bitlist

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Pure-Python library for working with bit vectors.
This library allows programmers to work with bit vectors using a pure-Python data structure. Its design prioritizes interoperability with built-in Python classes and operators.
CHAPTER TWO

INSTALLATION AND USAGE

This library is available as a package on PyPI:

```
python -m pip install bitlist
```

The library can be imported in the usual way:

```
import bitlist
from bitlist import bitlist
```

2.1 Examples

This library makes it possible to construct bit vectors from a variety of representations (including integers, bytes-like objects, strings of binary digits, lists of binary digits, and other bit vectors). Integer arguments are converted into a big-endian binary representation:

```
>>> bitlist(123)
bitlist('1111011')
>>> bitlist(bytes([255, 254]))
bitlist('1111111111111110')
>>> bitlist('101')
bitlist('101')
>>> bitlist([1, 0, 1, 1])
bitlist('1011')
>>> bitlist(bitlist('1010'))
bitlist('1010')
```

The optional length parameter can be used to specify the length of the created bit vector (padding consisting of zero bits is applied automatically on the left-hand size, if necessary):

```
>>> bitlist(bytes([123]), length=16)
bitlist('0000000001111011')
>>> bitlist(16, 64)
bitlist('0000000000000000000000000000000000000000000000000000000000010000')
>>> bitlist(bitlist(123), 8)
bitlist('10111011')
```

If the length parameter has a value that is less than the minimum number of bits that would be included according to the default constructor behaviors, the bit vector is truncated on the left-hand side to match the specified length:
Bit vectors are iterable sequences of individual bits (where each bit is represented as an integer). Both slice notation and retrieval of individual bits by index are supported. Furthermore, methods are available for converting a bit vector into other common representations:

```python
>>> b = bitlist('1111011')
>>> b[1:-1]
bitlist('11101')
>>> b[0]
1
>>> [bit for bit in b]
[1, 1, 1, 1, 0, 1, 1]
>>> b.bin()
'1111011'
>>> b.hex()
'7b'
>>> list(b.to_bytes())
[123]
```

Concatenation, partitioning, subscription and slicing, shift and rotation, comparison, and logical operations are also supported by instances of the `bitlist` class. The larger example below – a bitwise addition function – illustrates the use of various operators supported by instances of the `bitlist` class:

```python
>>> def add(x, y):
...     '''Bitwise addition algorithm.'''
...     r = bitlist(0)
...     carry = 0
...     # Use negative indices for big-endian interface.
...     for i in range(1, max(len(x), len(y)) + 1):
...         r[-i] = (x[-i] ^ y[-i]) ^ carry
...         carry = (x[-i] & y[-i]) | (x[-i] & carry) | (y[-i] & carry)
...     r[-(max(len(x), len(y)) + 1)] = carry
...     return r
... >>> int(add(bitlist(123), bitlist(456)))
579
```

The testing script that accompanies this library contains additional examples of bitwise arithmetic operations implemented with the help of `bitlist` operators.
CHAPTER THREE

DEVELOPMENT

All installation and development dependencies are fully specified in pyproject.toml. The `project.optional-dependencies` object is used to specify optional requirements for various development tasks. This makes it possible to specify additional options (such as docs, lint, and so on) when performing installation using pip:

```
python -m pip install .[docs,lint]
```

### 3.1 Documentation

The documentation can be generated automatically from the source files using Sphinx:

```
python -m pip install .[docs]
cd docs
sphinx-apidoc -f -E --templatedir=_templates -o _source .. && make html
```

### 3.2 Testing and Conventions

All unit tests are executed and their coverage is measured when using pytest (see the pyproject.toml file for configuration details):

```
python -m pip install .[test]
python -m pytest
```

The subset of the unit tests included in the module itself and the documentation examples that appear in the testing script can be executed separately using doctest:

```
python src/bitlist/bitlist.py -v
python test/test_bitlist.py -v
```

Style conventions are enforced using Pylint:

```
python -m pip install .[lint]
python -m pylint src/bitlist test/test_bitlist.py
```
3.3 Contributions

In order to contribute to the source code, open an issue or submit a pull request on the GitHub page for this library.

3.4 Versioning

Beginning with version 0.3.0, the version number format for this library and the changes to the library associated with version number increments conform with Semantic Versioning 2.0.0.

3.5 Publishing

This library can be published as a package on PyPI by a package maintainer. First, install the dependencies required for packaging and publishing:

```bash
python -m pip install .[publish]
```

Ensure that the correct version number appears in `pyproject.toml`, and that any links in this README document to the Read the Docs documentation of this package (or its dependencies) have appropriate version numbers. Also ensure that the Read the Docs project for this library has an automation rule that activates and sets as the default all tagged versions. Create and push a tag for this version (replacing `?.?.?` with the version number):

```bash
git tag ?.?.?
git push origin ?.?.?
```

Remove any old build/distribution files. Then, package the source into a distribution archive:

```bash
rm -rf build dist src/*.egg-info
clean --sdist --wheel .
```

Finally, upload the package distribution archive to PyPI:

```bash
python -m twine upload dist/*
```

3.5.1 bitlist module

Pure-Python library for working with bit vectors.

```python
class bitlist.bitlist.bitlist(
    argument: Optional[Union[int, str, bytes, bytearray, bitlist.bitlist.bitlist, Iterable[int]]] = None,
    length: Optional[int] = None)

Bases: object
```

Data structure for representing bit vectors. The constructor accepts a variety of input types (including integers, bytes-like objects, strings of binary digits, iterables of binary digits, and other bitlist instances) and parses them in an appropriate manner to build a bit vector. Integer arguments are converted into a big-endian binary representation.

```python
>>> bitlist(1)
bitlist('1')
>>> bitlist(123)
bitlist('111011')
```
>>> bitlist('111011')
bitlist('111011')
>>> bitlist(bytes([255, 254]))
bitlist('1111111111111110')
>>> bitlist([1, 0, 1, 1])
bitlist('1011')
>>> bitlist(bitlist('1010'))
bitlist('1010')

The `fromhex` method can be used to convert a hexadecimal string into an instance. This is equivalent to converting the hexadecimal string into a bytes-like object and then creating a bit vector from that object.

```python
>>> bitlist.fromhex('abcd')
bitlist('1010101111001101')
>>> bitlist(bytes.fromhex('abcd'))
bitlist('1010101111001101')
```

A `bitlist` instance can be converted into an integer using the built-in `int` function. By default, a big-endian representation of integers is used. The recommended approach for switching to a little-endian representation is to reverse the bit vector.

```python
>>> b = bitlist('111011')
>>> int(b)
123
>>> int(bitlist(list(reversed(b))))
111
```

An instance can be converted into a string of binary characters using the `bin` method and into a hexadecimal string using the `hex` method. Conversion to a bytes-like object is possible via the built-in `to_bytes` method.

```python
>>> b.bin()
'111011'
>>> b.hex()
'7b'
>>> b.to_bytes().hex()
'7b'
>>> list(b.to_bytes())
[123]
```

An instance is itself a `Sequence` and is iterable. Iterating over an instance yields the sequence of bits (i.e., integers that are 0 or 1).

```python
>>> [bit for bit in bitlist('10010011')]
[1, 0, 0, 1, 0, 0, 1, 1]
```

An individual bit can be retrieved (and assigned a new value) via its index. Slice notation is also supported.

```python
>>> b = bitlist('0101')
>>> b[3]
1
>>> b[3] = 0
>>> b
bitlist('0100')
```
Instances are mutable. Conversion to an integer, binary string, or tuple is recommended if a corresponding immutable object is required.

When the constructor is supplied a `bitlist` instance, a distinct copy of the supplied instance is created.

When the constructor is applied to a bytes-like object, the leading zero digits (*i.e.*, those on the left-hand side) are retained (up to the least multiple of eight larger than the minimum number of binary digits required).

When the constructor is applied to a string (consisting only of characters that correspond to binary digits), leading zero digits are also retained.

However, when the constructor is applied to an integer argument, the created bit vector has no leading (*i.e.*, left-hand) zeros and contains the minimum number of bits necessary to represent the supplied argument (using a big-endian representation).

The above implies that the empty bit vector represents (and is equivalent to) the numerical value of zero.
While the equality method `__eq__` determines equality between two bit vectors based on the integer values they represent, the fact that leading zero digits are retained in some cases means that two equivalent bit vectors may have different lengths.

```python
>>> bitlist('0') == bitlist('000')
True
>>> len(bitlist('0')) == len(bitlist('000'))
False
```

For all other (non-integer) input types, the length of the vector (and consequently the number of leading zeros) is preserved.

```python
>>> bitlist('0000')
bitlist('0000')
>>> bitlist([0, 1, 1])
bitlist('011')
>>> bitlist([0, 0, 1, 1])
bitlist('0011')
>>> bitlist(bitlist('0010'))
bitlist('0010')
```

Only strings that consist of characters corresponding to binary digits are accepted by the constructor.

```python
>>> bitlist('abcd')
Traceback (most recent call last):
  ... ValueError: each character in string must be '0' or '1'
```

To convert the underlying binary representation of a string into a bit vector, it is necessary to encode the string as a bytes-like object.

```python
>>> bitlist('abcd'.encode('utf8'))
bitlist('01100001011000100110001101100100')
```

The `length` parameter can be used to specify the length of the bit vector, overriding the default behaviors. If the length parameter has a value that is greater than the number of bits that would be included according to a default behavior, the bit vector is padded with zero bits on the left-hand side to match the specified length.

```python
>>> bitlist(bytes([123]), 16)
bitlist('0000000011111011')
>>> bitlist(16, 64)
bitlist('0000000000000000000000000000000000000000000000000000000000010000')
>>> bitlist(bitlist(123), 8)
bitlist('01111011')
```

If the `length` parameter has a value that is less than the minimum number of bits that would be included according to a default behavior, the bit vector is truncated on the left-hand side to match the specified length.

```python
>>> bitlist(bytes([123]), 7)
bitlist('1111011')
>>> bitlist(bytes([123]), 4)
bitlist('1011')
>>> bitlist(bytes([123]), 2)
bitlist('11')
```
>>> bitlist(bytes([123]), 0)
bitlist()
>>> bitlist(123, 0)
bitlist()
>>> bitlist([1, 1, 1], 0)
bitlist()

Any attempt to construct an instance using unsupported arguments raises an exception.

>>> bitlist([1.1, 2.2, 3.3])
Traceback (most recent call last):
...
TypeError: items in iterable must be integers

>>> bitlist([2, 3, 4, 5])
Traceback (most recent call last):
...
ValueError: each integer in iterable must be 0 or 1

>>> bitlist(float(1))
Traceback (most recent call last):
...
TypeError: bitlist constructor received unsupported argument

static fromhex(s: str) → bitlist.bitlist.bitlist
Build an instance from a hexadecimal string.

>>> bitlist.fromhex('abcd')
bitlist('1010101111001101')

__str__ () → str
Return a string representation (that can also be evaluated as a valid Python expression if the class is in the
namespace).

>>> bitlist('01')
bitlist('01')

__repr__ () → str
Return a string representation (that can also be evaluated as a valid Python expression if the class is in the
namespace).

__int__ () → int
Interpret the bit vector as a big-endian representation of an integer and return that integer.

>>> int(bitlist(bytes([128, 129]))) == int.from_bytes(bytes([128, 129]), 'big')
True

to_bytes() → bytes
Return a bytes-like object representation. Note that the number of bits will be padded (on the left) to a
multiple of eight.

>>> int.from_bytes(bitlist('10000000').to_bytes(), 'big')
128
>>> int.from_bytes(bitlist('1000000010000011').to_bytes(), 'big')
32899
```python
>>> int.from_bytes(bitlist('11000000').to_bytes(), 'big')
384
>>> bitlist(129 + 128*256).to_bytes().hex()
'8081'
>>> bitlist('11').to_bytes().hex()
'03'
```

**bin() → str**

Return a binary string representation. This matches the string emitted as part of the output of the default string conversion method.

```python
>>> bitlist('010011').bin()
'010011'
```

**hex() → str**

Return a hexadecimal string representation. Note that the number of bits will be padded (on the left) to a multiple of eight.

```python
>>> bitlist(bytes([123])).hex()
'7b'
```

**__len__() → int**

Return length of bit vector (defined to be the number of bits it contains).

```python
>>> bitlist('11') + bitlist('10')
bitlist('1110')
```

**__add__(other: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist**

The addition operator can be used for concatenation, as with other objects that have sequence types.

```python
>>> bitlist('11') + bitlist('10')
bitlist('1110')
```

**__mul__(other: int) → bitlist.bitlist.bitlist**

The multiplication operator can be used for repetition, as with other objects that have sequence types.

```python
>>> bitlist(256)*2
bitlist('1000000010000000')
>>> bitlist(256)*'a'
Traceback (most recent call last):
...
ValueError: repetition parameter must be an integer
```

**__truediv__(other: Union[int, Set[int], Sequence[int]]) → Sequence[bitlist.bitlist.bitlist]**

The division operator can be used to partition a bit vector into the specified number of parts, into parts of a specified length, or into a sequence of parts in which each part’s length is specified in a sequence of integers (leveraging and mirroring the capabilities of the `parts` function).

```python
>>> bitlist('11010001') / 2
[bitlist('1101'), bitlist('0001')]
>>> bitlist('11010001') / [2, 6]
[bitlist('11'), bitlist('010001')]
>>> bitlist('11010001') / {4}
```

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[bitlist('1101'), bitlist('0001')]  
>>> bitlist('11010001') / 3  
[bitlist('110'), bitlist('100'), bitlist('01')]

__getitem__(key: Union[int, slice]) → Union[int, bitlist.bitlist.bitlist]
Retrieve the bit at the specified index, or construct a slice of the bit vector.

>>> bitlist('1111011')[2]
1
>>> bitlist('0111011')[0]
0
>>> bitlist('10101000')[0:5]
bitlist('10101')
>>> bitlist('10101000101000101000101000')[:16]
bitlist('10100010101000101000')
>>> bitlist('101')[4]
Traceback (most recent call last):
...
IndexError: bitlist index out of range
>>> bitlist('101')['a']
Traceback (most recent call last):
...
TypeError: bitlist indices must be integers or slices

__setitem__(i: int, b: int)
Set the bit at the specified index to the supplied value.

>>> x = bitlist('111011')
>>> x[2] = 0
>>> x
bitlist('1101011')
>>> x[7] = 0
Traceback (most recent call last):
...
IndexError: bitlist index out of range

__lshift__(n: Union[int, Set[int]]) → bitlist.bitlist.bitlist
The left shift operator can be used for both performing a bit shift in the traditional manner (increasing the length of the bit vector) or for bit rotation (if the second parameter is a set).

>>> bitlist('11') << 2
bitlist('1100')
>>> bitlist('11011') << {0}
bitlist('11001')
>>> bitlist('111011') << {1}
bitlist('100111')
>>> bitlist('111011') << {2}
bitlist('011110')
>>> bitlist('111011') << {3}
bitlist('111101')
>>> bitlist('111011') << {13}
bitlist('111101')

(continues on next page)
__rshift__(n: Union[int, Set[int]]) → bitlist.bitlist.bitlist

The right shift operator can be used for both performing a bit shift in the traditional manner (truncating bits on the right-hand side as necessary) or for bit rotation (if the second parameter is a set).

```python
>>> bitlist('1') << {13}
bitlist('1')
```

```python
>>> bitlist('1111') >> 2
bitlist('11')
>>> bitlist('11011') >> {0}
bitlist('11011')
>>> bitlist('11011') >> {1}
bitlist('11101')
>>> bitlist('11011') >> {2}
bitlist('11110')
>>> bitlist('11011') >> {3}
bitlist('01111')
>>> bitlist('11011') >> {13}
bitlist('01111')
>>> bitlist('1') >> {13}
bitlist('1')
```

__and__(other: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist

Logical operators are applied bitwise without changing the length.

```python
>>> bitlist('0100') & bitlist('1100')
bitlist('0100')
>>> bitlist('010') & bitlist('11')
Traceback (most recent call last):
...
ValueError: arguments to logical operations must have equal lengths
```

__or__(other: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist

Logical operators are applied bitwise without changing the length.

```python
>>> bitlist('0100') | bitlist('1100')
bitlist('1100')
>>> bitlist('010') | bitlist('11')
Traceback (most recent call last):
...
ValueError: arguments to logical operations must have equal lengths
```

__xor__(other: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist

Logical operators are applied bitwise without changing the length.

```python
>>> bitlist('0100') ^ bitlist('1101')
bitlist('1001')
>>> bitlist('010') ^ bitlist('11')
Traceback (most recent call last):
...
ValueError: arguments to logical operations must have equal lengths
```

__invert__() → bitlist.bitlist.bitlist

Logical operators are applied bitwise without changing the length. Inversion flips all bits and corresponds
to bitwise logical negation.

```python
>>> ~bitlist('0100')
bitlist('1011')
```

__bool__() → bool
Any non-zero instance is interpreted as True.

```python
>>> bool(bitlist('0100'))
True
>>> bool(bitlist('0000'))
False
```

__eq__(other: bitlist.bitlist.bitlist) → bool
Instances are interpreted as integers when relational operators are applied.

```python
>>> bitlist('111') == bitlist(7)
True
>>> bitlist(123) == bitlist(0)
False
>>> bitlist(123) == bitlist('0001111011')
True
>>> bitlist('001') == bitlist('1')
True
```

__ne__(other: bitlist.bitlist.bitlist) → bool
Instances are interpreted as integers when relational operators are applied.

```python
>>> bitlist('111') != bitlist(7)
False
>>> bitlist(123) != bitlist(0)
True
>>> bitlist('001') != bitlist('1')
False
```

__lt__(other: bitlist.bitlist.bitlist) → bool
Instances are interpreted as integers when relational operators are applied.

```python
>>> bitlist(123) < bitlist(0)
False
>>> bitlist(123) < bitlist(123)
False
>>> bitlist(12) < bitlist(23)
True
```

__le__(other: bitlist.bitlist.bitlist) → bool
Instances are interpreted as integers when relational operators are applied.

```python
>>> bitlist(123) <= bitlist(0)
False
>>> bitlist(123) <= bitlist(123)
True
>>> bitlist(12) <= bitlist(23)
True
```


```python
>>> bitlist(123) > bitlist(0)
True
>>> bitlist(123) > bitlist(123)
False
>>> bitlist(12) > bitlist(23)
False
```

```python
>>> bitlist(123) >= bitlist(0)
True
>>> bitlist(123) >= bitlist(123)
True
>>> bitlist(12) >= bitlist(23)
False
```

### 3.5.2 examples

Test suite containing examples and functional unit tests (based on bit vector implementations of common arithmetic operations) that demonstrate how this library’s features can be used.

To view the source code of an example function, click its [source] link.

#### `test.test_bitlist.add`

```python
add(x: bitlist.bitlist.bitlist, y: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist
Bitwise addition algorithm.
```

```python
>>> int(add(bitlist(123), bitlist(456)))
579
```

#### `test.test_bitlist.mul`

```python
mul(x: bitlist.bitlist.bitlist, y: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist
Bitwise multiplication algorithm.
```

```python
>>> int(mul(bitlist(123), bitlist(456)))
56088
```

#### `test.test_bitlist.exp`

```python
exp(x: bitlist.bitlist.bitlist, y: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist
Bitwise exponentiation algorithm.
```

```python
>>> int(exp(bitlist(123), bitlist(5)))
28153056843
```

#### `test.test_bitlist.div`

```python
div(x: bitlist.bitlist.bitlist, y: bitlist.bitlist.bitlist) → bitlist.bitlist.bitlist
Bitwise integer division algorithm.
```

```python
>>> int(div(bitlist(12345), bitlist(678)))
18
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