struct — Binary Data Structures

Purpose: Convert between strings and binary data.

The `struct` module includes functions for converting between strings of bytes and native Python data types such as numbers and strings.

Functions versus Struct Class

A set of module-level functions is available for working with structured values, as well as the `Struct` class. Format specifiers are converted from their string format to a compiled representation, similar to the way regular expressions are handled. The conversion takes some resources, so it is typically more efficient to do it once when creating a `Struct` instance and call methods on the instance instead of using the module-level functions. All of the following examples use the `Struct` class.

Packing and Unpacking

Structs support *packing* data into strings, and *unpacking* data from strings using format specifiers made up of characters representing the type of the data and optional count and endianness indicators. Refer to the standard library documentation for a complete list of the supported format specifiers.

In this example, the specifier calls for an integer or long integer value, a two-byte string, and a floating-point number. The spaces in the format specifier are included to separate the type indicators, and are ignored when the format is compiled.

```
# struct_pack.py

import struct
import binascii

values = (1, 'ab'.encode('utf-8'), 2.7)
s = struct.Struct('I 2s f')
packed_data = s.pack(*values)

print('Original values:', values)
print('Format string  :', s.format)
print('Uses           :', s.size, 'bytes')
print('Packed Value   :', binascii.hexlify(packed_data))
```

The example converts the packed value to a sequence of hex bytes for printing with `binascii.hexlify()`, since some of the characters are nulls.

```
$ python3 struct_pack.py

Original values: (1, b'ab', 2.7)
Format string  : I 2s f
Uses           : 12 bytes
Packed Value   : b'0100000061620000cdcc2c40'
```

Use `unpack()` to extract data from its packed representation.

```
# struct_unpack.py

import struct
import binascii

packed_data = binascii.unhexlify(b'0100000061620000cdcc2c40')

s = struct.Struct('I 2s f')
unpacked_data = s.unpack(packed_data)
print('Unpacked Values:', unpacked_data)
```

Passing the packed value to `unpack()`, gives basically the same values back (note the discrepancy in the floating point value).

```
$ python3 struct_unpack.py

Unpacked Values: (1, b'ab', 2.700000047683716)
```

Endianness

By default, values are encoded using the native C library notion of *endianness*. It is easy to override that choice by providing an explicit endianness directive in the format string.

```
# struct_endianness.py
```

```
import struct
import binascii

values = (1, 'ab'.encode('utf-8'), 2.7)
print('Original values:', values)

endianness = [
    ('@', 'native, native'),
    ('=', 'native, standard'),
    ('<', 'little-endian'),
    ('>', 'big-endian'),
    ('!', 'network'),
]

for code, name in endianness:
    s = struct.Struct(code + ' I 2s f')
    packed_data = s.pack(*values)
    print()
    print('Format string  :', s.format, 'for', name)
    print('Uses           :', s.size, 'bytes')
    print('Packed Value   :', binascii.hexlify(packed_data))
    print('Unpacked Value :', s.unpack(packed_data))
```

the table below lists the byte order specifiers used by `Struct`.

Byte Order Specifiers for struct

Code	Meaning
@	Native order
=	Native standard
<	little-endian
>	big-endian
!	Network order

```
$ python3 struct_endianness.py

Original values: (1, b'ab', 2.7)

Format string  : @ I 2s f for native, native
Uses           : 12 bytes
Packed Value   : b'01000000061620000cdcc2c40'
Unpacked Value : (1, b'ab', 2.700000047683716)

Format string  : = I 2s f for native, standard
Uses           : 10 bytes
Packed Value   : b'010000006162cdcc2c40'
Unpacked Value : (1, b'ab', 2.700000047683716)

Format string  : < I 2s f for little-endian
Uses           : 10 bytes
Packed Value   : b'010000006162cdcc2c40'
Unpacked Value : (1, b'ab', 2.700000047683716)

Format string  : > I 2s f for big-endian
```

```
Uses           : 10 bytes
Packed Value   : b'000000016162402ccccd'
Unpacked Value : (1, b'ab', 2.700000047683716)

Format string  : ! I 2s f for network
Uses           : 10 bytes
Packed Value   : b'000000016162402ccccd'
Unpacked Value : (1, b'ab', 2.700000047683716)
```

Buffers

Working with binary packed data is typically reserved for performance-sensitive situations or passing data into and out of extension modules. These cases can be optimized by avoiding the overhead of allocating a new buffer for each packed structure. The `pack_into()` and `unpack_from()` methods support writing to pre-allocated buffers directly.

```
# struct_buffers.py

import array
import binascii
import ctypes
import struct

s = struct.Struct('I 2s f')
values = (1, 'ab'.encode('utf-8'), 2.7)
print('Original:', values)

print()
print('ctypes string buffer')

b = ctypes.create_string_buffer(s.size)
print('Before  :', binascii.hexlify(b.raw))
s.pack_into(b, 0, *values)
print('After   :', binascii.hexlify(b.raw))
print('Unpacked:', s.unpack_from(b, 0))

print()
print('array')

a = array.array('b', b'\0' * s.size)
print('Before  :', binascii.hexlify(a))
s.pack_into(a, 0, *values)
print('After   :', binascii.hexlify(a))
print('Unpacked:', s.unpack_from(a, 0))
```

The `size` attribute of the `Struct` tells us how big the buffer needs to be.

```
$ python3 struct_buffers.py

Original: (1, b'ab', 2.7)

ctypes string buffer
Before  : b'000000000000000000000000'
After   : b'0100000061620000cdcc2c40'
Unpacked: (1, b'ab', 2.700000047683716)

array
Before  : b'000000000000000000000000'
After   : b'0100000061620000cdcc2c40'
Unpacked: (1, b'ab', 2.700000047683716)
```

See also

- Standard library documentation for struct
- Python 2 to 3 porting notes for struct
- `array` – The `array` module, for working with sequences of fixed-type values.
- `binascii` – The `binascii` module, for producing ASCII representations of binary data.
- WikiPedia: Endianness – Explanation of byte order and endianness in encoding.

Quick Links

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This page was last updated 2018-12-09.

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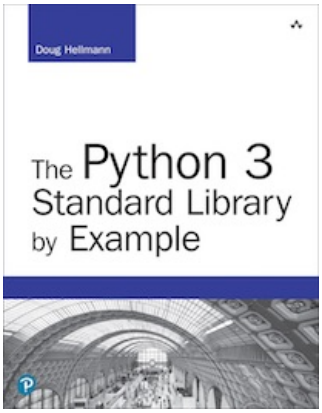

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The output from all the example programs from PyMOTW-3 has been generated with Python 3.7.1, unless otherwise noted. Some of the features described here may not be available in earlier versions of Python.

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