-for-different-class or shared-initialize. The keyword name of each keyword parameter specifier in the lambda-list of any method defined on update-instance-for-different-class or shared-initialize is declared as a valid initialization argument name for all classes for which that method is applicable.

Methods on update-instance-for-different-class can be defined to initialize slots differently from change-class. The default behavior of change-class is described in “Changing the Class of an Instance.”

See Also:

“Changing the Class of an Instance”
“Rules for Initialization Arguments”
“Declaring the Validity of Initialization Arguments”

change-class
shared-initialize
update-instance-for-redefined-class  

Standard Generic Function

Purpose:

The generic function `update-instance-for-redefined-class` is not intended to be called by programmers. Programmers may write methods for it. The generic function `update-instance-for-redefined-class` is called by the mechanism activated by `make-instances-obsolete`.

The system-supplied primary method on `update-instance-for-different-class` checks the validity of initialization arguments and signals an error if an initialization argument is supplied that is not declared as valid. This method then initializes slots with values according to the initialization arguments, and initializes the newly added slots with values according to their `:initform` forms. It does this by calling the generic function `shared-initialize` with the following arguments: the instance, a list of names of the newly added slots, and the initialization arguments it received. Newly added slots are those local slots for which no slot of the same name exists in the old version of the class.

Syntax:

```
(update-instance-for-redefined-class instance added-slots discarded-slots property-list &rest initargs)
```

Method Signatures:

```
(update-instance-for-redefined-class instance standard-object added-slots discarded-slots property-list &rest initargs)
```

Arguments:

When `make-instances-obsolete` is invoked or when a class has been redefined and an instance is being updated, a property list is created that captures the slot names and values of all the discarded slots with values in the original instance. The structure of the instance is transformed so that it conforms to the current class definition. The arguments to `update-instance-for-redefined-class` are this transformed instance, a list of the names of the new slots added to the instance, a list of the names of the old slots discarded from the instance, and the property list containing the slot names and values for slots that were discarded and had values. Included in this list of discarded slots are slots that were local in the old class and are shared in the new class.

The `initargs` argument consists of alternating initialization argument names and values.
update-instance-for-redefined-class

Values:

The value returned by update-instance-for-redefined-class is ignored.

Remarks:

Initialization arguments are declared as valid by using the :initarg option to defclass, or by defining methods for update-instance-for-redefined-class or shared-initialize. The keyword name of each keyword parameter specifier in the lambda-list of any method defined on update-instance-for-redefined-class or shared-initialize is declared as a valid initialization argument name for all classes for which that method is applicable.

Examples:

```lisp
(defclass position () ())

(defun x-y-position (position)
  ((x :initform 0 :accessor position-x)
   (y :initform 0 :accessor position-y)))

;;; It turns out polar coordinates are used more than Cartesian
;;; coordinates, so the representation is altered and some new
;;; accessor methods are added.

(defun update-instance-for-redefined-class :before
  ((pos x-y-position) added deleted plist &key)
  ;; Transform the x-y coordinates to polar coordinates
  ;; and store into the new slots.
  (let ((x (getf plist 'x))
         (y (getf plist 'y)))
    (setf (position-rho pos) (sqrt (+ (* x x) (* y y)))
          (position-theta pos) (atan y x)))

(defun x-y-position (position)
  ((rho :initform 0 :accessor position-rho)
   (theta :initform 0 :accessor position-theta)))

;;; All instances of the old x-y-position class will be updated
;;; automatically.

;;; The new representation is given the look and feel of the old one.

(defun position-x ((pos x-y-position))
  (with-slots (rho theta) pos (* rho (cos theta))))
```
(defmethod (setf position-x) (new-x (pos x-y-position))
  (with-slots (rho theta) pos
    (let ((y (position-y pos)))
      (setq rho (sqrt (+ (* new-x new-x) (* y y)))
            theta (atan y new-x))
      new-x)))

(defmethod position-y ((pos x-y-position))
  (with-slots (rho theta) pos (* rho (sin theta))))

(defmethod (setf position-y) (new-y (pos x-y-position))
  (with-slots (rho theta) pos
    (let ((x (position-x pos)))
      (setq rho (sqrt (+ (* x x) (* new-y new-y)))
            theta (atan new-y x))
      new-y)))

See Also:

“Redefining Classes”
“Rules for Initialization Arguments”
“Declaring the Validity of Initialization Arguments”
make-instances-obsolete
shared-initialize
with-accessors

Macro

Purpose:
The macro **with-accessors** creates a lexical environment in which specified slots are lexically available through their accessors as if they were variables. The macro **with-accessors** invokes the appropriate accessors to access the specified slots. Both **setf** and **setq** can be used to set the value of the slot.

Syntax:

```lisp
(with-accessors (\{slot-entry\}* ) instance-form &body body)
```

Values:
The result returned is that obtained by executing the forms specified by the **body** argument.

Examples:

```lisp
(with-accessors ((x position-x) (y position-y))
  (setq x y))
```

Remarks:

A **with-accessors** expression of the form:

```lisp
(with-accessors (slot-entry₁ ... slot-entryₙ) instance form₁ ... formₖ)
```

expands into the equivalent of

```lisp
(let ((in instance))
  (symbol-macrolet (Q₁ ... Qₙ) form₁ ... formₖ))
```

where \(Q_i\) is

```lisp
(variable-nameᵢ (accessor-nameᵢ in))
```
See Also:

with-slots
symbol-macrolet
with-added-methods

**Purpose:**

The `with-added-methods` special form produces new generic functions and establishes new lexical function definition bindings. Each generic function is created by adding the set of methods specified by its method definitions to a copy of the lexically visible generic function of the same name and its methods. If such a generic function does not already exist, a new generic function is created; this generic function has lexical scope.

The special form `with-added-methods` is used to define functions whose names are meaningful only locally and to execute a series of forms with these function definition bindings.

The names of functions defined by `with-added-methods` have lexical scope; they retain their local definitions only within the body of the `with-added-methods` construct. Any references within the body of the `with-added-methods` construct to functions whose names are the same as those defined within the `with-added-methods` form are thus references to the local functions instead of to any global functions of the same names. The scope of these generic function definition bindings includes the method bodies themselves as well as the body of the `with-added-methods` construct.

**Syntax:**

```lisp
(with-added-methods (function-specifier lambda-list
                     \[\[\{\{option\} \| method-description\}^{*}\]\]
                     \{form\}^{*})
                   )
```

`function-specifier::=\{symbol \| (setf symbol)\}`

`option::=\{:\argument-precedence-order \{parameter-name\}^{+}\}\|\`

`\{declare \{declaration\}^{+}\}\|\`

`\{:documentation string\}\|\`

`\{:method-combination symbol \{arg\}^{*}\}\|\`

`\{:generic-function-class class-name\}\|\`

`\{:method-class class-name\}\`

`method-description::=\{\{method\} \{method-qualifier\}^{*} \{specialized-lambda-list\}\`

`\{\{declaration \| documentation\}^{*} \{form\}^{*}\}`
with-added-methods

Arguments:

The `function-specifier`, `option`, `method-qualifier`, and `specialized-lambda-list` arguments are the same as for `defgeneric`.

The body of each method is enclosed in an implicit block. If `function-specifier` is a symbol, this block bears the same name as the generic function. If `function-specifier` is a list of the form `(setf symbol)`, the name of the block is `symbol`.

Values:

The result returned by `with-added-methods` is the value or values returned by the last form executed. If no forms are specified, `with-added-methods` returns `nil`.

Remarks:

If a generic function with the given name already exists, the lambda-list specified in the `with-added-methods` form must be congruent with the lambda-lists of all existing methods on that function as well as with the lambda-lists of all methods defined by the `with-added-methods` form; otherwise an error is signaled.

If `function-specifier` specifies an existing generic function that has a different value for any of the following `option` arguments, the copy of that generic function is modified to have the new value: `:argument-precedence-order`, `declare`, `:documentation`, `:generic-function-class`, `:method-combination`.

If `function-specifier` specifies an existing generic function that has a different value for the `:method-class option` argument, that value is changed in the copy of that generic function, but any methods copied from the existing generic function are not changed.

If a function of the given name already exists, that function is copied into the default method for a generic function of the given name. Note that this behavior differs from that of `defgeneric`.

If a macro or special form of the given name already exists, an error is signaled.

If there is no existing generic function, the `option` arguments have the same default values as the `option` arguments to `defgeneric`.

See Also:

- `generic-labels`
- `generic-flet`
- `defmethod`
- `defgeneric`
- `ensure-generic-function`
with-slots

Macro

Purpose:
The macro `with-slots` creates a lexical context for referring to specified slots as though they were variables. Within such a context the value of the slot can be specified by using its slot name, as if it were a lexically bound variable. Both `setf` and `setq` can be used to set the value of the slot.

The macro `with-slots` translates an appearance of the slot name as a variable into a call to `slot-value`.

Syntax:

```
with-slots ((slot-entry)* instance-form &body body)  
```

(slot-entry ::= slot-name | (variable-name slot-name))

Values:
The result returned is that obtained by executing the forms specified by the `body` argument.

Examples:

```
(with-slots (x y) position-1
  (sqrt (+ (* x x) (* y y))))
```

```
(with-slots ((x1 x) (y1 y)) position-1
  (with-slots ((x2 x) (y2 y)) position-2
    (psetf x1 x2
      y1 y2)))
```

```
(with-slots (x y) position
  (setq x (+ x x)
        y (+ y y)))
```

Remarks:
A `with-slots` expression of the form:

```
(with-slots (slot-entry1 ... slot-entryn) instance form1 ... formk)
```

expands into the equivalent of

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(let ((in instance))
  (symbol-macrolet (Q₁...Qₙ) form₁...formₖ)))

where Qᵢ is

(slot-entryᵢ (slot-value in ’slot-entryᵢ))

if slot-entryᵢ is a symbol and is

(variable-nameᵢ (slot-value in ’slot-nameᵢ))

if slot-entryᵢ is of the form

(variable-nameᵢ slot-nameᵢ)

See Also:

with-accessors
symbol-macrolet