

The UDUNITS-2 C API

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1 Synopsis

Coding:

```
#include <udunits2.h>
ut_system*
ut_system*
void
ut_system*
ut_unit*
ut_unit*
ut_unit*
ut_unit*
ut_status
ut_status
ut_status
ut_unit*
ut_unit*
ut_unit*
void
const char*
```

```
ut_read_xml(const char* path);
ut_new_system(void);
ut_free_system(ut_system* system);
ut_get_system(const ut_unit* unit);
ut_get_dimensionless_unit_one(const ut_system* system);
ut_get_unit_by_name(const ut_system* system, const char* name);
ut_get_unit_by_symbol(const ut_system* system, const char* symbol);
ut_set_second(const ut_unit* second);
ut_add_name_prefix(ut_system* system, const char* name, double value);
ut_add_symbol_prefix(ut_system* system, const char* symbol, double value);
ut_new_base_unit(ut_system* system);
ut_new_dimensionless_unit(ut_system* system);
ut_clone(const ut_unit* unit);
ut_free(ut_unit* unit);
ut_get_name(const ut_unit* unit, ut_encoding encoding);
```

| | |
|---------------|---------------------------------------------------------------------------------------------------------------------|
| ut_status | ut_map_name_to_unit(const char* <i>name</i> , const ut_encoding <i>encoding</i> , const ut_unit* <i>unit</i>); |
| ut_status | ut_unmap_name_to_unit(ut_system* <i>system</i> , const char* <i>name</i> , const ut_encoding <i>encoding</i>); |
| ut_status | ut_map_unit_to_name(const ut_unit* <i>unit</i> , const char* <i>encoding</i>); |
| ut_status | ut_unmap_unit_to_name(const ut_unit* <i>unit</i> , ut_encoding <i>encoding</i>); |
| const char* | ut_get_symbol(const ut_unit* <i>unit</i> , ut_encoding <i>encoding</i>); |
| ut_status | ut_map_symbol_to_unit(const char* <i>symbol</i> , const ut_encoding <i>encoding</i> , const ut_unit* <i>unit</i>); |
| ut_status | ut_unmap_symbol_to_unit(ut_system* <i>system</i> , const char* <i>symbol</i> , const ut_encoding <i>encoding</i>); |
| ut_status | ut_map_unit_to_symbol(const ut_unit* <i>unit</i> , const char* <i>encoding</i>); |
| ut_status | ut_unmap_unit_to_symbol(const ut_unit* <i>unit</i> , ut_encoding <i>encoding</i>); |
| int | ut_is_dimensionless(const ut_unit* <i>unit</i>); |
| int | ut_same_system(const ut_unit* <i>unit1</i> , const ut_unit* <i>unit2</i>); |
| int | ut_compare(const ut_unit* <i>unit1</i> , const ut_unit* <i>unit2</i>); |
| int | ut_are_convertible(const ut_unit* <i>unit1</i> , const ut_unit* <i>unit2</i>); |
| cv_converter* | ut_get_converter(ut_unit* <i>from</i> , ut_unit* <i>to</i>); |
| ut_unit* | ut_scale(double <i>factor</i> , const ut_unit* <i>unit</i>); |
| ut_unit* | ut_offset(const ut_unit* <i>unit</i> , double <i>offset</i>); |

| | |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>ut_unit*</code> | <code>ut_offset_by_time(const ut_unit* <i>unit</i>, double <i>origin</i>);</code> |
| <code>ut_unit*</code> | <code>ut_multiply(const ut_unit* <i>unit1</i>, const ut_unit* <i>unit2</i>);</code> |
| <code>ut_unit*</code> | <code>ut_invert(const ut_unit* <i>unit</i>);</code> |
| <code>ut_unit*</code> | <code>ut_divide(const ut_unit* <i>numer</i>, const ut_unit* <i>denom</i>);</code> |
| <code>ut_unit*</code> | <code>ut_raise(const ut_unit* <i>unit</i>, int <i>power</i>);</code> |
| <code>ut_unit*</code> | <code>ut_root(const ut_unit* <i>unit</i>, int <i>root</i>);</code> |
| <code>ut_unit*</code> | <code>ut_log(double <i>base</i>, const ut_unit* <i>reference</i>);</code> |
| <code>ut_unit*</code> | <code>ut_parse(const ut_system* <i>system</i>, const char* <i>string</i>, ut_encoding <i>encoding</i>);</code> |
| <code>char*</code> | <code>ut_trim(char* <i>string</i>, ut_encoding <i>encoding</i>);</code> |
| <code>int</code> | <code>ut_format(const ut_unit* <i>unit</i>, char* <i>buf</i>, size_t <i>size</i>, signed <i>opts</i>);</code> |
| <code>ut_status</code> | <code>ut_accept_visitor(const ut_unit* <i>unit</i>, const ut_visitor* <i>visitor</i>, void* <i>arg</i>);</code> |
| <code>double</code> | <code>ut_encode_date(int <i>year</i>, int <i>month</i>, int <i>day</i>);</code> |
| <code>double</code> | <code>ut_encode_clock(int <i>hours</i>, int <i>minutes</i>, double <i>seconds</i>);</code> |
| <code>double</code> | <code>ut_encode_time(int <i>year</i>, int <i>month</i>, int <i>day</i>, int <i>hour</i>, double <i>second</i>);</code> |
| <code>void</code> | <code>ut_decode_time(double <i>value</i>, int* <i>year</i>, int* <i>month</i>, int* <i>day</i>, int* <i>hour</i>, double* <i>second</i>, double* <i>resolution</i>);</code> |
| <code>ut_status</code> | <code>ut_get_status(void);</code> |
| <code>void</code> | <code>ut_set_status(ut_status <i>status</i>);</code> |

```

int                ut_handle_error_message(const char* fmt, ...);

ut_error_message_handler  ut_set_error_message_handler(ut_error_message_handler
dler);

int                ut_write_to_stderr(const char* fmt, va_list args);

int                ut_ignore(const char* fmt, va_list args);


float              cv_convert_float(const cv_converter* converter, float value);

double            cv_convert_double(const cv_converter* converter, double value);

float*            cv_convert_floats(const cv_converter* converter, const float* in, size_t count, float* out);

double*          cv_convert_doubles(const cv_converter* converter, const double* const in, size_t count, double* out);

void              cv_free(cv_converter* conv);

```

Compiling:

```
c89 -I includedir ...
```

Where *includedir* is the installation-directory for C header files (e.g., /usr/local/include).

Linking:

```
c89 ... -Llibdir -ludunits2 -lexpat ... -lm
```

Where *libdir* is the installation-directory for object code libraries (e.g., /usr/local/lib).

2 What's a Unit Package Good For?

The existence of a software package is justified by what you can do with it. The three main things you can do with the UDUNIT-2 package are

1. [Chapter 4 \[Value Conversion\]](#), [page 11](#).
2. Convert a string representation of a unit into a binary one — enabling the programatic manipulation of units. There are three ways to do this:
 - [Section 3.2 \[Extracting\]](#), [page 7](#) from a [\[unit-system\]](#), [page 5](#). This requires that you know the unit's name or symbol and that the unit is in a unit-system.
 - [Chapter 5 \[Parsing\]](#), [page 13](#). This requires that the string be parsable by `[ut_parse()]`, [page 13](#).
 - [Chapter 8 \[Operations\]](#), [page 19](#).
3. [Chapter 7 \[Formatting\]](#), [page 18](#) — enabling the printing and storing of units in a human-readable form.

While the above might seem to be trivial activities, their general availability at the time might have helped prevent the [Mars Climate Orbiter](#) fiasco.

3 Unit-Systems

A unit-system is a set of units that are all defined in terms of the same set of base units. In the SI system of units, for example, the base units are the meter, kilogram, second, ampere, kelvin, mole, and candela. (For definitions of these base units, see <http://physics.nist.gov/cuu/Units/current.html>.)

In the UDUNITS-2 package, every accessible unit belongs to one and only one unit-system. It is not possible to convert numeric values between units of different unit-systems. Similarly, units belonging to different unit-systems always compare unequal.

There are several categories of operations on unit-systems:

3.1 Obtaining a Unit-System

Typically, you would obtain a unit-system of predefined units by reading the default unit database using `[ut_read_xml()]`, page 6 with a NULL pathname argument. If this doesn't quite match your needs, then there are alternatives. Together with the typical solution, the means for obtaining a useful unit-system are (in order of increasing difficulty):

- Obtain the default unit-system using `[ut_read_xml()]`, page 6(NULL).
- Copy and customize the unit database and then call `[ut_read_xml()]`, page 6 with the pathname of the customized database to obtain a customized unit-system.
- Same as either of the above but then adding new units to the unit-system using `[ut_new_base_unit()]`, page 8 and `[ut_new_dimensionless_unit()]`, page 8.
- Same as the above but also deriving new units using Chapter 8 [Operations], page 19 and then adding them to the unit-system using Chapter 9 [Mapping], page 25.
- Same as the above but starting with an empty unit-system obtained from `[ut_new_system()]`, page 7, in which case you will definitely have to start with `[ut_new_base_unit()]`, page 8 and `[ut_new_dimensionless_unit()]`, page 8.

You should pass every unit-system pointer to `[ut_free_system()]`, page 9 when you no longer need the corresponding unit-system.

`ut_system*` `ut_read_xml (const char* path)` [Function]

Reads the XML-formatted unit-database specified by *path* and returns the corresponding unit-system. If *path* is NULL, then the pathname specified by the environment variable UDUNITS2_XML_PATH is used if set; otherwise, the compile-time pathname of the installed, default, unit database is used. You should pass the returned pointer to `ut_free_system()` when you no longer need the unit-system. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

UT_OPEN_ARG

path is non-NULL but the file couldn't be opened. See `errno` for the reason.

UT_OPEN_ENV

path is NULL and environment variable UDUNITS2_XML_PATH is set but the file couldn't be opened. See `errno` for the reason.

UT_OPEN_DEFAULT

path is NULL, environment variable UDUNITS2_XML_PATH is unset, and the installed, default, unit database couldn't be opened. See `errno` for the reason.

UT_OS Operating-system error. See `errno`.

UT_PARSE The database file couldn't be parsed.

`ut_system* ut_new_system (void)` [Function]

Creates and returns a new unit-system. On success, the unit-system will be empty except for the dimensionless unit one. You should pass the returned pointer to `ut_free_system()` when you no longer need the unit-system. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return the following:

UT_OS Operating-system error. See `errno`.

3.2 Extracting Units from a Unit-System

NOTE: This section covers low-level access to the individual units of a `[unit-system]`, page 5. General parsing of arbitrary unit specifications is covered in the section [Chapter 5 \[Parsing\]](#), page 13.

A `[unit-system]`, page 5 contains mappings from identifiers to units (and vice versa). Consequently, once you have a unit-system, you can easily obtain a unit for which you know the name or symbol using the function `[ut_get_unit_by_name()]`, page 7 or `[ut_get_unit_by_symbol()]`, page 7.

`ut_unit* ut_get_unit_by_name (const ut_system* system, [Function]
const char* name)`

Returns the unit to which *name* maps from the unit-system referenced by *system* or NULL if no such unit exists. Name comparisons are case-insensitive. If this function returns NULL, then `[ut_get_status()]`, page 29 will return one of the following:

UT_SUCCESS

name doesn't map to a unit of *system*.

UT_BAD_ARG

system or *name* is NULL.

`ut_unit* ut_get_unit_by_symbol (const ut_system* system, [Function]
const char* symbol)`

Returns the unit to which *symbol* maps from the unit-system referenced by *system* or NULL if no such unit exists. Symbol comparisons are case-sensitive. If this function returns NULL, then `[ut_get_status()]`, page 29 will return one of the following:

UT_SUCCESS

symbol doesn't map to a unit of *system*.

UT_BAD_ARG

system or *symbol* is NULL.

`ut_unit* ut_get_dimensionless_unit_one (const ut_system* system)` [Function]

Returns the dimensionless unit one of the unit-system referenced by *system*. While not necessary, the returned pointer may be passed to `ut_free()` when you no longer need the unit. If *system* is NULL, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return `UT_BAD_ARG`.

3.3 Adding Units to a Unit-System

If you use `[ut_read_xml()]`, page 6, then you should not normally need to add any new units to a unit-system.

Because you get units via their names or symbols, adding a unit to a unit-system actually means mapping one or more identifiers (i.e., names or symbols) to the unit. Thereafter, you can use `[ut_get_unit_by_name()]`, page 7 and `[ut_get_unit_by_symbol()]`, page 7 to retrieve the unit. The mapping of identifiers to units is covered Chapter 9 [Mapping], page 25.

Having said that, it is possible to create a new base or dimensionless unit within a unit-system using `[ut_new_base_unit()]`, page 8 or `[ut_new_dimensionless_unit()]`, page 8—you'll just also have to map identifiers to the newly-created unit in order to be able to retrieve it later by identifier.

`ut_unit* ut_new_base_unit (ut_system* system)` [Function]

Creates and adds a new base-unit to the unit-system referenced by *system*. This function returns the new base-unit. You should pass the returned pointer to `ut_free()` when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

`UT_BAD_ARG`

system is NULL.

`UT_OS`

Operating-system failure. See `errno`.

If you use `[ut_read_xml()]`, page 6, then you should not normally need to call this function.

`ut_unit* ut_new_dimensionless_unit (ut_system* system)` [Function]

Creates and adds a new dimensionless-unit to the unit-system referenced by *system*. This function returns the new dimensionless-unit. You should pass the returned pointer to `ut_free()` when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

`UT_BAD_ARG`

system is NULL.

`UT_OS`

Operating-system failure. See `errno`.

If you use `[ut_read_xml()]`, page 6, then you should not normally need to call this function.

3.4 Adding Unit-Prefixes to a Unit-System

A prefix is a word or symbol that is appended to the beginning of a word or symbol that represents a unit in order to modify the value of that unit. For example, the prefix “kilo” in the word “kiloamperes” changes the value from one ampere to one-thousand amperes.

If you use `[ut_read_xml()]`, page 6, then you should not normally need to add any new prefixes to a unit-system.

`[ut_status]`, page 29 `ut_add_name_prefix (ut_system* system, const char* name, double value)` [Function]

Adds the name-prefix *name* with the value *value* to the unit-system *system*. A name-prefix is something like “mega” or “milli”. Comparisons between name-prefixes are case-insensitive. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

system or *name* is NULL, or *value* is 0.

UT_EXISTS

name already maps to a different value.

UT_OS

Operating-system failure. See `errno`.

`[ut_status]`, page 29 `ut_add_symbol_prefix (ut_system* system, const char* symbol, double value)` [Function]

Adds the symbol-prefix *symbol* with the value *value* to the unit-system *system*. A symbol-prefix is something like “M” or “m”. Comparisons between symbol-prefixes are case-sensitive. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

system or *symbol* is NULL, or *value* is 0.

UT_EXISTS

symbol already maps to a different value.

UT_OS

Operating-system failure. See `errno`.

3.5 Miscellaneous Operations on Unit-Systems

`void ut_free_system (ut_system* system)` [Function]

Frees the unit-system referenced by *system*. All unit-to-identifier and identifier-to-unit mappings are removed. Use of *system* after this function returns results in undefined behavior.

`[ut_status]`, page 29 `ut_set_second (const ut_unit* second)` [Function]

Sets the “second” unit of a unit-system. This function must be called before the first call to `ut_offset_by_time()` for a unit in the same unit-system. `[ut_read_xml()]`, page 6 calls this function if the unit-system it’s reading contains a unit named “second”. This function returns one of the following:

UT_SUCCESS

The “second” unit of *system* was successfully set.

UT_EXISTS

The “second” unit of *system* is set to a different unit.

UT_BAD_ARG

second is NULL.

4 Converting Values Between Units

You can convert numeric values in one unit to equivalent values in another, compatible unit by means of a converter. For example

```
#include <udunits2.h>

...
ut_unit*      from = ...;
ut_unit*      to = ...;
cv_converter* converter = ut_get_converter(from, to);
double        fromValue = ...;
double        toValue = cv_convert_double(converter, fromValue);

cv_free(converter);
```

The converter API is declared in the header-file `<converter.h>`, which is automatically included by the UDUNITS-2 header-file (`<udunits2.h>`) so you don't need to explicitly include it.

`int ut_are_convertible (const ut_unit* unit1, uconst_t_unit* [Function]
unit2)`

Indicates if numeric values in unit *unit1* are convertible to numeric values in unit *unit2* via `[ut_get_converter()]`, page 11. In making this determination, dimensionless units are ignored. This function returns a non-zero value if conversion is possible; otherwise, 0 is returned and `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit1 or *unit2* is NULL.

UT_NOT_SAME_SYSTEM

unit1 and *unit2* belong to different `[unit-system]`, page 5s.

UT_SUCCESS

Conversion between the units is not possible (e.g., *unit1* refers to a meter and *unit2* refers to a kilogram).

`cv_converter* ut_get_converter (ut_unit* const from, [Function]
ut_unit* const to)`

Creates and returns a converter of numeric values in the *from* unit to equivalent values in the *to* unit. You should pass the returned pointer to `cv_free()` when you no longer need the converter. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

from or *to* is NULL.

UT_NOT_SAME_SYSTEM

The units *from* and *to* don't belong to the same unit-system.

UT_MEANINGLESS

The units belong to the same unit-system but conversion between them is meaningless (e.g., conversion between seconds and kilograms is meaningless).

UT_OS Operating-system failure. See `errno`.

`float cv_convert_float (const cv_converter* converter, [Function]
 const float value)`

Converts the single floating-point value *value* and returns the new value.

`double cv_convert_double (const cv_converter* converter, [Function]
 const double value)`

Converts the single double-precision value *value* and returns the new value.

`float* cv_convert_floats (const cv_converter* converter, [Function]
 const float* in, size_t count, float* out)`

Converts the *count* floating-point values starting at *in*, writing the new values starting at *out* and, as a convenience, returns *out*. The input and output arrays may overlap or be identical.

`double* cv_convert_doubles (const cv_converter* converter, [Function]
 const double* in, size_t count, double* out)`

Converts the *count* double-precision values starting at *in*, writing the new values starting at *out* and, as a convenience, returns *out*. The input and output arrays may overlap or be identical.

`void cv_free (cv_converter* conv); [Function]`

Frees resources associated with the converter referenced by *conv*. You should call this function when you no longer need the converter. Use of *conv* upon return results in undefined behavior.

5 Parsing a String into a Unit

Here's an example of parsing a string representation of a unit into its binary representation:

```
#include <stdlib.h>
#include <udunits2.h>
...
ut_system*   unitSystem = [ut_read_xml()], page 6;
const char* string = "kg.m2/s3";
ut_unit*     watt = [ut_parse()], page 13(unitSystem, string, UT_ASCII);

if (watt == NULL) {
    /* Unable to parse string. */
}
else {
    /* Life is good. */
}
```

`ut_unit* ut_parse (const ut_system* system, const char* string, ut_encoding encoding)` [Function]

Returns the binary unit representation corresponding to the string unit representation *string* in the character-set *encoding* using the unit-system *system*. *string* must have no leading or trailing whitespace (see `[ut_trim()], page 13`). If an error occurs, then this function returns NULL and `[ut_get_status()], page 29` will return one of the following:

UT_BAD_ARG

system or *string* is NULL.

UT_SYNTAX

string contained a syntax error.

UT_UNKNOWN

string contained an unknown identifier.

UT_OS

Operating-system failure. See `errno` for the reason.

`size_t ut_trim (char* string, ut_encoding encoding)` [Function]

Removes all leading and trailing whitespace from the NUL-terminated string *string*. Returns *string*, which is modified if it contained leading or trailing whitespace.

6 Unit Syntax

For the most part, the UDUNITS-2 package follows the syntax for unit-strings promulgated by the US National Institute for Standards and Technology (NIST). Details, of which, can be found at <http://physics.nist.gov/cuu/Units/index.html>. The one general exception to this is the invention of a syntax for “offset”-units (e.g., the definition of the degree Celsius is “K @ 273.15”).

6.1 Unit Specification Examples

| String Type | Using Names | Using Symbols | Comment |
|-------------|-----------------------|---------------|-----------------------------------------------------|
| Simple | meter | m | |
| Raised | meter^2 | m2 | higher precedence than multiplying or dividing |
| Product | newton meter | N.m | |
| Quotient | meter per second | m/s | |
| Scaled | 60 second | 60 s | |
| Prefixed | kilometer | km | |
| Offset | kelvin from 273.15 | K @ 273.15 | lower precedence than multiplying or dividing |
| Logarithmic | lg(re milliwatt) | lg(re mW) | "lg" is base 10, "ln" is base e, and "lb" is base 2 |
| Grouped | (5 meter)/(30 second) | (5 m)/(30 s) | |

The above may be combined, e.g., "0.1 lg(re m/(5 s)^2) @ 50".

You may also look at the <def> elements in [Chapter 12 \[Database\]](#), [page 31](#) to see examples of string unit specifications.

You may use the [\[udunits2\]](#), [page \[undefined\]](#) utility to experiment with string unit specifications.

6.2 Unit Grammar

Here is the unit-syntax understood by the UDUNITS-2 package. Words printed *Thusly* indicate non-terminals; words printed **THUSLY** indicate terminals; and words printed <thusly> indicate lexical elements.

```

Unit-Spec: one of
    nothing
    Shift-Spec

Shift-Spec: one of
    Product-Spec
    Product-Spec SHIFT REAL
    Product-Spec SHIFT INT
    Product-Spec SHIFT Timestamp

Product-Spec: one of
    Power-Spec
    Product-Spec Power-Spec

```

Product-Spec MULTIPLY *Power-Spec*
Product-Spec DIVIDE *Power-Spec*

Power-Spec: one of
 Basic-Spec
 Basic-Spec INT
 Basic-Spec EXPONENT
 Basic-Spec RAISE INT

Basic-Spec: one of
 ID
 "(" *Shift-Spec* ")"
 LOGREF *Product_Spec* ")"
 Number

Number: one of
 INT
 REAL

Timestamp: one of
 DATE
 DATE CLOCK
 DATE CLOCK CLOCK
 DATE CLOCK INT
 DATE CLOCK ID
 TIMESTAMP
 TIMESTAMP INT
 TIMESTAMP ID

SHIFT:
 <space>* <shift_op> <space>*

<shift_op>: one of
 "@"
 "after"
 "from"
 "since"
 "ref"

REAL:
 the usual floating-point format

INT:
 the usual integer format

MULTIPLY: one of
 "_"

" . "
 " * "
 <space>+
 <centered m i d d o t>

D I V I D E:
 <space>* <d i v i d e _ o p> <space>*

<d i v i d e _ o p>: one of
 per
 PER
 "/"

EXPONENT:
 ISO-8859-9 or UTF-8 encoded exponent characters

R A I S E: one of
 "^"
 "*"

I D: one of
 <i d>
 "%"
 "' "
 "\""
 degree sign
 greek mu character

<i d>:
 <a l p h a> <a l p h a n u m>*

<a l p h a>:
 [A-Za-z_]
 ISO-8859-1 alphabetic characters
 non-breaking space

<a l p h a n u m>: one of
 <a l p h a>
 <d i g i t>

<d i g i t>:
 [0-9]

LOGREF:
 <l o g> <space>* <l o g r e f>

<l o g>: one of

```
"l og"
"l g"
"l n"
"l b"
```

```
<l o g r e f>:
  "(" <space>* <re> ":"? <space>*
```

```
DATE:
  <year> "-" <month> ("-" <day>)?
```

```
<year>:
  [+]?[0-9]{1,4}
```

```
<month>:
  "0"?[1-9]|1[0-2]
```

```
<day>:
  "0"?[1-9]|1[1-2][0-9]|"30"|"31"
```

```
CLOCK:
  <hour> ":" <mi nute> (":" <second>)?
```

```
TIMESTAMP:
  <year> (<month> <day>)? "T" <hour> (<mi nute> <second>)?
```

```
<hour>:
  [+]?[0-1]?[0-9]|2[0-3]
```

```
<mi nute>:
  [0-5]?[0-9]
```

```
<second>:
  (<mi nute>|60) (\.[0-9]*)?
```

7 Formatting a Unit into a String

Use the `[ut_format()]`, page 18 function to obtain the string representation of a binary unit. For example, the following gets the definition of the unit "watt" in ASCII characters using unit-symbols rather than unit-names:

```
ut_unit*    watt = ...;
char        buf[128];
unsigned    opts = [ut_encoding], page 32 | UT_DEFINITION;
int         len = [ut_format()], page 18(watt, buf, sizeof(buf), opts);

if (len == -1) {
    /* Couldn't get string */
}
else if (len == sizeof(buf)) {
    /* Entire buffer used: no terminating NUL */
}
else {
    /* Have string with terminating NUL */
}
```

`int ut_format (const ut_unit* unit, char* buf, size_t size, [Function] unsigned opts)`

Formats the unit *unit* (i.e., returns its string representation) into the buffer pointed-to by *buf* of size *size*. The argument *opts* specifies how the formatting is to be done and is a bitwise OR of a `[ut_encoding]`, page 32 value and zero or more of the following:

`UT_NAMES` Use unit names instead of symbols.

`UT_DEFINITION`

The formatted string should be the definition of *unit* in terms of basic-units instead of stopping any expansion at the highest level possible.

On success, this function returns either the number of bytes – excluding the terminating NUL – that were written into *buf* or the number of bytes that *would have been written*. The difference is due to the runtime `snprintf()` function that was used.

On failure, this function returns -1 and `[ut_get_status()]`, page 29 will return one of the following:

`UT_BAD_ARG`

unit or *buf* is NULL, or *opts* contains the bit patterns of both `UT_LATIN1` and `UT_UTF8`.

`UT_CANT_FORMAT`

unit can't be formatted in the desired manner (e.g., *opts* contains `UT_ASCII` but *unit* doesn't have an identifier in that character-set or *opts* doesn't contain `UT_NAMES` and a necessary symbol doesn't exist).

8 Unit Operations

You can use unit operations to construct new units, get information about units, or compare units.

8.1 Unary Unit Operations

`void ut_free (ut_unit* unit)` [Function]

Frees resources associated with *unit*. You should invoke this function on every unit that you no longer need. Use of *unit* upon return from this function results in undefined behavior.

`ut_unit* ut_scale (double factor, const ut_unit* unit)` [Function]

Returns a unit equivalent to another unit scaled by a numeric factor. For example:

```
const ut_unit* meter = ...
const ut_unit* kilometer = ut_scale(1000, meter);
```

The returned unit is equivalent to *unit* multiplied by *factor*. You should pass the returned pointer to `[ut_free()]`, page 19 when you no longer need the unit.

`ut_unit* ut_offset (const ut_unit* unit, double offset)` [Function]

Returns a unit equivalent to another unit relative to a particular origin. For example:

```
const ut_unit* kelvin = ...
const ut_unit* celsius = ut_offset(kelvin, 273.15);
```

The returned unit is equivalent to *unit* with an origin of *offset*. You should pass the returned pointer to `[ut_free()]`, page 19 when you no longer need the unit. If an error occurs, then this function returns NULL and `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit is NULL.

UT_OS

Operating-system error. See `errno` for the reason.

`ut_unit* ut_offset_by_time (const ut_unit* const unit, const double origin)` [Function]

Returns a timestamp-unit equivalent to the time unit *unit* referenced to the time-origin *origin* (as returned by `[ut_encode_time()]`, page 28). For example:

```
const ut_unit* second = ...
const ut_unit* secondsSinceTheEpoch =
    ut_offset_by_time(second, ut_encode_time(1970, 1, 1, 0, 0, 0.0));
```

Leap seconds are not taken into account. You should pass the returned pointer to `[ut_free()]`, page 19 when you no longer need the unit. If an error occurs, then this function returns NULL and `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit is NULL.

UT_OS

Operating-system error. See `errno` for the reason.

UT_MEANINGLESS

Creation of a timestamp unit based on *unit* is not meaningful. It might not be a time-unit, for example.

UT_NO_SECOND

The associated unit-system doesn't contain a "second" unit. See `[ut_set_second()]`, page 9.

CAUTION: The timestamp-unit was created to be analogous to, for example, the degree celsius—but for the time dimension. I've come to believe, however, that creating such a unit was a mistake, primarily because users try to use the unit in ways for which it was not designed (such as converting dates in a calendar whose year is exactly 365 days long). Such activities are much better handled by a dedicated calendar package. Please be careful about using timestamp-units. See also the section on [Chapter 10 \[Time\]](#), page 28.

`ut_unit* ut_invert (const ut_unit* unit)` [Function]

Returns the inverse (i.e., reciprocal) of the unit *unit*. This convenience function is equal to `[ut_raise()]`, page 20. You should pass the returned pointer to `[ut_free()]`, page 19 when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit is NULL.

UT_OS

Operating-system error. See `errno` for the reason.

`ut_unit* ut_raise (const ut_unit* unit, int power)` [Function]

Returns the unit equal to unit *unit* raised to the power *power*. You should pass the returned pointer to `ut_free()` when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit is NULL.

UT_OS

Operating-system error. See `errno` for the reason.

`ut_unit* ut_root (const ut_unit* unit, int root)` [Function]

Returns the unit equal to the *root* root of unit *unit*. You should pass the returned pointer to `ut_free()` when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit is NULL.

UT_MEANINGLESS

It's meaningless to take the given root of the given unit. This could be because the resulting unit would have fractional (i.e., non-integral) dimensionality, or because the unit is, for example, a logarithmic unit.

UT_OS Operating-system error. See `errno` for the reason.

`ut_unit* ut_log (double base, const ut_unit* reference)` [Function]

Returns the logarithmic unit corresponding to the logarithmic base *base* and a reference level specified as the unit *reference*. For example, the following creates a decibel unit with a one milliwatt reference level:

```
const ut_unit* milliWatt = ...;
const ut_unit* bel_1_mW = ut_log(10.0, milliWatt);

if (bel_1_mW != NULL) {
    const ut_unit* decibel_1_mW = [ut_scale()], page 19(0.1, bel_1_mW);
    [ut_free()], page 19(bel_1_mW);    /* no longer needed */

    if (decibel_1_mW != NULL) {
        /* Have decibel unit with 1 mW reference */
        ...
        [ut_free()], page 19(decibel_1_mW);
    }
    /* "decibel_1_mW" allocated */
}
```

You should pass the returned pointer to `ut_free()` when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()], page 30` and returns `NULL`. Also, `[ut_get_status()], page 29` will return one of the following:

UT_BAD_ARG
 reference is `NULL`.

UT_OS Operating-system error. See `errno` for the reason.

UT_BAD_ARG
 base is invalid (e.g., it must be greater than one).

`const char* ut_get_name (const ut_unit* unit, ut_encoding encoding)` [Function]

Returns the name to which the unit referenced by *unit* maps in the character-encoding specified by *encoding*. If this function returns `NULL`, then `[ut_get_status()], page 29` will return one of the following:

UT_BAD_ARG
 name is `NULL`.

UT_SUCCESS
 unit doesn't map to a name in the given character-set.

`const char* ut_get_symbol (const ut_unit* unit, ut_encoding encoding)` [Function]

Returns the symbol to which the unit referenced by *unit* maps in the character-encoding specified by *encoding*. If this function returns NULL, then `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

symbol is NULL.

UT_SUCCESS

unit doesn't map to a symbol in the given character-set.

`ut_system* ut_get_system (const ut_unit* unit)` [Function]

Returns the unit-system to which the unit referenced by *unit* belongs. If *unit* is NULL, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return UT_BAD_ARG.

`int ut_is_dimensionless (const ut_unit* unit)` [Function]

Indicates if unit *unit* is dimensionless (like "radian"). This function returns a non-zero value if the unit is dimensionfull; otherwise, 0 is returned and `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit1 is NULL.

UT_SUCCESS

The unit is dimensionless.

`ut_unit* ut_clone (const ut_unit* unit)` [Function]

Returns a copy of the unit referenced by *unit*. You should pass the returned pointer to `ut_free()` when you no longer need the unit. If an error occurs, then this function writes an error-message using `[ut_handle_error_message()]`, page 30 and returns NULL. Also, `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit is NULL.

UT_OS

Operating-system failure. See `errno`.

If you use `[ut_read_xml()]`, page 6, then you should not normally need to call this function.

`[ut_status]`, page 29 `ut_accept_visitor (const ut_unit* unit, const [ut_visitor], page 23* visitor, void* arg)` [Function]

Accepts the visitor *visitor* to the unit *unit*. The argument *arg* is passed to the visitor's functions. This function returns one of the following:

UT_BAD_ARG

visitor or *unit* is NULL.

UT_VISIT_ERROR

An error occurred in *visitor* while visiting *unit*.

UT_SUCCESS

Success.

`ut_visitor` *int foo(int) int bar(int, int)* [Data type]

You pass a pointer to a data object of this type if and when you call `[ut_accept_visitor()]`, page 22. It contains the following pointers to functions that implement your unit-visitor:

`[ut_status]`, page 29 `(*visit_basic)(const ut_unit* unit, void* arg);`

Visits the basic-unit *unit*. A basic-unit is a base unit like “meter” or a non-dimensional but named unit like “radian”. This function returns `[ut_status]`, page 29 on and only on success.

`[ut_status]`, page 29 `(*visit_product)(const ut_unit* unit, int count, const ut_unit* const* basicUnits, const int* powers, void* arg);`

Visits the product-unit *unit*. The product-unit is a product of the *count* basic-units referenced by *basicUnits*, each raised to their respective, non-zero power in *powers*. This function returns `[ut_status]`, page 29 on and only on success.

`[ut_status]`, page 29 `(*visit_galilean)(const ut_unit* unit, double scale, const ut_unit* underlyingUnit, double origin, void* arg);`

Visits the Galilean-unit *unit*. The Galilean-unit has the underlying unit *underlyingUnit* and either the non-unity scale factor *scale* or the non-zero origin *origin*, or both. This function returns `[ut_status]`, page 29 on and only on success.

UT_BAD_ARG

unit1 or *unit2* is NULL.

UT_NOT_SAME_SYSTEM

unit1 and *unit2* belong to different [unit-system], page 5s.

UT_OS

Operating-system error. See *errno* for the reason.

`ut_unit* ut_divide (const ut_unit* numer, const ut_unit* denom)` [Function]

Returns the result of dividing unit *numer* by unit *denom*. You should pass the pointer to `[ut_free()]`, page 19 when you no longer need the unit. On failure, this function returns NULL and `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

numer or *denom* is NULL.

UT_NOT_SAME_SYSTEM

unit1 and *unit2* belong to different [unit-system], page 5s.

UT_OS

Operating-system error. See *errno* for the reason.

`int ut_compare (const ut_unit* unit1, const ut_unit* unit2)` [Function]

Compares two units. Returns a value less than, equal to, or greater than zero as *unit1* is considered less than, equal to, or greater than *unit2*, respectively. Units from different [unit-system], page 5s never compare equal. The value zero is also returned if both unit pointers are NULL.

`int ut_same_system (const ut_unit* unit1, const ut_unit* unit2)` [Function]

Indicates if two units belong to the same unit-system. This function returns a non-zero value if the two units belong to the same [unit-system], page 5; otherwise, 0 is returned and `[ut_get_status()]`, page 29 will return one of the following:

UT_BAD_ARG

unit1 or *unit2* is NULL.

UT_SUCCESS

The units belong to different [unit-system], page 5s.

9 Mapping Between Identifiers and Units

Within a unit-system, you can map an identifier to a unit and vice versa. If an identifier maps to a unit, then the unit can be retrieved from the unit-system via the identifier. Similarly, if a unit maps to an identifier, then the unit can be printed using the identifier.

There are two kinds of identifiers: names and symbols.

9.1 Names

You can map a name to a unit and vice versa. If you use `[ut_read_xml()]`, page 6, then you shouldn't normally need to do this.

[ut_status], page 29 `ut_map_name_to_unit (const char* name, [Function]
const ut_encoding encoding, const ut_unit* unit)`

Maps the name referenced by *name*, in character-set *encoding*, to the unit referenced by *unit* in the unit-system that contains *unit*. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

name or *unit* is NULL.

UT_OS

Operating-system failure. See `errno`.

UT_EXISTS

name already maps to a different unit.

[ut_status], page 29 `ut_unmap_name_to_unit (ut_system* [Function]
system, const char* name, const ut_encoding encoding)`

Removes any mapping from name *name*, in character-set *encoding*, to a unit in unit-system *system*. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

system or *name* is NULL.

[ut_status], page 29 `ut_map_unit_to_name (const ut_unit* [Function]
unit, const char* name, ut_encoding encoding)`

Maps the unit *unit* to the name *name*, which is in character-set *encoding*, in the unit-system that contains the unit. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

unit or *name* is NULL, or *name* is not in the character-set *encoding*.

UT_OS

Operating-system failure. See `errno`.

UT_EXISTS

unit already maps to a different name.

[[ut_status](#)], [page 29](#) `ut_unmap_unit_to_name (const ut_unit* unit, ut_encoding encoding)` [Function]

Removes any mapping from unit *unit* to a name in character-set *encoding* from the unit-system that contains the unit. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

unit is NULL.

9.2 Symbols

You can map a symbol to a unit and vice versa. If you use [[ut_read_xml\(\)](#)], [page 6](#), then you shouldn't normally need to do this.

[[ut_status](#)], [page 29](#) `ut_map_symbol_to_unit (const char* symbol, const ut_encoding encoding, const ut_unit* unit)` [Function]

Maps the symbol referenced by *symbol*, in character-set *encoding*, to the unit referenced by *unit* in the unit-system that contains *unit*. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

symbol or *unit* is NULL.

UT_OS

Operating-system failure. See `errno`.

UT_EXISTS

symbol already maps to a different unit.

[[ut_status](#)], [page 29](#) `ut_unmap_symbol_to_unit (ut_system* system, const char* symbol, const ut_encoding encoding)` [Function]

Removes any mapping from symbol *symbol*, in character-set *encoding*, to a unit in unit-system *system*. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

system or *symbol* is NULL.

[[ut_status](#)], [page 29](#) `ut_map_unit_to_symbol (const ut_unit* unit, const char* symbol, ut_encoding encoding)` [Function]

Maps the unit *unit* to the symbol *symbol*, which is in character-set *encoding*, in the unit-system that contains the unit. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

unit or *symbol* is NULL.

UT_BAD_ARG

Symbol *symbol* is not in the character-set *encoding*.

UT_OS

Operating-system failure. See `errno`.

UT_EXISTS

unit already maps to a different symbol.

[[ut_status](#)], [page 29](#) `ut_unmap_unit_to_symbol (const ut_unit* unit, ut_encoding encoding)` [Function]

Removes any mapping from unit *unit* to a symbol in character-set *encoding* from the unit-system that contains the unit. This function returns one of the following:

UT_SUCCESS

Success.

UT_BAD_ARG

unit is NULL.

10 The Handling of Time

You should use a true calendar package rather than the UDUNITS-2 package to handle time. Having said that, many people use the time-handling capabilities of the UDUNITS-2 package because it supports "units" like "seconds since 1970-01-01". You should be aware, however, that the hybrid Gregorian/Julian calendar used by the UDUNITS-2 package *cannot be changed*. Dates on or after 1582-10-15 are assumed to be Gregorian dates; dates before that are assumed to be Julian dates. In particular, the year 1 BCE is immediately followed by the year 1 CE.

In general, the UDUNITS-2 package handles time by encoding it as double-precision value, which can then be acted upon arithmetically.

```
double ut_encode_time (int year, int month, int day, int hour, int minute, double second) [Function]
```

Encodes a time as a double-precision value. This convenience function is equivalent to

```
[ut_encode_date()], page 28(year, month, day) + [ut_encode_clock()],  
page 28(hour, minute, second)
```

```
double ut_encode_date (int year, int month, int day) [Function]
```

Encodes a date as a double-precision value. You probably won't use this function. Dates on or after 1582-10-15 are assumed to be Gregorian dates; dates before that are assumed to be Julian dates. In particular, the year 1 BCE is immediately followed by the year 1 CE.

```
double ut_encode_clock (int hour, int minute, double second) [Function]
```

Encodes a clock-time as a double-precision value. You probably won't use this function.

```
void ut_decode_time (double time, int* year, int* month, int* day, int* hour, int* minute, double* second, double*  
resolution) [Function]
```

Decodes a time from a double-precision value into its individual components. The variable referenced by *resolution* will be set to the resolution (i.e., uncertainty) of the time in seconds.

11 Error Handling

Error-handling in the units module has two aspects: the status of the last operation performed by the module and the handling of error-messages:

11.1 Status of Last Operation

UDUNITS-2 functions set their status by calling `[ut_set_status()], page 29`. You can use the function `[ut_get_status()], page 29` to retrieve that status.

`[ut_status], page 29` `ut_get_status (void)` [Function]

Returns the value specified in the last call to `[ut_set_status()], page 29`

`void ut_set_status ([ut_status], page 29 status)` [Function]

Set the status of the units module to *status*.

`ut_status` [Data type]

This enumeration has the following values:

`UT_SUCCESS`

Success

`UT_BAD_ARG`

An argument violates the the function's contract (e.g., it's NULL).

`UT_EXISTS`

Unit, prefix, or identifier already exists

`UT_NO_UNIT`

No such unit exists

`UT_OS`

Operating-system error. See `errno` for the reason.

`UT_NOT_SAME_SYSTEM`

The units belong to different unit-systems

`UT_MEANINGLESS`

The operation on the unit or units is meaningless

`UT_NO_SECOND`

The unit-system doesn't have a unit named "second"

`UT_VISIT_ERROR`

An error occurred while visiting a unit

`UT_CANT_FORMAT`

A unit can't be formatted in the desired manner

`UT_SYNTAX`

String unit representation contains syntax error

`UT_UNKNOWN`

String unit representation contains unknown word

`UT_OPEN_ARG`

Can't open argument-specified unit database

UT_OPEN_ENV
Can't open environment-specified unit database

UT_OPEN_DEFAULT
Can't open installed, default, unit database

UT_PARSE Error parsing unit database

11.2 Error-Messages

`int ut_handle_error_message (const char* fmt, ...)` [Function]
Handles the error-message corresponding to the format-string *fmt* and any subsequent arguments referenced by it. The interpretation of the formatting-string is identical to that of the UNIX function `printf()`. On success, this function returns the number of bytes in the error-message; otherwise, this function returns -1.
Use the function `[ut_set_error_message_handler()]`, page 30 to change how error-messages are handled.

`[ut_error_message_handler]`, page 30 [Function]
`ut_set_error_message_handler ([ut_error_message_handler],
page 30 handler)`
Sets the function that handles error-messages and returns the previous error-message handler. The initial error-message handler is `[ut_write_to_stderr()]`, page 30.

`int ut_write_to_stderr (const char* fmt, va_list args)` [Function]
Writes the variadic error-message corresponding to formatting-string *fmt* and arguments *args* to the standard-error stream and appends a newline. The interpretation of the formatting-string is identical to that of the UNIX function `printf()`. On success, this function returns the number of bytes in the error-message; otherwise, this function returns -1.

`int ut_ignore (const char* fmt, va_list args)` [Function]
Does nothing. In particular, it ignores the variadic error-message corresponding to formatting-string *fmt* and arguments *args*. Pass this function to `[ut_set_error_message_handler()]`, page 30 when you don't want the unit module to print any error-messages.

`ut_error_message_handler` [Data type]
This is the type of an error-message handler. It's definition is
`typedef int (*ut_error_message_handler)(const char* fmt, va_list args);` ■

12 The Units Database

The database of units that comes with the UDUNITS-2 package is an XML-formatted file that is based on the SI system of units. It contains the names and symbols of most of the units that you will ever encounter. The pathname of the installed file is *datadir*/udunits2.xml, where *datadir* is the installation-directory for read-only, architecture-independent data (e.g., /usr/local/share). This pathname is the default that `[ut_read_xml()]`, page 6 uses.

Naturally, because the database is a regular file, it can be edited to add new units or remove existing ones. Be very careful about doing this, however, because you might lose the benefit of exchanging unit-based information with others who haven't modified their database.

13 Data Types

The data types `[ut_visitor]`, page 23, `[ut_status]`, page 29, and `[ut_error_message_handler]`, page 30 are documented elsewhere.

`ut_encoding`

[Data type]

This enumeration has the following values:

`UT_ASCII` **US ASCII** character-set.

`UT_ISO_8859_1`

The **ISO-8859-1** character-set.

`UT_LATIN1`

Synonym for `UT_ISO_8859_1`.

`UT_UTF8` The **UTF-8** encoding of the Unicode character-set.

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