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# Vyper Documentation

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Vyper is a contract-oriented, pythonic programming language that targets the [Ethereum Virtual Machine \(EVM\)](#)



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## Principles and Goals

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- **Security:** It should be possible and natural to build secure smart-contracts in Vyper.
- **Language and compiler simplicity:** The language and the compiler implementation should strive to be simple.
- **Auditability:** Vyper code should be maximally human-readable. Furthermore, it should be maximally difficult to write misleading code. Simplicity for the reader is more important than simplicity for the writer, and simplicity for readers with low prior experience with Vyper (and low prior experience with programming in general) is particularly important.

Because of this Vyper aims to provide the following features:

- **Bounds and overflow checking:** On array accesses as well as on arithmetic level.
- **Support for signed integers and decimal fixed point numbers**
- **Decidability:** It should be possible to compute a precise upper bound for the gas consumption of any function call.
- **Strong typing:** Including support for units (e.g. timestamp, timedelta, seconds, wei, wei per second, meters per second squared).
- **Small and understandable compiler code**
- **Limited support for pure functions:** Anything marked constant is not allowed to change the state.

Following the principles and goals, Vyper **does not** provide the following features:

- **Modifiers:** For example in Solidity you can define a function `foo() mod1 { ... }`, where `mod1` can be defined elsewhere in the code to include a check that is done before execution, a check that is done after execution, some state changes, or possibly other things. Vyper does not have this, because it makes it too easy to write misleading code. `mod1` just looks too innocuous for something that could add arbitrary pre-conditions, post-conditions or state changes. Also, it encourages people to write code where the execution jumps around the file, harming auditability. The usual use case for a modifier is something that performs a single check before execution of a program; our recommendation is to simply inline these checks as asserts.
- **Class inheritance:** Class inheritance requires people to jump between multiple files to understand what a program is doing, and requires people to understand the rules of precedence in case of conflicts (“Which class’s

function ‘X’ is the one that’s actually used?”). Hence, it makes code too complicated to understand which negatively impacts auditability.

- **Inline assembly:** Adding inline assembly would make it no longer possible to search for a variable name in order to find all instances where that variable is read or modified.
- **Function overloading** - This can cause lots of confusion on which function is called at any given time. Thus it’s easier to write misleading code (`foo("hello")` logs “hello” but `foo("hello", "world")` steals you funds). Another problem with function overloading is that it makes the code much harder to search through as you have to keep track on which call refers to which function.
- **Operator overloading:** Operator overloading makes writing misleading code possible. For example “+” could be overloaded so that it executes commands that are not visible at a first glance, such as sending funds the user did not want to send.
- **Recursive calling:** Recursive calling makes it impossible to set an upper bound on gas limits, opening the door for gas limit attacks.
- **Infinite-length loops:** Similar to recursive calling, infinite-length loops make it impossible to set an upper bound on gas limits, opening the door for gas limit attacks.
- **Binary fixed point:** Decimal fixed point is better, because any decimal fixed point value written as a literal in code has an exact representation, whereas with binary fixed point approximations are often required (e.g.  $(0.2)_{10} = (0.001100110011\dots)_2$ , which needs to be truncated), leading to unintuitive results, e.g. in Python  $0.3 + 0.3 + 0.3 + 0.1 \neq 1$ .

Some changes that may be considered after Metropolis when `STATICCALL` becomes available include:

- Forbidding state changes after non-static calls unless the address being non-statically called is explicitly marked “trusted”. This would reduce risk of re-entrancy attacks.
- Forbidding “inline” non-static calls, e.g. `send(some_address, contract.do_something_and_return_a_weivalue())`, enforcing clear separation between “call to get a response” and “call to do something”.

Vyper does NOT strive to be a 100% replacement for everything that can be done in Solidity; it will deliberately forbid things or make things harder if it deems fit to do so for the goal of increasing security.

## 2.1 Installing Vyper

Don't panic if the installation fails. Vyper is still under development and undergoes constant changes. Installation will be much more simplified and optimized after a stable version release.

Take a deep breath, follow the instructions, and please [create an issue](#) if you encounter any errors.

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**Note:** The easiest way to try out the language, experiment with examples, and compile code to `bytecode` or `LLL` is to use the online compiler at <https://vyper.online/>.

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### 2.1.1 Prerequisites

#### Installing Python 3.6

Vyper can only be built using Python 3.6 and higher. If you are already running Python 3.6, skip to the next section, else follow the instructions here to make sure you have the correct Python version installed, and are using that version.

#### Ubuntu

##### 16.04 and older

Start by making sure your packages are up-to-date:

```
sudo apt-get update
sudo apt-get -y upgrade
```

Install Python 3.6 and some necessary packages:

```
sudo apt-get install build-essential libssl-dev libffi-dev
wget https://www.python.org/ftp/python/3.6.2/Python-3.6.2.tgz
tar xzf Python-3.6.2.tgz
cd Python-3.6.2/
./configure --prefix /usr/local/lib/python3.6
sudo make
sudo make install
```

### 16.10 and newer

From Ubuntu 16.10 onwards, the Python 3.6 version is in the *universe* repository.

Run the following commands to install:

```
sudo apt-get update
sudo apt-get install python3.6
```

---

**Note:** If you get the error *Python.h: No such file or directory* you need to install the python header files for the Python C API with

```
sudo apt-get install python3-dev
```

---

### Using a BASH script

Vyper can be installed using a bash script.

```
https://github.com/balajipachai/Scripts/blob/master/install_vyper/install_vyper_
↳ubuntu.sh
```

*Reminder:* Please read and understand the commands in any bash script before executing, especially with *sudo*.

### Arch

Using your aur helper of choice (*yay* here).

```
yay -S vyper
```

### MacOS

Make sure you have Homebrew installed. If you don't have the *brew* command available on the terminal, follow [these instructions](#) to get Homebrew on your system.

To install Python 3.6, follow the instructions here: [Installing Python 3 on Mac OS X](#)

Also, ensure the following libraries are installed using *brew*:

```
brew install gmp leveldb
```

## Windows

Windows users can first [install Windows Subsystem for Linux](#) and then follow the instructions for Ubuntu, or [install Docker for Windows](#) and then follow the instructions for Docker.

---

### Note:

- Windows Subsystem for Linux is only available for Windows 10.
  - Windows versions that are < 10 and Windows 10 Home should install the slightly outdated [Docker Toolbox](#), as explained in the link.
- 

## Creating a virtual environment

It is **strongly recommended** to install Vyper in a **virtual Python environment**, so that new packages installed and dependencies built are strictly contained in your Vyper project and will not alter or affect your other development environment set-up.

To create a new virtual environment for Vyper run the following commands:

```
sudo apt install virtualenv
virtualenv -p python3.6 --no-site-packages ~/vyper-venv
source ~/vyper-venv/bin/activate
```

To find out more about virtual environments, check out: [virtualenv guide](#).

You can also create a virtual environment without virtualenv:

```
python3.6 -m venv ~/vyper-env
source ~/vyper-env/bin/activate
```

### 2.1.2 Installation

Again, it is **strongly recommended to install Vyper** in a **virtual Python environment**. This guide assumes you are in a virtual environment containing Python 3.6.

Get the latest version of Vyper by cloning the Github repository, and run the install and test commands:

```
git clone https://github.com/ethereum/vyper.git
cd vyper
make
make dev-deps
make test
```

Additionally, you may try to compile an example contract by running:

```
vyper examples/crowdfund.vy
```

If everything works correctly, you are now able to compile your own smart contracts written in Vyper. If any unexpected errors or exceptions are encountered, please feel free to [create an issue](#).

---

**Note:** If you get the error *fatal error: openssl/aes.h: No such file or directory* in the output of *make*, then run *sudo apt-get install libssl-dev*, then run *make* again.

### For MacOS users:

Apple has deprecated use of OpenSSL in favor of its own TLS and crypto libraries. This means that you will need to export some OpenSSL settings yourself, before you can install Vyper.

Use the following commands:

```
export CFLAGS="-I$(brew --prefix openssl)/include"
export LDFLAGS="-L$(brew --prefix openssl)/lib"
pip install scrypt
```

Now you can run the install and test commands again:

```
make
make dev-deps
make test
```

If you get the error *ld: library not found for -lyaml* in the output of *make*, make sure *libyaml* is installed using *brew info libyaml*. If it is installed, add its location to the compile flags as well:

```
export CFLAGS="-I$(brew --prefix openssl)/include -I$(brew --prefix libyaml)/include"
export LDFLAGS="-L$(brew --prefix openssl)/lib -L$(brew --prefix libyaml)/lib"
```

You can then run *make* and *make test* again.

---

## 2.1.3 PIP

Each tagged version of vyper is also uploaded to pypi, and can be installed using pip.

```
pip install vyper
```

To install a specific version use:

```
pip install vyper==0.1.0b2
```

## 2.1.4 Docker

### Dockerhub

Vyper can be downloaded as docker image from dockerhub:

```
docker pull ethereum/vyper
```

To run the compiler use the *docker run* command:

```
docker run -v $(pwd):/code ethereum/vyper /code/<contract_file.vy>
```

Alternatively you can log into the docker image and execute vyper on the prompt.

```
docker run -v $(pwd):/code/ -it --entrypoint /bin/bash ethereum/vyper
root@d35252d1fb1b:/code# vyper <contract_file.vy>
```

The normal paramaters are also supported, for example:

```
docker run -v $(pwd):/code ethereum/vyper -f abi /code/<contract_file.vy>
[{'name': 'test1', 'outputs': [], 'inputs': [{'type': 'uint256', 'name': 'a'}, {'type': 'bytes', 'name': 'b'}], 'constant': False, 'payable': False, 'type': 'function', 'gas': 441}, {'name': 'test2', 'outputs': [], 'inputs': [{'type': 'uint256', 'name': 'a'}], 'constant': False, 'payable': False, 'type': 'function', 'gas': 316}]
```

## Dockerfile

A Dockerfile is provided in the master branch of the repository. In order to build a Docker Image please run:

```
docker build https://github.com/ethereum/vyper.git -t vyper:1
docker run -it --entrypoint /bin/bash vyper:1
```

To ensure that everything works correctly after the installation, please run the test commands and try compiling a contract:

```
python setup.py test
vyper examples/crowdfund.vy
```

### 2.1.5 Snap

Vyper is published in the snap store. In any of the [supported Linux distros](#), install it with (Note that installing the above snap is the latest master):

```
sudo snap install vyper --edge --devmode
```

To install the latest beta version use:

```
sudo snap install vyper --beta --devmode
```

## 2.2 Compiling a Contract

To compile a contract, use:

```
vyper yourFileName.vy
```

You can also compile to other formats such as ABI using the below format:

```
vyper -f ['abi', 'bytecode', 'bytecode_runtime', 'ir', 'asm', 'source_map', 'method_
identifiers', 'combined_json'] yourFileName.vy
```

It is also possible to use the *-f json* option, which is a legacy alias for *-f abi*.

**Note:** Since *.vy* is not officially a language supported by any syntax highlighters or linters, it is recommended to name your Vyper file ending with *.py* in order to have Python syntax highlighting.

An [online compiler](#) is available as well, which lets you experiment with the language without having to install Vyper. The online compiler allows you to compile to bytecode and/or LLL.

**Note:** While the vyper version of the online compiler is updated on a regular basis it might be a bit behind the latest version found in the master branch of the repository.

---

## 2.3 Testing a Contract

This documentation recommends the use of the `pytest` framework with the `ethereum-tester` package. Prior to testing, the vyper specific contract conversion and the blockchain related fixtures need to be set up. These fixtures will be used in every test file and should therefore be defined in `confestest.py`.

**Note:** Since the testing is done in the `pytest` framework, you can make use of `pytest.ini`, `tox.ini` and `setup.cfg` and you can use most IDEs' `pytest` plugins.

---

### 2.3.1 Vyper Contract and Basic Fixtures

```
1 from eth_tester import (
2     EthereumTester,
3 )
4 from eth_tester.exceptions import (
5     TransactionFailed,
6 )
7 from eth_utils.toolz import (
8     compose,
9 )
10 import pytest
11 from web3 import Web3
12 from web3.contract import (
13     Contract,
14     mk_collision_prop,
15 )
16 from web3.providers.eth_tester import (
17     EthereumTesterProvider,
18 )
19
20 from vyper import (
21     compiler,
22 )
23
24
25 class VyperMethod:
26     ALLOWED_MODIFIERS = {'call', 'estimateGas', 'transact', 'buildTransaction'}
27
28     def __init__(self, function, normalizers=None):
29         self._function = function
30         self._function._return_data_normalizers = normalizers
31
32     def __call__(self, *args, **kwargs):
33         return self.__prepared_function(*args, **kwargs)
34
35     def __prepared_function(self, *args, **kwargs):
36         if not kwargs:
```

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```

37     modifier, modifier_dict = 'call', {}
38     fn_abi = [
39         x
40         for x
41         in self._function.contract_abi
42         if x.get('name') == self._function.function_identifier
43     ].pop()
44     # To make tests faster just supply some high gas value.
45     modifier_dict.update({'gas': fn_abi.get('gas', 0) + 50000})
46     elif len(kwargs) == 1:
47         modifier, modifier_dict = kwargs.popitem()
48         if modifier not in self.ALLOWED_MODIFIERS:
49             raise TypeError(
50                 "The only allowed keyword arguments are: %s" % self.ALLOWED_
↪MODIFIERS)
51         else:
52             raise TypeError("Use up to one keyword argument, one of: %s" % self.
↪ALLOWED_MODIFIERS)
53         return getattr(self._function(*args), modifier)(modifier_dict)
54
55
56 class VyperContract:
57     """
58     An alternative Contract Factory which invokes all methods as `call()`,
59     unless you add a keyword argument. The keyword argument assigns the prep method.
60     This call
61     > contract.withdraw(amount, transact={'from': eth.accounts[1], 'gas': 100000, ...}
↪)
62     is equivalent to this call in the classic contract:
63     > contract.functions.withdraw(amount).transact({'from': eth.accounts[1], 'gas': ↪
↪100000, ...})
64     """
65
66     def __init__(self, classic_contract, method_class=VyperMethod):
67         classic_contract._return_data_normalizers += CONCISE_NORMALIZERS
68         self._classic_contract = classic_contract
69         self.address = self._classic_contract.address
70         protected_fn_names = [fn for fn in dir(self) if not fn.endswith('__')]
71         for fn_name in self._classic_contract.functions:
72             # Override namespace collisions
73             if fn_name in protected_fn_names:
74                 _concise_method = mk_collision_prop(fn_name)
75             else:
76                 _classic_method = getattr(
77                     self._classic_contract.functions,
78                     fn_name)
79                 _concise_method = method_class(
80                     _classic_method,
81                     self._classic_contract._return_data_normalizers
82                 )
83             setattr(self, fn_name, _concise_method)
84
85     @classmethod
86     def factory(cls, *args, **kwargs):
87         return compose(cls, Contract.factory(*args, **kwargs))
88
89

```

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```
90 def _none_addr(datatype, data):
91     if datatype == 'address' and int(data, base=16) == 0:
92         return (datatype, None)
93     else:
94         return (datatype, data)
95
96
97 CONCISE_NORMALIZERS = (_none_addr,)
98
99
100 @pytest.fixture
101 def tester():
102     t = EthereumTester()
103     return t
104
105
106 def zero_gas_price_strategy(web3, transaction_params=None):
107     return 0 # zero gas price makes testing simpler.
108
109
110 @pytest.fixture
111 def w3(tester):
112     w3 = Web3(EthereumTesterProvider(tester))
113     w3.eth.setGasPriceStrategy(zero_gas_price_strategy)
114     return w3
115
116
117 def _get_contract(w3, source_code, *args, **kwargs):
118     out = compiler.compile_code(
119         source_code,
120         ['abi', 'bytecode'],
121         interface_codes=kwargs.pop('interface_codes', None),
122     )
123     abi = out['abi']
124     bytecode = out['bytecode']
125     value = kwargs.pop('value_in_eth', 0) * 10 ** 18 # Handle deploying with an eth_
↪value.
126     c = w3.eth.contract(abi=abi, bytecode=bytecode)
127     deploy_transaction = c.constructor(*args)
128     tx_info = {
129         'from': w3.eth.accounts[0],
130         'value': value,
131         'gasPrice': 0,
132     }
133     tx_info.update(kwargs)
134     tx_hash = deploy_transaction.transact(tx_info)
135     address = w3.eth.getTransactionReceipt(tx_hash)['contractAddress']
136     contract = w3.eth.contract(
137         address,
138         abi=abi,
139         bytecode=bytecode,
140         ContractFactoryClass=VyperContract,
141     )
142     return contract
143
144
145 @pytest.fixture
```

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```

146 def get_contract(w3):
147     def get_contract(source_code, *args, **kwargs):
148         return _get_contract(w3, source_code, *args, **kwargs)
149
150     return get_contract
151
152
153 @pytest.fixture
154 def get_logs(w3):
155     def get_logs(tx_hash, c, event_name):
156         tx_receipt = w3.eth.getTransactionReceipt(tx_hash)
157         logs = c._classic_contract.events[event_name]().processReceipt(tx_receipt)
158         return logs
159
160     return get_logs
161
162
163 @pytest.fixture
164 def assert_tx_failed(tester):
165     def assert_tx_failed(function_to_test, exception=TransactionFailed, exc_
↳text=None):
166         snapshot_id = tester.take_snapshot()
167         with pytest.raises(exception) as excinfo:
168             function_to_test()
169         tester.revert_to_snapshot(snapshot_id)
170         if exc_text:
171             assert exc_text in str(excinfo.value)
172
173     return assert_tx_failed

```

This is the base requirement to load a vyper contract and start testing. The last two fixtures are optional and will be discussed later. The rest of this chapter assumes, that you have this code set up in your `confest.py` file. Alternatively, you can import the fixtures to `confest.py` or use [pytest plugins](#).

## 2.3.2 Load Contract and Basic Tests

Assume the following simple contract `storage.vy`. It has a single integer variable and a function to set that value.

```

storedData: public(int128)

@public
def __init__(_x: int128):
    self.storedData = _x

@public
def set(_x: int128):
    self.storedData = _x

```

We create a test file `test_storage.py` where we write our tests in pytest style.

```

import pytest

INITIAL_VALUE = 4

```

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```
@pytest.fixture
def storage_contract(w3, get_contract):
    with open('examples/storage/storage.vy') as f:
        contract_code = f.read()
        # Pass constructor variables directly to the contract
        contract = get_contract(contract_code, INITIAL_VALUE)
    return contract

def test_initial_state(storage_contract):
    # Check if the constructor of the contract is set up properly
    assert storage_contract.storedData() == INITIAL_VALUE

def test_set(w3, storage_contract):
    k0 = w3.eth.accounts[0]

    # Let k0 try to set the value to 10
    storage_contract.set(10, transact={"from": k0})
    assert storage_contract.storedData() == 10 # Directly access storedData

    # Let k0 try to set the value to -5
    storage_contract.set(-5, transact={"from": k0})
    assert storage_contract.storedData() == -5
```

First we create a fixture for the contract which will compile our contract and set up a Web3 contract object. We then use this fixture for our test functions to interact with the contract.

**Note:** To run the tests, call `pytest` or `python -m pytest` from your project directory.

### 2.3.3 Events and Failed Transactions

To test events and failed transactions we expand our simple storage contract to include an event and two conditions for a failed transaction: `advanced_storage.vy`

```
DataChange: event({_setter: indexed(address), _value: int128})

storedData: public(int128)

@public
def __init__(_x: int128):
    self.storedData = _x

@public
def set(_x: int128):
    assert _x >= 0 # No negative values
    assert self.storedData < 100 # Storage will lock when 100 or more is stored
    self.storedData = _x
    log.DataChange(msg.sender, _x)

@public
def reset():
    self.storedData = 0
```

Next, we take a look at the two fixtures that will allow us to read the event logs and to check for failed transactions.

```
@pytest.fixture
def assert_tx_failed(tester):
    def assert_tx_failed(function_to_test, exception=TransactionFailed, exc_
↳text=None):
        snapshot_id = tester.take_snapshot()
        with pytest.raises(exception) as excinfo:
            function_to_test()
        tester.revert_to_snapshot(snapshot_id)
        if exc_text:
            assert exc_text in str(excinfo.value)

    return assert_tx_failed
```

The fixture to assert failed transactions defaults to check for a `TransactionFailed` exception, but can be used to check for different exceptions too, as shown below. Also note that the chain gets reverted to the state before the failed transaction.

```
@pytest.fixture
def get_logs(w3):
    def get_logs(tx_hash, c, event_name):
        tx_receipt = w3.eth.getTransactionReceipt(tx_hash)
        logs = c._classic_contract.events[event_name]().processReceipt(tx_receipt)
        return logs

    return get_logs
```

This fixture will return a tuple with all the logs for a certain event and transaction. The length of the tuple equals the number of events (of the specified type) logged and should be checked first.

Finally, we create a new file `test_advanced_storage.py` where we use the new fixtures to test failed transactions and events.

```
import pytest
from web3.exceptions import (
    ValidationError,
)

INITIAL_VALUE = 4

@pytest.fixture
def adv_storage_contract(w3, get_contract):
    with open('examples/storage/advanced_storage.vy') as f:
        contract_code = f.read()
        # Pass constructor variables directly to the contract
        contract = get_contract(contract_code, INITIAL_VALUE)
    return contract

def test_initial_state(adv_storage_contract):
    # Check if the constructor of the contract is set up properly
    assert adv_storage_contract.storedData() == INITIAL_VALUE

def test_failed_transactions(w3, adv_storage_contract, assert_tx_failed):
    k1 = w3.eth.accounts[1]
```

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```
# Try to set the storage to a negative amount
assert_tx_failed(lambda: adv_storage_contract.set(-10, transact={"from": k1}))

# Lock the contract by storing more than 100. Then try to change the value
adv_storage_contract.set(150, transact={"from": k1})
assert_tx_failed(lambda: adv_storage_contract.set(10, transact={"from": k1}))

# Reset the contract and try to change the value
adv_storage_contract.reset(transact={"from": k1})
adv_storage_contract.set(10, transact={"from": k1})
assert adv_storage_contract.storedData() == 10

# Assert a different exception (ValidationError for non matching argument type)
assert_tx_failed(
    lambda: adv_storage_contract.set("foo", transact={"from": k1}),
    ValidationError
)

# Assert a different exception that contains specific text
assert_tx_failed(
    lambda: adv_storage_contract.set(1, 2, transact={"from": k1}),
    ValidationError,
    "invocation failed due to improper number of arguments",
)

def test_events(w3, adv_storage_contract, get_logs):
    k1, k2 = w3.eth.accounts[:2]

    tx1 = adv_storage_contract.set(10, transact={"from": k1})
    tx2 = adv_storage_contract.set(20, transact={"from": k2})
    tx3 = adv_storage_contract.reset(transact={"from": k1})

    # Save DataChange logs from all three transactions
    logs1 = get_logs(tx1, adv_storage_contract, "DataChange")
    logs2 = get_logs(tx2, adv_storage_contract, "DataChange")
    logs3 = get_logs(tx3, adv_storage_contract, "DataChange")

    # Check log contents
    assert len(logs1) == 1
    assert logs1[0].args._value == 10

    assert len(logs2) == 1
    assert logs2[0].args._setter == k2

    assert not logs3    # tx3 does not generate a log
```

## 2.4 Deploying a Contract

Once you are ready to deploy your contract to a public test net or the main net, you have several options:

- Take the bytecode generated by the vyper compiler and manually deploy it through mist or geth:

```
vyper yourFileName.vy
# returns bytecode
```

- Take the byte code and ABI and depoly it with your current browser on [myetherwallet's](#) contract menu:

```
vyper -f abi yourFileName.vy
# returns ABI
```

- Use the remote compiler provided by the [Remix IDE](#) to compile and deploy your contract on your net of choice. Remix also provides a JavaScript VM to test deploy your contract.

**Note:** While the vyper version of the Remix IDE compiler is updated on a regular basis it might be a bit behind the latest version found in the master branch of the repository. Make sure the byte code matches the output from your local compiler.

## 2.5 Structure of a Contract

Contracts in Vyper are contained within files, with each file being one smart-contract. Files in Vyper are similar to classes in object-oriented languages. Each file can contain declarations of *State Variables* and *Functions*.

### 2.5.1 State Variables

State variables are values which are permanently stored in contract storage.

```
storedData: int128
```

See the [Types](#) section for valid state variable types.

### 2.5.2 Functions

Functions are the executable units of code within a contract.

```
@public
@payable
def bid(): // Function
    // ...
```

Function calls can happen internally or externally and have different levels of visibility (see [Decorators](#)) towards other contracts. Functions must be explicitly declared as public or private.

#### Public Functions

Public functions (decorated with `@public`) are a part of the contract interface and may be called via transactions or from other contracts. They cannot be called internally.

Public functions in Vyper are equivalent to external functions in Solidity.

### Private Functions

Private functions (decorated with `@private`) are only accessible from other functions within the same contract. They are called via the `self` variable:

```
@private
def _times_two(amount: uint256) -> uint256:
    return amount * 2

@public
def calculate(amount: uint256) -> uint256:
    return self._times_two(amount)
```

Private functions do not have access to `msg.sender` or `msg.value`. If you require these values within a private function they must be passed as parameters.

### Decorators

The following decorators are available:

Decorator	Description
<code>@public</code>	Can only be called externally.
<code>@private</code>	Can only be called within current contract.
<code>@constant</code>	Does not alter contract state.
<code>@payable</code>	The contract is open to receive Ether.
<code>@nonreentrant(&lt;unique_key&gt;)</code>	Function can only be called once, both externally and internally. Used to prevent reentrancy attacks.

The visibility decorators `@public` or `@private` are mandatory on function declarations, whilst the other decorators (`@constant`, `@payable`, `@nonreentrant`) are optional.

### Default function

A contract can also have a default function, which is executed on a call to the contract if no other functions match the given function identifier (or if none was supplied at all, such as through someone sending it Eth). It is the same construct as fallback functions in [Solidity](#).

This function is always named `__default__` and must be annotated with `@public`. It cannot have arguments and cannot return anything.

If the function is annotated as `@payable`, this function is executed whenever the contract is sent Ether (without data). This is why the default function cannot accept arguments and return values - it is a design decision of Ethereum to make no differentiation between sending ether to a contract or a user address.

#### Example:

```
Payment: event({amount: int128, from: indexed(address)})

@public
@payable
def __default__():
    log.Payment(msg.value, msg.sender)
```

## Considerations

Just as in Solidity, Vyper generates a default function if one isn't found, in the form of a REVERT call. Note that this still *generates an exception* and thus will not succeed in receiving funds.

Ethereum specifies that the operations will be rolled back if the contract runs out of gas in execution. `send` calls to the contract come with a free stipend of 2300 gas, which does not leave much room to perform other operations except basic logging. **However**, if the sender includes a higher gas amount through a `call` instead of `send`, then more complex functionality can be run.

It is considered a best practice to ensure your payable default function is compatible with this stipend. The following operations will consume more than 2300 gas:

- Writing to storage
- Creating a contract
- Calling an external function which consumes a large amount of gas
- Sending Ether

Lastly, although the default function receives no arguments, it can still access the `msg` global, including:

- the address of who is interacting with the contract (`msg.sender`)
- the amount of ETH sent (`msg.value`)
- the gas provided (`msg.gas`).

### 2.5.3 Events

Events may be logged in specially indexed data structures that allow clients, including light clients, to efficiently search for them.

```
Payment: event({amount: int128, arg2: indexed(address)})

total_paid: int128

@public
@payable
def pay():
    self.total_paid += msg.value
    log.Payment(msg.value, msg.sender)
```

Events must be declared before global declarations and function definitions.

### 2.5.4 NatSpec Metadata

Vyper supports structured documentation for state variables and functions and events.

```
carrotsEaten: int128
"""
@author Bob Clampett
@notice Number of carrots eaten
@dev Chewing does not count, carrots must pass the throat to be "eaten"
"""
```

```
@public
@payable
def doesEat(food: string):
    """
    @author Bob Clampett
    @notice Determine if Bugs will accept `food` to eat
    @dev Compares the entire string and does not rely on a hash
    @param food The name of a food to evaluate (in English)
    @return true if Bugs will eat it, false otherwise
    """

    // ...
```

```
Ate: event({food: string})
"""
@author Bob Clampett
@notice Bugs did eat `food`
@dev Chewing does not count, carrots must pass the throat to be "eaten"
@param food The name of a food that was eaten (in English)
"""
```

Additional information about Ethereum Natural Specification (NatSpec) can be found [here](#).

### 2.5.5 Contract Interfaces

An interface is a set of function definitions used to enable communication between smart contracts. A contract interface defines all of that contract's publicly available functions. By importing the interface, your contract now knows how to call these functions in other contracts.

#### Defining Interfaces and Making External Calls

Interfaces can be added to contracts either through inline definition, or by importing them from a separate file.

The `contract` keyword is used to define an inline external interface:

```
contract FooBar:
    def calculate() -> uint256: constant
    def test1(): modifying
```

The defined interface can then be used to make external calls, given a contract address:

```
@public
def test(some_address: address):
    FooBar(some_address).calculate()
```

The interface name can also be used as a type annotation for storage variables. You then assign an address value to the variable to access that interface. Note that assignment of an address requires the value to be cast using the contract type e.g. `FooBar(<address_var>)`:

```
foobar_contract: FooBar

@public
def __init__(foobar_address: address):
    self.foobar_contract = FooBar(foobar_address)
```

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```
@public
def test():
    self.foobar_contract.calculate()
```

Specifying modifying annotation indicates that the call made to the external contract will be able to alter storage, whereas the constant call will use a `STATICCALL` ensuring no storage can be altered during execution.

```
contract FooBar:
    def calculate() -> uint256: constant
    def test1(): modifying

@public
def test(some_address: address):
    FooBar(some_address).calculate() # cannot change storage
    FooBar(some_address).test1() # storage can be altered
```

## Importing Interfaces

Interfaces are imported with `import` or `from ... import` statements.

Imported interfaces are written using standard Vyper syntax, with the body of each function replaced by a `pass` statement:

```
@public
def test1():
    pass

@public
def calculate() -> uint256:
    pass
```

You can also import a fully implemented contract and Vyper will automatically convert it to an interface.

## Imports via `import`

With absolute `import` statements, you **must** include an alias as a name for the imported package. In the following example, failing to include `as Foo` will raise a compile error:

```
import contract.foo as Foo
```

## Imports via `from ... import`

Using `from` you can perform both absolute and relative imports. With `from import` statements you **cannot** use an alias - the name of the interface will always be that of the file:

```
from contract import foo
```

Relative imports are possible by prepending dots to the contract name. A single leading dot indicates a relative import starting with the current package. Two leading dots indicate a relative import from the parent of the current package:

```
from . import foo
from ..interfaces import baz
```

### Searching For Interface Files

When looking for a file to import Vyper will first search relative to the same folder as the contract being compiled. For absolute imports, it also searches relative to the root path for the project. Vyper checks for the file name with a `.vy` suffix first, then `.json`.

When using the command line compiler, the root path defaults to to the current working directory. You can change it with the `-p` flag:

```
$ vyper my_project/contracts/my_contract.vy -p my_project
```

In the above example, the `my_project` folder is set as the root path. A contract cannot perform a relative import that goes beyond the top-level folder.

### Built-in Interfaces

Vyper includes common built-in interfaces such as [ERC20](#) and [ERC721](#). These are imported from `vyper.interfaces`:

```
from vyper.interfaces import ERC20

implements: ERC20
```

You can see all the available built-in interfaces in the [Vyper GitHub repo](#).

### Implementing an Interface

You can define an interface for your contract with the `implements` statement:

```
import an_interface as FooBarInterface

implements: FooBarInterface
```

This imports the defined interface from the `vyper` file at `an_interface.vy` (or `an_interface.json` if using ABI json interface type) and ensures your current contract implements all the necessary public functions. If any interface functions are not included in the contract, it will fail to compile. This is especially useful when developing contracts around well-defined standards such as [ERC20](#).

### Extracting Interfaces

Vyper has a built-in format option to allow you to make your own vyper interfaces easily.

```
$ vyper -f interface examples/voting/ballot.vy

# Functions

@constant
@public
def delegated(addr: address) -> bool:
```

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```

    pass
# ...

```

If you want to do an external call to another contract, vyper provides an external contract extract utility as well.

```

$ vyper -f external_interface examples/voting/ballot.vy

# External Contracts
contract Ballot:
    def delegated(addr: address) -> bool: constant
    def directlyVoted(addr: address) -> bool: constant
    def giveRightToVote(voter: address): modifying
    def forwardWeight(delegate_with_weight_to_forward: address): modifying
    # ...

```

The output can then easily be copy-pasted to be consumed.

## 2.6 Vyper by Example

### 2.6.1 Simple Open Auction

As an introductory example of a smart contract written in Vyper, we will begin with a simple open auction contract. As we dive into the code, it is important to remember that all Vyper syntax is valid Python3 syntax, however not all Python3 functionality is available in Vyper.

In this contract, we will be looking at a simple open auction contract where participants can submit bids during a limited time period. When the auction period ends, a predetermined beneficiary will receive the amount of the highest bid.

```

1  # Open Auction
2
3  # Auction params
4  # Beneficiary receives money from the highest bidder
5  beneficiary: public(address)
6  auctionStart: public(timestamp)
7  auctionEnd: public(timestamp)
8
9  # Current state of auction
10 highestBidder: public(address)
11 highestBid: public(wei_value)
12
13 # Set to true at the end, disallows any change
14 ended: public(bool)
15
16 # Keep track of refunded bids so we can follow the withdraw pattern
17 pendingReturns: public(map(address, wei_value))
18
19 # Create a simple auction with `_bidding_time`
20 # seconds bidding time on behalf of the
21 # beneficiary address `_beneficiary`.
22 @public
23 def __init__(_beneficiary: address, _bidding_time: timedelta):
24     self.beneficiary = _beneficiary

```

(continues on next page)

```
25     self.auctionStart = block.timestamp
26     self.auctionEnd = self.auctionStart + _bidding_time
27
28     # Bid on the auction with the value sent
29     # together with this transaction.
30     # The value will only be refunded if the
31     # auction is not won.
32     @public
33     @payable
34     def bid():
35         # Check if bidding period is over.
36         assert block.timestamp < self.auctionEnd
37         # Check if bid is high enough
38         assert msg.value > self.highestBid
39         # Track the refund for the previous high bidder
40         self.pendingReturns[self.highestBidder] += self.highestBid
41         # Track new high bid
42         self.highestBidder = msg.sender
43         self.highestBid = msg.value
44
45     # Withdraw a previously refunded bid. The withdraw pattern is
46     # used here to avoid a security issue. If refunds were directly
47     # sent as part of bid(), a malicious bidding contract could block
48     # those refunds and thus block new higher bids from coming in.
49     @public
50     def withdraw():
51         pending_amount: wei_value = self.pendingReturns[msg.sender]
52         self.pendingReturns[msg.sender] = 0
53         send(msg.sender, pending_amount)
54
55     # End the auction and send the highest bid
56     # to the beneficiary.
57     @public
58     def endAuction():
59         # It is a good guideline to structure functions that interact
60         # with other contracts (i.e. they call functions or send Ether)
61         # into three phases:
62         # 1. checking conditions
63         # 2. performing actions (potentially changing conditions)
64         # 3. interacting with other contracts
65         # If these phases are mixed up, the other contract could call
66         # back into the current contract and modify the state or cause
67         # effects (Ether payout) to be performed multiple times.
68         # If functions called internally include interaction with external
69         # contracts, they also have to be considered interaction with
70         # external contracts.
71
72         # 1. Conditions
73         # Check if auction endtime has been reached
74         assert block.timestamp >= self.auctionEnd
75         # Check if this function has already been called
76         assert not self.ended
77
78         # 2. Effects
79         self.ended = True
80
81         # 3. Interaction
```

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```
82 send(self.beneficiary, self.highestBid)
```

As you can see, this example only has a constructor, two methods to call, and a few variables to manage the contract state. Believe it or not, this is all we need for a basic implementation of an auction smart contract.

Let's get started!

```
# Auction params
# Beneficiary receives money from the highest bidder
beneficiary: public(address)
auctionStart: public(timestamp)
auctionEnd: public(timestamp)

# Current state of auction
highestBidder: public(address)
highestBid: public(wei_value)

# Set to true at the end, disallows any change
ended: public(bool)
```

We begin by declaring a few variables to keep track of our contract state. We initialize a global variable `beneficiary` by calling `public` on the datatype `address`. The `beneficiary` will be the receiver of money from the highest bidder. We also initialize the variables `auctionStart` and `auctionEnd` with the datatype `timestamp` to manage the open auction period and `highestBid` with datatype `wei_value`, the smallest denomination of ether, to manage auction state. The variable `ended` is a boolean to determine whether the auction is officially over.

You may notice all of the variables being passed into the `public` function. By declaring the variable `public`, the variable is callable by external contracts. Initializing the variables without the `public` function defaults to a private declaration and thus only accessible to methods within the same contract. The `public` function additionally creates a 'getter' function for the variable, accessible through an external call such as `contract.beneficiary()`.

Now, the constructor.

The contract is initialized with two arguments: `_beneficiary` of type `address` and `_bidding_time` with type `timedelta`, the time difference between the start and end of the auction. We then store these two pieces of information into the contract variables `self.beneficiary` and `self.auctionEnd`. Notice that we have access to the current time by calling `block.timestamp`. `block` is an object available within any Vyper contract and provides information about the block at the time of calling. Similar to `block`, another important object available to us within the contract is `msg`, which provides information on the method caller as we will soon see.

With initial setup out of the way, lets look at how our users can make bids.

The `@payable` decorator will allow a user to send some ether to the contract in order to call the decorated method. In this case, a user wanting to make a bid would call the `bid()` method while sending an amount equal to their desired bid (not including gas fees). When calling any method within a contract, we are provided with a built-in variable `msg` and we can access the public address of any method caller with `msg.sender`. Similarly, the amount of ether a user sends can be accessed by calling `msg.value`.

---

**Note:** `msg.sender` and `msg.value` can only be accessed from public functions. If you require these values within a private function they must be passed as parameters.

---

Here, we first check whether the current time is before the auction's end time using the `assert` function which takes any boolean statement. We also check to see if the new bid is greater than the highest bid. If the two `assert` statements pass, we can safely continue to the next lines; otherwise, the `bid()` method will throw an error and revert the transaction. If the two `assert` statements and the check that the previous bid is not equal to zero pass, we can

safely conclude that we have a valid new highest bid. We will send back the previous `highestBid` to the previous `highestBidder` and set our new `highestBid` and `highestBidder`.

With the `endAuction()` method, we check whether our current time is past the `auctionEnd` time we set upon initialization of the contract. We also check that `self.ended` had not previously been set to `True`. We do this to prevent any calls to the method if the auction had already ended, which could potentially be malicious if the check had not been made. We then officially end the auction by setting `self.ended` to `True` and sending the highest bid amount to the beneficiary.

And there you have it - an open auction contract. Of course, this is a simplified example with barebones functionality and can be improved. Hopefully, this has provided some insight into the possibilities of Vyper. As we move on to exploring more complex examples, we will encounter more design patterns and features of the Vyper language.

And of course, no smart contract tutorial is complete without a note on security.

---

**Note:** It's always important to keep security in mind when designing a smart contract. As any application becomes more complex, the greater the potential for introducing new risks. Thus, it's always good practice to keep contracts as readable and simple as possible.

---

Whenever you're ready, let's turn it up a notch in the next example.

### 2.6.2 Blind Auction

Before we dive into our other examples, let's briefly explore another type of auction that you can build with Vyper. Similar to its `counterpart` written in Solidity, this blind auction allows for an auction where there is no time pressure towards the end of the bidding period.

```
1 # Blind Auction # Adapted to Vyper from [Solidity by Example](https://github.com/
  ↳ethereum/solidity/blob/develop/docs/solidity-by-example.rst#blind-auction-1)
2
3 struct Bid:
4     blindedBid: bytes32
5     deposit: wei_value
6
7 # Note: because Vyper does not allow for dynamic arrays, we have limited the
8 # number of bids that can be placed by one address to 128 in this example
9 MAX_BIDS: constant(int128) = 128
10
11 # Event for logging that auction has ended
12 AuctionEnded: event({_highestBidder: address, _highestBid: wei_value})
13
14 # Auction parameters
15 beneficiary: public(address)
16 biddingEnd: public(timestamp)
17 revealEnd: public(timestamp)
18
19 # Set to true at the end of auction, disallowing any new bids
20 ended: public(bool)
21
22 # Final auction state
23 highestBid: public(wei_value)
24 highestBidder: public(address)
25
26 # State of the bids
27 bids: map(address, Bid[128])
```

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```

28 bidCounts: map(address, int128)
29
30 # Allowed withdrawals of previous bids
31 pendingReturns: map(address, wei_value)
32
33
34 # Create a blinded auction with `_biddingTime` seconds bidding time and
35 # `_revealTime` seconds reveal time on behalf of the beneficiary address
36 # `_beneficiary`.
37 @public
38 def __init__(_beneficiary: address, _biddingTime: timedelta, _revealTime: timedelta):
39     self.beneficiary = _beneficiary
40     self.biddingEnd = block.timestamp + _biddingTime
41     self.revealEnd = self.biddingEnd + _revealTime
42
43
44 # Place a blinded bid with:
45 #
46 # _blindedBid = keccak256(concat(
47 #     convert(value, bytes32),
48 #     convert(fake, bytes32),
49 #     secret)
50 # )
51 #
52 # The sent ether is only refunded if the bid is correctly revealed in the
53 # revealing phase. The bid is valid if the ether sent together with the bid is
54 # at least "value" and "fake" is not true. Setting "fake" to true and sending
55 # not the exact amount are ways to hide the real bid but still make the
56 # required deposit. The same address can place multiple bids.
57 @public
58 @payable
59 def bid(_blindedBid: bytes32):
60     # Check if bidding period is still open
61     assert block.timestamp < self.biddingEnd
62
63     # Check that payer hasn't already placed maximum number of bids
64     numBids: int128 = self.bidCounts[msg.sender]
65     assert numBids < MAX_BIDS
66
67     # Add bid to mapping of all bids
68     self.bids[msg.sender][numBids] = Bid({
69         blindedBid: _blindedBid,
70         deposit: msg.value
71     })
72     self.bidCounts[msg.sender] += 1
73
74
75 # Returns a boolean value, `True` if bid placed successfully, `False` otherwise.
76 @private
77 def placeBid(bidder: address, value: wei_value) -> bool:
78     # If bid is less than highest bid, bid fails
79     if (value <= self.highestBid):
80         return False
81
82     # Refund the previously highest bidder
83     if (self.highestBidder != ZERO_ADDRESS):
84         self.pendingReturns[self.highestBidder] += self.highestBid

```

(continues on next page)

```
85
86     # Place bid successfully and update auction state
87     self.highestBid = value
88     self.highestBidder = bidder
89
90     return True
91
92
93     # Reveal your blinded bids. You will get a refund for all correctly blinded
94     # invalid bids and for all bids except for the totally highest.
95 @public
96 def reveal(_numBids: int128, _values: wei_value[128], _fakes: bool[128], _secrets: _
↳ bytes32[128]):
97     # Check that bidding period is over
98     assert block.timestamp > self.biddingEnd
99
100     # Check that reveal end has not passed
101     assert block.timestamp < self.revealEnd
102
103     # Check that number of bids being revealed matches log for sender
104     assert _numBids == self.bidCounts[msg.sender]
105
106     # Calculate refund for sender
107     refund: wei_value
108     for i in range(MAX_BIDS):
109         # Note that loop may break sooner than 128 iterations if i >= _numBids
110         if (i >= _numBids):
111             break
112
113         # Get bid to check
114         bidToCheck: Bid = (self.bids[msg.sender])[i]
115
116         # Check against encoded packet
117         value: wei_value = _values[i]
118         fake: bool = _fakes[i]
119         secret: bytes32 = _secrets[i]
120         blindedBid: bytes32 = keccak256(concat(
121             convert(value, bytes32),
122             convert(fake, bytes32),
123             secret
124         ))
125
126         # Bid was not actually revealed
127         # Do not refund deposit
128         if (blindedBid != bidToCheck.blindedBid):
129             assert 1 == 0
130             continue
131
132         # Add deposit to refund if bid was indeed revealed
133         refund += bidToCheck.deposit
134         if (not fake and bidToCheck.deposit >= value):
135             if (self.placeBid(msg.sender, value)):
136                 refund -= value
137
138         # Make it impossible for the sender to re-claim the same deposit
139         zeroBytes32: bytes32
140         bidToCheck.blindedBid = zeroBytes32
```

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```

141
142     # Send refund if non-zero
143     if (refund != 0):
144         send(msg.sender, refund)
145
146
147 # Withdraw a bid that was overbid.
148 @public
149 def withdraw():
150     # Check that there is an allowed pending return.
151     pendingAmount: wei_value = self.pendingReturns[msg.sender]
152     if (pendingAmount > 0):
153         # If so, set pending returns to zero to prevent recipient from calling
154         # this function again as part of the receiving call before `transfer`
155         # returns (see the remark above about conditions -> effects ->
156         # interaction).
157         self.pendingReturns[msg.sender] = 0
158
159         # Then send return
160         send(msg.sender, pendingAmount)
161
162
163 # End the auction and send the highest bid to the beneficiary.
164 @public
165 def auctionEnd():
166     # Check that reveal end has passed
167     assert block.timestamp > self.revealEnd
168
169     # Check that auction has not already been marked as ended
170     assert not self.ended
171
172     # Log auction ending and set flag
173     log.AuctionEnded(self.highestBidder, self.highestBid)
174     self.ended = True
175
176     # Transfer funds to beneficiary
177     send(self.beneficiary, self.highestBid)

```

While this blind auction is almost functionally identical to the blind auction implemented in Solidity, the differences in their implementations help illustrate the differences between Solidity and Vyper.

```

# Final auction state
highestBid: public(wei_value)
highestBidder: public(address)

```

One key difference is that, because Vyper does not allow for dynamic arrays, we have limited the number of bids that can be placed by one address to 128 in this example. Bidders who want to make more than this maximum number of bids would need to do so from multiple addresses.

### 2.6.3 Safe Remote Purchases

In this example, we have an escrow contract implementing a system for a trustless transaction between a buyer and a seller. In this system, a seller posts an item for sale and makes a deposit to the contract of twice the item's value. At this moment, the contract has a balance of  $2 * \text{value}$ . The seller can reclaim the deposit and close the sale as long as a buyer has not yet made a purchase. If a buyer is interested in making a purchase, they would make a payment

and submit an equal amount for deposit (totaling  $2 * \text{value}$ ) into the contract and locking the contract from further modification. At this moment, the contract has a balance of  $4 * \text{value}$  and the seller would send the item to buyer. Upon the buyer's receipt of the item, the buyer will mark the item as received in the contract, thereby returning the buyer's deposit (not payment), releasing the remaining funds to the seller, and completing the transaction.

There are certainly others ways of designing a secure escrow system with less overhead for both the buyer and seller, but for the purpose of this example, we want to explore one way how an escrow system can be implemented trustlessly.

Let's go!

```
1 # Safe Remote Purchase
2 # Originally from
3 # https://github.com/ethereum/solidity/blob/develop/docs/solidity-by-example.rst
4 # Ported to vyper and optimized.
5
6 # Rundown of the transaction:
7 # 1. Seller posts item for sale and posts safety deposit of double the item value.
8 #     Balance is 2*value.
9 #     (1.1. Seller can reclaim deposit and close the sale as long as nothing was
10 #        ↪purchased.)
11 # 2. Buyer purchases item (value) plus posts an additional safety deposit (Item
12 #    ↪value).
13 #     Balance is 4*value.
14 # 3. Seller ships item.
15 # 4. Buyer confirms receiving the item. Buyer's deposit (value) is returned.
16 #     Seller's deposit (2*value) + items value is returned. Balance is 0.
17
18 value: public(wei_value) #Value of the item
19 seller: public(address)
20 buyer: public(address)
21 unlocked: public(bool)
22 ended: public(bool)
23
24 @public
25 @payable
26 def __init__():
27     assert (msg.value % 2) == 0
28     self.value = msg.value / 2 # The seller initializes the contract by
29     # posting a safety deposit of 2*value of the item up for sale.
30     self.seller = msg.sender
31     self.unlocked = True
32
33 @public
34 def abort():
35     assert self.unlocked #Is the contract still refundable?
36     assert msg.sender == self.seller # Only the seller can refund
37     # his deposit before any buyer purchases the item.
38     selfdestruct(self.seller) # Refunds the seller and deletes the contract.
39
40 @public
41 @payable
42 def purchase():
43     assert self.unlocked # Is the contract still open (is the item still up
44     # for sale)?
45     assert msg.value == (2 * self.value) # Is the deposit the correct value?
46     self.buyer = msg.sender
47     self.unlocked = False
```

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```

47 @public
48 def received():
49     # 1. Conditions
50     assert not self.unlocked # Is the item already purchased and pending
51                             # confirmation from the buyer?
52     assert msg.sender == self.buyer
53     assert not self.ended
54
55     # 2. Effects
56     self.ended = True
57
58     # 3. Interaction
59     send(self.buyer, self.value) # Return the buyer's deposit (=value) to the buyer.
60     selfdestruct(self.seller) # Return the seller's deposit (=2*value) and the
61                             # purchase price (=value) to the seller.

```

This is also a moderately short contract, however a little more complex in logic. Let's break down this contract bit by bit.

```

value: public(wei_value) #Value of the item
seller: public(address)
buyer: public(address)
unlocked: public(bool)

```

Like the other contracts, we begin by declaring our global variables public with their respective data types. Remember that the public function allows the variables to be *readable* by an external caller, but not *writable*.

With a @payable decorator on the constructor, the contract creator will be required to make an initial deposit equal to twice the item's value to initialize the contract, which will be later returned. This is in addition to the gas fees needed to deploy the contract on the blockchain, which is not returned. We assert that the deposit is divisible by 2 to ensure that the seller deposited a valid amount. The constructor stores the item's value in the contract variable self.value and saves the contract creator into self.seller. The contract variable self.unlocked is initialized to True.

The abort() method is a method only callable by the seller and while the contract is still unlocked—meaning it is callable only prior to any buyer making a purchase. As we will see in the purchase() method that when a buyer calls the purchase() method and sends a valid amount to the contract, the contract will be locked and the seller will no longer be able to call abort().

When the seller calls abort() and if the assert statements pass, the contract will call the selfdestruct() function and refunds the seller and subsequently destroys the contract.

Like the constructor, the purchase() method has a @payable decorator, meaning it can be called with a payment. For the buyer to make a valid purchase, we must first assert that the contract's unlocked property is True and that the amount sent is equal to twice the item's value. We then set the buyer to the msg.sender and lock the contract. At this point, the contract has a balance equal to 4 times the item value and the seller must send the item to the buyer.

Finally, upon the buyer's receipt of the item, the buyer can confirm their receipt by calling the received() method to distribute the funds as intended—where the seller receives 3/4 of the contract balance and the buyer receives 1/4.

By calling received(), we begin by checking that the contract is indeed locked, ensuring that a buyer had previously paid. We also ensure that this method is only callable by the buyer. If these two assert statements pass, we refund the buyer their initial deposit and send the seller the remaining funds. The contract is finally destroyed and the transaction is complete.

Whenever we're ready, let's move on to the next example.

## 2.6.4 Crowdfund

Now, let's explore a straightforward example for a crowdfunding contract where prospective participants can contribute funds to a campaign. If the total contribution to the campaign reaches or surpasses a predetermined funding goal, the funds will be sent to the beneficiary at the end of the campaign deadline. Participants will be refunded their respective contributions if the total funding does not reach its target goal.

```

1  # Setup private variables (only callable from within the contract)
2
3  struct Funder :
4      sender: address
5      value: wei_value
6
7  funders: map(int128, Funder)
8  nextFunderIndex: int128
9  beneficiary: address
10 deadline: public(timestamp)
11 goal: public(wei_value)
12 refundIndex: int128
13 timelimit: public(timedelta)
14
15
16 # Setup global variables
17 @public
18 def __init__(_beneficiary: address, _goal: wei_value, _timelimit: timedelta):
19     self.beneficiary = _beneficiary
20     self.deadline = block.timestamp + _timelimit
21     self.timelimit = _timelimit
22     self.goal = _goal
23
24
25 # Participate in this crowdfunding campaign
26 @public
27 @payable
28 def participate():
29     assert block.timestamp < self.deadline, "deadline not met (yet)"
30
31     nfi: int128 = self.nextFunderIndex
32
33     self.funders[nfi] = Funder({sender: msg.sender, value: msg.value})
34     self.nextFunderIndex = nfi + 1
35
36
37 # Enough money was raised! Send funds to the beneficiary
38 @public
39 def finalize():
40     assert block.timestamp >= self.deadline, "deadline not met (yet)"
41     assert self.balance >= self.goal, "invalid balance"
42
43     selfdestruct(self.beneficiary)
44
45 # Not enough money was raised! Refund everyone (max 30 people at a time
46 # to avoid gas limit issues)
47 @public
48 def refund():
49     assert block.timestamp >= self.deadline and self.balance < self.goal
50
51     ind: int128 = self.refundIndex

```

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```

52
53     for i in range(ind, ind + 30):
54         if i >= self.nextFunderIndex:
55             self.refundIndex = self.nextFunderIndex
56             return
57
58         send(self.funders[i].sender, self.funders[i].value)
59         clear(self.funders[i])
60
61     self.refundIndex = ind + 30

```

Most of this code should be relatively straightforward after going through our previous examples. Let's dive right in.

```

# Setup private variables (only callable from within the contract)

struct Funder :
    sender: address
    value: wei_value

funders: map(int128, Funder)
nextFunderIndex: int128

```

Like other examples, we begin by initiating our variables - except this time, we're not calling them with the `public` function. Variables initiated this way are, by default, private.

---

**Note:** Unlike the existence of the function `public()`, there is no equivalent `private()` function. Variables simply default to private if initiated without the `public()` function.

---

The `funders` variable is initiated as a mapping where the key is a number, and the value is a struct representing the contribution of each participant. This struct contains each participant's public address and their respective value contributed to the fund. The key corresponding to each struct in the mapping will be represented by the variable `nextFunderIndex` which is incremented with each additional contributing participant. Variables initialized with the `int128` type without an explicit value, such as `nextFunderIndex`, defaults to 0. The beneficiary will be the final receiver of the funds once the crowdfunding period is over—as determined by the `deadline` and `timelimit` variables. The `goal` variable is the target total contribution of all participants. `refundIndex` is a variable for bookkeeping purposes in order to avoid gas limit issues in the scenario of a refund.

Our constructor function takes 3 arguments: the beneficiary's address, the goal in wei value, and the difference in time from start to finish of the crowdfunding. We initialize the arguments as contract variables with their corresponding names. Additionally, a `self.deadline` is initialized to set a definitive end time for the crowdfunding period.

Now let's take a look at how a person can participate in the crowdfund.

Once again, we see the `@payable` decorator on a method, which allows a person to send some ether along with a call to the method. In this case, the `participate()` method accesses the sender's address with `msg.sender` and the corresponding amount sent with `msg.value`. This information is stored into a struct and then saved into the `funders` mapping with `self.nextFunderIndex` as the key. As more participants are added to the mapping, `self.nextFunderIndex` increments appropriately to properly index each participant.

The `finalize()` method is used to complete the crowdfunding process. However, to complete the crowdfunding, the method first checks to see if the crowdfunding period is over and that the balance has reached/passed its set goal. If those two conditions pass, the contract calls the `selfdestruct()` function and sends the collected funds to the beneficiary.

---

**Note:** Notice that we have access to the total amount sent to the contract by calling `self.balance`, a variable we

---

never explicitly set. Similar to `msg` and `block`, `self.balance` is a built-in variable that's available in all Vyper contracts.

We can finalize the campaign if all goes well, but what happens if the crowdfunding campaign isn't successful? We're going to need a way to refund all the participants.

In the `refund()` method, we first check that the crowdfunding period is indeed over and that the total collected balance is less than the goal with the `assert` statement. If those two conditions pass, we then loop through every participant and call `send()` to send each participant their respective contribution. For the sake of gas limits, we group the number of contributors in batches of 30 and refund them one at a time. Unfortunately, if there's a large number of participants, multiple calls to `refund()` may be necessary.

### 2.6.5 Voting

In this contract, we will implement a system for participants to vote on a list of proposals. The chairperson of the contract will be able to give each participant the right to vote, and each participant may choose to vote, or delegate their vote to another voter. Finally, a winning proposal will be determined upon calling the `winningProposals()` method, which iterates through all the proposals and returns the one with the greatest number of votes.

```
1 # Voting with delegation.
2
3 # Information about voters
4 struct Voter:
5     # weight is accumulated by delegation
6     weight: int128
7     # if true, that person already voted (which includes voting by delegating)
8     voted: bool
9     # person delegated to
10    delegate: address
11    # index of the voted proposal, which is not meaningful unless `voted` is True.
12    vote: int128
13
14 # Users can create proposals
15 struct Proposal:
16     # short name (up to 32 bytes)
17     name: bytes32
18     # number of accumulated votes
19     voteCount: int128
20
21 voters: public(map(address, Voter))
22 proposals: public(map(int128, Proposal))
23 voterCount: public(int128)
24 chairperson: public(address)
25 int128Proposals: public(int128)
26
27
28 @private
29 @constant
30 def _delegated(addr: address) -> bool:
31     return self.voters[addr].delegate != ZERO_ADDRESS
32
33
34 @public
35 @constant
36 def delegated(addr: address) -> bool:
37     return self._delegated(addr)
```

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```

38
39
40 @private
41 @constant
42 def _directlyVoted(addr: address) -> bool:
43     return self.voters[addr].voted and (self.voters[addr].delegate == ZERO_ADDRESS)
44
45
46 @public
47 @constant
48 def directlyVoted(addr: address) -> bool:
49     return self._directlyVoted(addr)
50
51
52 # Setup global variables
53 @public
54 def __init__(_proposalNames: bytes32[2]):
55     self.chairperson = msg.sender
56     self.voterCount = 0
57     for i in range(2):
58         self.proposals[i] = Proposal({
59             name: _proposalNames[i],
60             voteCount: 0
61         })
62     self.int128Proposals += 1
63
64 # Give a `voter` the right to vote on this ballot.
65 # This may only be called by the `chairperson`.
66 @public
67 def giveRightToVote(voter: address):
68     # Throws if the sender is not the chairperson.
69     assert msg.sender == self.chairperson
70     # Throws if the voter has already voted.
71     assert not self.voters[voter].voted
72     # Throws if the voter's voting weight isn't 0.
73     assert self.voters[voter].weight == 0
74     self.voters[voter].weight = 1
75     self.voterCount += 1
76
77 # Used by `delegate` below, callable externally via `forwardWeight`
78 @private
79 def _forwardWeight(delegate_with_weight_to_forward: address):
80     assert self._delegated(delegate_with_weight_to_forward)
81     # Throw if there is nothing to do:
82     assert self.voters[delegate_with_weight_to_forward].weight > 0
83
84     target: address = self.voters[delegate_with_weight_to_forward].delegate
85     for i in range(4):
86         if self._delegated(target):
87             target = self.voters[target].delegate
88             # The following effectively detects cycles of length <= 5,
89             # in which the delegation is given back to the delegator.
90             # This could be done for any int128ber of loops,
91             # or even infinitely with a while loop.
92             # However, cycles aren't actually problematic for correctness;
93             # they just result in spoiled votes.
94             # So, in the production version, this should instead be

```

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```
95         # the responsibility of the contract's client, and this
96         # check should be removed.
97         assert target != delegate_with_weight_to_forward
98     else:
99         # Weight will be moved to someone who directly voted or
100        # hasn't voted.
101        break
102
103    weight_to_forward: int128 = self.voters[delegate_with_weight_to_forward].weight
104    self.voters[delegate_with_weight_to_forward].weight = 0
105    self.voters[target].weight += weight_to_forward
106
107    if self._directlyVoted(target):
108        self.proposals[self.voters[target].vote].voteCount += weight_to_forward
109        self.voters[target].weight = 0
110
111    # To reiterate: if target is also a delegate, this function will need
112    # to be called again, similarly to as above.
113
114    # Public function to call _forwardWeight
115    @public
116    def forwardWeight(delegate_with_weight_to_forward: address):
117        self._forwardWeight(delegate_with_weight_to_forward)
118
119    # Delegate your vote to the voter `to`.
120    @public
121    def delegate(to: address):
122        # Throws if the sender has already voted
123        assert not self.voters[msg.sender].voted
124        # Throws if the sender tries to delegate their vote to themselves or to
125        # the default address value of 0x000000000000000000000000000000000000
126        # (the latter might not be problematic, but I don't want to think about it).
127        assert to != msg.sender
128        assert to != ZERO_ADDRESS
129
130        self.voters[msg.sender].voted = True
131        self.voters[msg.sender].delegate = to
132
133        # This call will throw if and only if this delegation would cause a loop
134        # of length <= 5 that ends up delegating back to the delegator.
135        self._forwardWeight(msg.sender)
136
137    # Give your vote (including votes delegated to you)
138    # to proposal `proposals[proposal].name`.
139    @public
140    def vote(proposal: int128):
141        # can't vote twice
142        assert not self.voters[msg.sender].voted
143        # can only vote on legitimate proposals
144        assert proposal < self.int128Proposals
145
146        self.voters[msg.sender].vote = proposal
147        self.voters[msg.sender].voted = True
148
149        # transfer msg.sender's weight to proposal
150        self.proposals[proposal].voteCount += self.voters[msg.sender].weight
151        self.voters[msg.sender].weight = 0
```

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```

152
153 # Computes the winning proposal taking all
154 # previous votes into account.
155 @private
156 @constant
157 def _winningProposal() -> int128:
158     winning_vote_count: int128 = 0
159     winning_proposal: int128 = 0
160     for i in range(2):
161         if self.proposals[i].voteCount > winning_vote_count:
162             winning_vote_count = self.proposals[i].voteCount
163             winning_proposal = i
164     return winning_proposal
165
166 @public
167 @constant
168 def winningProposal() -> int128:
169     return self._winningProposal()
170
171
172 # Calls winningProposal() function to get the index
173 # of the winner contained in the proposals array and then
174 # returns the name of the winner
175 @public
176 @constant
177 def winnerName() -> bytes32:
178     return self.proposals[self._winningProposal()].name

```

As we can see, this is the contract of moderate length which we will dissect section by section. Let's begin!

```

# Information about voters
struct Voter:
    # weight is accumulated by delegation
    weight: int128
    # if true, that person already voted (which includes voting by delegating)
    voted: bool
    # person delegated to
    delegate: address
    # index of the voted proposal, which is not meaningful unless `voted` is True.
    vote: int128

# Users can create proposals
struct Proposal:
    # short name (up to 32 bytes)
    name: bytes32
    # number of accumulated votes
    voteCount: int128

voters: public(map(address, Voter))
proposals: public(map(int128, Proposal))
voterCount: public(int128)
chairperson: public(address)
int128Proposals: public(int128)

```

The variable `voters` is initialized as a mapping where the key is the voter's public address and the value is a struct describing the voter's properties: `weight`, `voted`, `delegate`, and `vote`, along with their respective data types.

Similarly, the `proposals` variable is initialized as a public mapping with `int128` as the key's datatype and a

struct to represent each proposal with the properties `name` and `vote_count`. Like our last example, we can access any value by key'ing into the mapping with a number just as one would with an index in an array.

Then, `voterCount` and `chairperson` are initialized as `public` with their respective datatypes.

Let's move onto the constructor.

---

**Note:** `msg.sender` and `msg.value` can only be accessed from public functions. If you require these values within a private function they must be passed as parameters.

---

In the constructor, we hard-coded the contract to accept an array argument of exactly two proposal names of type `bytes32` for the contracts initialization. Because upon initialization, the `__init__()` method is called by the contract creator, we have access to the contract creator's address with `msg.sender` and store it in the contract variable `self.chairperson`. We also initialize the contract variable `self.voter_count` to zero to initially represent the number of votes allowed. This value will be incremented as each participant in the contract is given the right to vote by the method `giveRightToVote()`, which we will explore next. We loop through the two proposals from the argument and insert them into `proposals` mapping with their respective index in the original array as its key.

Now that the initial setup is done, lets take a look at the functionality.

---

**Note:** Throughout this contract, we use a pattern where `@public` functions return data from `@private` functions that have the same name prepended with an underscore. This is because Vyper does not allow calls between public functions within the same contract. The private function handles the logic and allows internal access, while the public function acts as a getter to allow external viewing.

---

We need a way to control who has the ability to vote. The method `giveRightToVote()` is a method callable by only the chairperson by taking a voter address and granting it the right to vote by incrementing the voter's `weight` property. We sequentially check for 3 conditions using `assert`. The `assert not` function will check for falsy boolean values - in this case, we want to know that the voter has not already voted. To represent voting power, we will set their `weight` to 1 and we will keep track of the total number of voters by incrementing `voterCount`.

In the method `delegate`, firstly, we check to see that `msg.sender` has not already voted and secondly, that the target `delegate` and the `msg.sender` are not the same. Voters shouldn't be able to delegate votes to themselves. We, then, loop through all the voters to determine whether the person `delegate` to had further delegated their vote to someone else in order to follow the chain of delegation. We then mark the `msg.sender` as having voted if they delegated their vote. We increment the proposal's `voterCount` directly if the `delegate` had already voted or increase the `delegate`'s vote `weight` if the `delegate` has not yet voted.

Now, let's take a look at the logic inside the `vote()` method, which is surprisingly simple. The method takes the key of the proposal in the `proposals` mapping as an argument, check that the method caller had not already voted, sets the voter's `vote` property to the proposal key, and increments the proposals `voteCount` by the voter's `weight`.

With all the basic functionality complete, what's left is simply returning the winning proposal. To do this, we have two methods: `winningProposal()`, which returns the key of the proposal, and `winnerName()`, returning the name of the proposal. Notice the `@constant` decorator on these two methods. We do this because the two methods only read the blockchain state and do not modify it. Remember, reading the blockchain state is free; modifying the state costs gas. By having the `@constant` decorator, we let the EVM know that this is a read-only function and we benefit by saving gas fees.

```
# Computes the winning proposal taking all
# previous votes into account.
@private
@constant
def _winningProposal() -> int128:
```

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```

winning_vote_count: int128 = 0
winning_proposal: int128 = 0
for i in range(2):
    if self.proposals[i].voteCount > winning_vote_count:
        winning_vote_count = self.proposals[i].voteCount
        winning_proposal = i
return winning_proposal

@public
@constant
def winningProposal() -> int128:
    return self._winningProposal()

```

The `_winningProposal()` method returns the key of proposal in the `proposals` mapping. We will keep track of greatest number of votes and the winning proposal with the variables `winningVoteCount` and `winningProposal`, respectively by looping through all the proposals.

`winningProposal()` is a public function allowing external access to `_winningProposal()`.

And finally, the `winnerName()` method returns the name of the proposal by key'ing into the `proposals` mapping with the return result of the `winningProposal()` method.

And there you have it - a voting contract. Currently, many transactions are needed to assign the rights to vote to all participants. As an exercise, can we try to optimize this?

Now that we're familiar with basic contracts. Let's step up the difficulty.

## 2.6.6 Company Stock

This contract is just a tad bit more thorough than the ones we've previously encountered. In this example, we are going to look at a comprehensive contract that manages the holdings of all shares of a company. The contract allows for a person to buy, sell and transfer shares of a company as well as allowing for the company to pay a person in ether. The company, upon initialization of the contract, holds all shares of the company at first but can sell them all.

Let's get started.

```

1 units: {
2     currency_value: "Currency Value"
3 }
4
5 # Financial events the contract logs
6 Transfer: event({_from: indexed(address), _to: indexed(address), _value: _
7     ↪uint256(currency_value)})
8 Buy: event({_buyer: indexed(address), _buy_order: uint256(currency_value)})
9 Sell: event({_seller: indexed(address), _sell_order: uint256(currency_value)})
10 Pay: event({_vendor: indexed(address), _amount: wei_value})
11
12 # Initiate the variables for the company and it's own shares.
13 company: public(address)
14 totalShares: public(uint256(currency_value))
15 price: public(uint256(wei / currency_value))
16
17 # Store a ledger of stockholder holdings.
18 holdings: map(address, uint256(currency_value))

```

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```
19 # Set up the company.
20 @public
21 def __init__(_company: address, _total_shares: uint256(currency_value),
22             initial_price: uint256(wei / currency_value) ):
23     assert _total_shares > 0
24     assert initial_price > 0
25
26     self.company = _company
27     self.totalShares = _total_shares
28     self.price = initial_price
29
30     # The company holds all the shares at first, but can sell them all.
31     self.holdings[self.company] = _total_shares
32
33 # Find out how much stock the company holds
34 @private
35 @constant
36 def _stockAvailable() -> uint256(currency_value):
37     return self.holdings[self.company]
38
39 # Public function to allow external access to _stockAvailable
40 @public
41 @constant
42 def stockAvailable() -> uint256(currency_value):
43     return self._stockAvailable()
44
45 # Give some value to the company and get stock in return.
46 @public
47 @payable
48 def buyStock():
49     # Note: full amount is given to company (no fractional shares),
50     #       so be sure to send exact amount to buy shares
51     buy_order: uint256(currency_value) = msg.value / self.price # rounds down
52
53     # Check that there are enough shares to buy.
54     assert self._stockAvailable() >= buy_order
55
56     # Take the shares off the market and give them to the stockholder.
57     self.holdings[self.company] -= buy_order
58     self.holdings[msg.sender] += buy_order
59
60     # Log the buy event.
61     log.Buy(msg.sender, buy_order)
62
63 # Find out how much stock any address (that's owned by someone) has.
64 @private
65 @constant
66 def _getHolding(_stockholder: address) -> uint256(currency_value):
67     return self.holdings[_stockholder]
68
69 # Public function to allow external access to _getHolding
70 @public
71 @constant
72 def getHolding(_stockholder: address) -> uint256(currency_value):
73     return self._getHolding(_stockholder)
74
75 # Return the amount the company has on hand in cash.
```

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```

76 @public
77 @constant
78 def cash() -> wei_value:
79     return self.balance
80
81 # Give stock back to the company and get money back as ETH.
82 @public
83 def sellStock(sell_order: uint256(currency_value)):
84     assert sell_order > 0 # Otherwise, this would fail at send() below,
85         # due to an OOG error (there would be zero value available for gas).
86     # You can only sell as much stock as you own.
87     assert self._getHolding(msg.sender) >= sell_order
88     # Check that the company can pay you.
89     assert self.balance >= (sell_order * self.price)
90
91     # Sell the stock, send the proceeds to the user
92     # and put the stock back on the market.
93     self.holdings[msg.sender] -= sell_order
94     self.holdings[self.company] += sell_order
95     send(msg.sender, sell_order * self.price)
96
97     # Log the sell event.
98     log.Sell(msg.sender, sell_order)
99
100 # Transfer stock from one stockholder to another. (Assume that the
101 # receiver is given some compensation, but this is not enforced.)
102 @public
103 def transferStock(receiver: address, transfer_order: uint256(currency_value)):
104     assert transfer_order > 0 # This is similar to sellStock above.
105     # Similarly, you can only trade as much stock as you own.
106     assert self._getHolding(msg.sender) >= transfer_order
107
108     # Debit the sender's stock and add to the receiver's address.
109     self.holdings[msg.sender] -= transfer_order
110     self.holdings[receiver] += transfer_order
111
112     # Log the transfer event.
113     log.Transfer(msg.sender, receiver, transfer_order)
114
115 # Allow the company to pay someone for services rendered.
116 @public
117 def payBill(vendor: address, amount: wei_value):
118     # Only the company can pay people.
119     assert msg.sender == self.company
120     # Also, it can pay only if there's enough to pay them with.
121     assert self.balance >= amount
122
123     # Pay the bill!
124     send(vendor, amount)
125
126     # Log the payment event.
127     log.Pay(vendor, amount)
128
129 # Return the amount in wei that a company has raised in stock offerings.
130 @private
131 @constant
132 def _debt() -> wei_value:

```

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```

133     return (self.totalShares - self._stockAvailable()) * self.price
134
135 # Public function to allow external access to _debt
136 @public
137 @constant
138 def debt() -> wei_value:
139     return self._debt()
140
141 # Return the cash holdings minus the debt of the company.
142 # The share debt or liability only is included here,
143 # but of course all other liabilities can be included.
144 @public
145 @constant
146 def worth() -> wei_value:
147     return self.balance - self._debt()

```

**Note:** Throughout this contract, we use a pattern where `@public` functions return data from `@private` functions that have the same name prepended with an underscore. This is because Vyper does not allow calls between public functions within the same contract. The private function handles the logic and allows internal access, while the public function acts as a getter to allow external viewing.

The contract contains a number of methods that modify the contract state as well as a few ‘getter’ methods to read it. We first declare several events that the contract logs. We then declare our global variables, followed by function definitions.

```

# Initiate the variables for the company and it's own shares.
company: public(address)
totalShares: public(uint256(currency_value))
price: public(uint256 (wei / currency_value))

# Store a ledger of stockholder holdings.
holdings: map(address, uint256(currency_value))

```

We initiate the `company` variable to be of type `address` that’s `public`. The `totalShares` variable is of type `currency_value`, which in this case represents the total available shares of the company. The `price` variable represents the wei value of a share and `holdings` is a mapping that maps an address to the number of shares the address owns.

In the constructor, we set up the contract to check for valid inputs during the initialization of the contract via the two `assert` statements. If the inputs are valid, the contract variables are set accordingly and the company’s address is initialized to hold all shares of the company in the `holdings` mapping.

```

# Find out how much stock the company holds
@private
@constant
def _stockAvailable() -> uint256(currency_value):
    return self.holdings[self.company]

# Public function to allow external access to _stockAvailable
@public
@constant
def stockAvailable() -> uint256(currency_value):
    return self._stockAvailable()

```

We will be seeing a few `@constant` decorators in this contract—which is used to decorate methods that simply read the contract state or return a simple calculation on the contract state without modifying it. Remember, reading the blockchain is free, writing on it is not. Since Vyper is a statically typed language, we see an arrow following the definition of the `_stockAvailable()` method, which simply represents the data type which the function is expected to return. In the method, we simply key into `self.holdings` with the company’s address and check it’s holdings. Because `_stockAvailable()` is a private method, we also include the public `stockAvailable()` method to allow external access.

Now, lets take a look at a method that lets a person buy stock from the company’s holding.

The `buyStock()` method is a `@payable` method which takes an amount of ether sent and calculates the `buyOrder` (the stock value equivalence at the time of call). The number of shares is deducted from the company’s holdings and transferred to the sender’s in the `holdings` mapping.

Now that people can buy shares, how do we check someone’s holdings?

```
# Find out how much stock any address (that's owned by someone) has.
@private
@constant
def _getHolding(_stockholder: address) -> uint256(currency_value):
    return self.holdings[_stockholder]

# Public function to allow external access to _getHolding
@public
@constant
def getHolding(_stockholder: address) -> uint256(currency_value):
    return self._getHolding(_stockholder)
```

The `_getHolding()` is another `@constant` method that takes an address and returns its corresponding stock holdings by keying into `self.holdings`. Again, a public function `getHolding()` is included to allow external access.

To check the ether balance of the company, we can simply call the getter method `cash()`.

To sell a stock, we have the `sellStock()` method which takes a number of stocks a person wishes to sell, and sends the equivalent value in ether to the seller’s address. We first `assert` that the number of stocks the person wishes to sell is a value greater than 0. We also `assert` to see that the user can only sell as much as the user owns and that the company has enough ether to complete the sale. If all conditions are met, the holdings are deducted from the seller and given to the company. The ethers are then sent to the seller.

A stockholder can also transfer their stock to another stockholder with the `transferStock()` method. The method takes a receiver address and the number of shares to send. It first `asserts` that the amount being sent is greater than 0 and `asserts` whether the sender has enough stocks to send. If both conditions are satisfied, the transfer is made.

The company is also allowed to pay out an amount in ether to an address by calling the `payBill()` method. This method should only be callable by the company and thus first checks whether the method caller’s address matches that of the company. Another important condition to check is that the company has enough funds to pay the amount. If both conditions satisfy, the contract sends its ether to an address.

```
# Return the amount in wei that a company has raised in stock offerings.
@private
@constant
def _debt() -> wei_value:
    return (self.totalShares - self._stockAvailable()) * self.price

# Public function to allow external access to _debt
@public
@constant
```

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```
def debt () -> wei_value:
    return self._debt ()
```

We can also check how much the company has raised by multiplying the number of shares the company has sold and the price of each share. Internally, we get this value by calling the `_debt ()` method. Externally it is accessed via `debt ()`.

Finally, in this `worth ()` method, we can check the worth of a company by subtracting its debt from its ether balance.

This contract has been the most thorough example so far in terms of its functionality and features. Yet despite the thoroughness of such a contract, the logic remained simple. Hopefully, by now, the Vyper language has convinced you of its capabilities and readability in writing smart contracts.

## 2.7 Event Logging

Like Solidity and other EVM languages, Vyper can log events to be caught and displayed by user interfaces.

### 2.7.1 Example of Logging

This example is taken from the [sample ERC20 contract](#) and shows the basic flow of event logging.

```
# Events of the token.
Transfer: event({_from: indexed(address), _to: indexed(address), _value: uint256})
Approval: event({_owner: indexed(address), _spender: indexed(address), _value:
->uint256})

# Transfer some tokens from message sender to another address
def transfer(_to : address, _value : uint256) -> bool:

    ... Logic here to do the real work ...

    # All done, log the event for listeners
    log.Transfer(msg.sender, _to, _amount)
```

Let's look at what this is doing. First, we declare two event types to log. The two events are similar in that they contain two indexed address fields. Indexed fields do not make up part of the event data itself, but can be searched by clients that want to catch the event. Also, each event contains one single data field, in each case called `_value`. Events can contain several arguments with any names desired.

Next, in the `transfer` function, after we do whatever work is necessary, we log the event. We pass three arguments, corresponding with the three arguments of the `Transfer` event declaration.

Clients listening to the events will declare and handle the events they are interested in using a library such as `web3.js`:

```
var abi = /* abi as generated by the compiler */;
var MyToken = web3.eth.contract(abi);
var myToken = MyToken.at("0x1234...ab67" /* address */);

// watch for changes in the callback
var event = myToken.Transfer(function(error, result) {
    if (!error) {
        var args = result.args;
        console.log('value transferred = ', args._amount);
    }
});
```

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```
    }  
});
```

In this example, the listening client declares the event to listen for. Any time the contract sends this log event, the callback will be invoked.

## 2.7.2 Declaring Events

Let's look at an event declaration in more detail.

```
Transfer: event({_from: indexed(address), _to: indexed(address), _value: uint256})
```

Event declarations look like state variable declarations but use the special keyword `event`. `event` takes its arguments that consists of all the arguments to be passed as part of the event. Typical events will contain two kinds of arguments:

- Indexed arguments, which can be searched for by listeners. Each indexed argument is identified by the *indexed* keyword. Here, each indexed argument is an address. You can have any number of indexed arguments, but indexed arguments are not passed directly to listeners, although some of this information (such as the sender) may be available in the listener's *results* object.
- Value arguments, which are passed through to listeners. You can have any number of value arguments and they can have arbitrary names, but each is limited by the EVM to be no more than 32 bytes.

Note that while the argument definition syntax looks like a Python dictionary, it's actually an order-sensitive definition. (Python dictionaries [maintain order starting with 3.7.](#)) Thus, the first element (`_from`) will be matched up with the first argument passed in the `log.Transfer` call.

## 2.7.3 Logging Events

Once an event is declared, you can log (send) events. You can send events as many times as you want to. Please note that events sent do not take state storage and thus do not cost gas: this makes events a good way to save some information. However, the drawback is that events are not available to contracts, only to clients.

Logging events is done using the magic keyword *log*:

```
log.Transfer(msg.sender, _to, _amount)
```

The order and types of arguments sent needs to match up with the order of declarations in the dictionary.

## 2.7.4 Listening for Events

In the example listener above, the *result* arg actually passes a [large amount of information](#). Here we're most interested in *result.args*. This is an object with properties that match the properties declared in the event. Note that this object does not contain the indexed properties, which can only be searched in the original *myToken.Transfer* that created the callback.

## 2.8 Contributing

Help is always appreciated!

To get started, you can try [installing Vyper](#) in order to familiarize yourself with the components of Vyper and the build process. Also, it may be useful to become well-versed at writing smart-contracts in Vyper.

### 2.8.1 Types of Contributions

In particular, we need help in the following areas:

- Improving the documentation
- Responding to questions from other users on [StackExchange](#) and the [Vyper Gitter](#)
- Suggesting Improvements
- Fixing and responding to [Vyper's GitHub issues](#)

### 2.8.2 How to Suggest Improvements

To suggest an improvement, please create a Vyper Improvement Proposal (VIP for short) using the [VIP Template](#).

### 2.8.3 How to Report Issues

To report an issue, please use the [GitHub issues tracker](#). When reporting issues, please mention the following details:

- Which version of Vyper you are using
- What was the source code (if applicable)
- Which platform are you running on
- Your operating system name and version
- Detailed steps to reproduce the issue
- What was the result of the issue
- What the expected behaviour is

Reducing the source code that caused the issue to a bare minimum is always very helpful and sometimes even clarifies a misunderstanding.

### 2.8.4 Fix Bugs

Find or report bugs at our [issues page](#). Anything tagged with “bug” is open to whoever wants to implement it.

### 2.8.5 Workflow for Pull Requests

In order to contribute, please fork off of the `master` branch and make your changes there. Your commit messages should detail *why* you made your change in addition to *what* you did (unless it is a tiny change).

If you need to pull in any changes from `master` after making your fork (for example, to resolve potential merge conflicts), please avoid using `git merge` and instead, `git rebase` your branch.

#### Implement Features

If you are writing a new feature, please ensure you write appropriate Boost test cases and place them under `tests/`.

If you are making a larger change, please consult first with the Gitter channel.

Although we do CI testing, please make sure that the tests pass for supported Python version and ensure that it builds locally before submitting a pull request.

Thank you for your help!

## 2.9 Frequently Asked Questions

### 2.9.1 Basic Questions

#### What is Vyper?

Vyper is a smart contract development language. Vyper aims to be auditable, secure, and human-readable. Being simple to read is more important than being simple to write.

#### Vyper or Solidity?

For the majority of use-cases, this is personal preference. To support the aims of being secure, auditable, and human-readable, a number of programming constructs included in Solidity are not included in Vyper. If your use-case requires these, use Solidity not Vyper.

#### What is not included in Vyper?

The following constructs are not included because their use can lead to misleading or difficult to understand code:

- Modifiers
- Class inheritance
- Inline assembly
- Function overloading
- Operator overloading
- Binary fixed point.

Recursive calling and infinite-length loops are not included because they cannot set an upper bound on gas limits. An upper bound is required to prevent gas limit attacks and ensure the security of smart contracts built in Vyper.

#### How do for loops work?

Like Python for loops but with one significant difference. Vyper does not allow looping over variable lengths. Looping over variables introduces the possibility of infinite-length loops which make gas limit attacks possible.

#### How do structs work?

Structs group variables and are accessed using `struct . argname`. They are similar to Python classes:

```
# define the struct
struct MyStruct:
    arg1: int128
    arg2: decimal
struct: MyStruct

#access arg1 in struct
struct.arg1 = 1
```

## 2.10 Built in Functions

Vyper provides a collection of built in functions available in the global namespace of all contracts.

### 2.10.1 Functions

#### floor

```
def floor(a) -> b:
    """
    :param a: value to round down
    :type a: decimal

    :output b: int128
    """
```

Rounds a decimal down to the nearest integer.

#### ceil

```
def ceil(a) -> b:
    """
    :param a: value to round up
    :type a: decimal

    :output b: int128
    """
```

Rounds a decimal up to the nearest integer.

#### convert

```
def convert(a, b) -> c:
    """
    :param a: value to convert
    :type a: either bool, decimal, int128, uint256 or bytes32
    :param b: the destination type to convert to
    :type b: type of either bool, decimal, int128, uint256 or bytes32

    :output c: either decimal, int128, uint256 or bytes32
    """
```

Converts a variable or literal from one type to another.

For more details on available type conversions, see *Type Conversions*.

#### clear

```
def clear(a):
    """
    :param a: variable to reset to its default value
```

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```
:type a: all types
"""
```

Clears a variable's contents to the default value of its type.

### as\_wei\_value

```
def as_wei_value(a, b) -> c:
    """
    :param a: value for the ether unit
    :type a: uint256 or int128 or decimal
    :param b: ether unit name (e.g. ``"wei"``)
    :type b: str_literal

    :output c: wei_value
    """
```

Takes an amount of ether currency specified by a number and a unit (e.g. "wei", "ether", "gwei", etc.) and returns the integer quantity of wei equivalent to that amount.

### as\_unitless\_number

```
def as_unitless_number(a) -> b:
    """
    :param a: value to remove units from
    :type a: either decimal or int128

    :output b: either decimal or int128
    """
```

Converts a int128, uint256, or decimal value with units into one without units (used for assignment and math).

### slice

```
def slice(a, start=b, len=c) -> d:
    """
    :param a: bytes to be sliced
    :type a: either bytes or bytes32
    :param b: start position of the slice
    :type b: int128
    :param c: length of the slice
    :type c: int128

    :output d: bytes
    """
```

Takes a list of bytes and copies, then returns a specified chunk.

### len

```
def len(a) -> b:
    """
    :param a: value to get the length of
    :type a: bytes

    :output b: int128
    """
```

Returns the length of a given list of bytes.

### concat

```
def concat(a, b, ...) -> c:
    """
    :param a: value to combine
    :type a: bytes, bytes32
    :param b: value to combine
    :type b: bytes, bytes32

    :output c: bytes
    """
```

Takes 2 or more bytes arrays of type bytes32 or bytes and combines them into one.

### keccak256

```
def keccak256(a) -> b:
    """
    :param a: value to hash
    :type a: either str_literal, bytes, bytes32

    :output b: bytes32
    """
```

Returns keccak256 hash of input.

### sha256

```
def sha256(a) -> b:
    """
    :param a: value to hash
    :type a: either str_literal, bytes, bytes32

    :output b: bytes32
    """
```

Returns sha256 (SHA2 256bit output) hash of input.

## sqrt

```
def sqrt(a: decimal) -> decimal:
    """
    :param a:
    :type a: decimal, larger than 0.0

    :output sqrt: decimal
    """
```

Returns the square of the provided decimal number, using the Babylonian square root algorithm.

## method\_id

```
def method_id(a, b) -> c:
    """
    :param a: method declaration
    :type a: str_literal
    :param b: type of output
    :type b: either bytes32 or bytes[4]

    :output c: either bytes32 or bytes[4]
    """
```

Takes a function declaration and returns its `method_id` (used in data field to call it).

## ecrecover

```
def ecrecover(hash, v, r, s) -> b:
    """
    :param hash: a signed hash
    :type hash: bytes32
    :param v:
    :type v: uint256
    :param r: elliptic curve point
    :type r: uint256
    :param s: elliptic curve point
    :type s: uint256

    :output b: address
    """
```

Takes a signed hash and vrs and returns the public key of the signer.

## ecadd

```
def ecadd(a, b) -> sum:
    """
    :param a: pair to be added
    :type a: uint256[2]
    :param b: pair to be added
    :type b: uint256[2]
```

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```
:output sum: uint256[2]
"""
```

Takes two elliptic curves and adds them together.

### **ecmul**

```
def ecmul(a, b) -> product:
    """
    :param a: pair to be multiplied
    :type a: uint256[2]
    :param b: number to be multiplied
    :type b: uint256

    :output product: uint256[2]
    """
```

Takes two elliptic curves and multiplies them together.

### **extract32**

```
def extract32(a, b, type=c) -> d:
    """
    :param a: where 32 bytes are extracted from
    :type a: bytes
    :param b: start point of bytes to be extracted
    :type b: int128
    :param c: type of output (Optional, default: bytes32)
    :type c: either bytes32, int128, or address

    :output d: either bytes32, int128, or address
    """
```

### **RLPList**

```
def _RLPList(a, b) -> c:
    """
    :param a: encoded data
    :type a: bytes
    :param b: RLP list
    :type b: list

    :output c: LLLnode
    """
```

Takes encoded RLP data and an unencoded list of types. Usage:

```
vote_msg: bytes <= 1024 = ...

values = RLPList(vote_msg, [int128, int128, bytes32, bytes, bytes])

var1: int128 = values[0]
```

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```
:output g: bytes[outsized]
"""
```

Calls to the specified Ethereum address. The call should pass data and may optionally send eth value (specified in wei) as well. The call must specify a gas amount to attach the call and the outsized. Returns the data returned by the call as a bytes array with the outsized as the max length.

### selfdestruct

```
def selfdestruct(a):
    """
    :param a: the address to send the contracts left ether to
    :type a: address
    """
```

Causes a self destruction of the contract, triggers the SELFDESTRUCT opcode (0xff). CAUTION! This method will delete the contract from the Ethereum blockchain. All none ether assets associated with this contract will be “burned” and the contract will be inaccessible.

### raise

```
def raise(a):
    """
    :param a: the exception reason (must be <= 32 bytes)
    :type a: str
    """
```

Raises an exception by triggering the OPCODE REVERT (0xfd) with the provided reason given as the error message. The code will stop operation, the contract’s state will be reverted to the state before the transaction took place and the remaining gas will be returned to the transaction’s sender.

Note: To give it a more Python-like syntax, the raise function can be called without parenthesis, the syntax would be `raise "An exception"`. Even though both options will compile, it’s recommended to use the Pythonic version without parentheses.

### assert

```
def assert(a, reason=None):
    """
    :param a: the boolean condition to assert
    :type a: bool
    :param reason: the reason provided to REVERT
    :param reason=UNREACHABLE: generate an INVALID opcode
    :type b: str
    """
```

Asserts the specified condition. The behavior is equivalent to:

```
if not a:
    raise reason
```

(the only difference in behavior is that `assert` can be called without a reason string, while `raise` requires a reason string).

If `assert` is passed to an `assert` statement, an `INVALID (0xFE)` opcode will be used instead of an `REVERT` opcode.

Note: To give it a more Python-like syntax, the `assert` function can be called without parenthesis, the syntax would be `assert your_bool_condition`. Even though both options will compile, it's recommended to use the Pythonic version without parenthesis.

## raw\_log

```
def raw_log(a, b):
    """
    :param a: 0-4 topics.
    :type a: list of bytes32 of length 0-4
    :param b: the name of the logged event
    :type b: bytes
    """
```

Emits a log without specifying the abi type, with the arguments entered as the first input.

## create\_forwarder\_to

```
def create_forwarder_to(a, value=b):
    """
    :param a: the address of the contract to duplicate.
    :type a: address
    :param b: the wei value to send to the new contract instance (Optional, default: 0)
    :type b: uint256(wei)
    """
```

Duplicates a contract's code and deploys it as a new instance, by means of a `DELEGATECALL`. You can also specify wei value to send to the new contract as `value=the_value`.

## blockhash

```
def blockhash(a) -> hash:
    """
    :param a: the number of the block to get
    :type a: uint256

    :output hash: bytes32
    """
```

Returns the hash of the block at the specified height.

**Note:** The EVM only provides access to the most 256 blocks. This function will return 0 if the block number is greater than or equal to the current block number or more than 256 blocks behind the current block.

## 2.12 Types

Vyper is a statically typed language, which means that the type of each variable (state and local) needs to be specified or at least known at compile-time. Vyper provides several elementary types which can be combined to form complex

types.

In addition, types can interact with each other in expressions containing operators.

### 2.12.1 Value Types

The following types are also called value types because variables of these types will always be passed by value, i.e. they are always copied when they are used as function arguments or in assignments.

#### Boolean

**Keyword:** `bool`

A boolean is a type to store a logical/truth value.

#### Values

The only possible values are the constants `True` and `False`.

#### Operators

Operator	Description
<code>x not y</code>	Logical negation
<code>x and y</code>	Logical conjunction
<code>x or y</code>	Logical disjunction
<code>x == y</code>	Equality
<code>x != y</code>	Inequality

The operators `or` and `and` do not apply short-circuiting rules, i.e. both `x` and `y` will always be evaluated.

#### Signed Integer (128 bit)

**Keyword:** `int128`

A signed integer (128 bit) is a type to store positive and negative integers.

#### Values

Signed integer values between  $-2^{127}$  and  $(2^{127} - 1)$ , inclusive.

#### Operators

#### Comparisons

Comparisons return a boolean value.

Operator	Description
<code>x &lt; y</code>	Less than
<code>x &lt;= y</code>	Less than or equal to
<code>x == y</code>	Equals
<code>x != y</code>	Does not equal
<code>x &gt;= y</code>	Greater than or equal to
<code>x &gt; y</code>	Greater than

`x` and `y` must be of the type `int128`.

## Arithmetic Operators

Operator	Description
<code>x + y</code>	Addition
<code>x - y</code>	Subtraction
<code>-x</code>	Unary minus/Negation
<code>x * y</code>	Multiplication
<code>x / y</code>	Division
<code>x**y</code>	Exponentiation
<code>x % y</code>	Modulo
<code>min(x, y)</code>	Minimum
<code>max(x, y)</code>	Maximum

`x` and `y` must be of the type `int128`.

## Unsigned Integer (256 bit)

**Keyword:** `uint256`

An unsigned integer (256 bit) is a type to store non-negative integers.

### Values

Integer values between 0 and  $(2^{256}-1)$ .

---

**Note:** Integer literals are interpreted as `int128` by default. In cases where `uint256` is more appropriate, such as assignment, the literal might be interpreted as `uint256`. Example: `_variable: uint256 = _literal`. In order to explicitly cast a literal to a `uint256` use `convert(_literal, uint256)`.

---

## Operators

### Comparisons

Comparisons return a boolean value.

Operator	Description
$x < y$	Less than
$x \leq y$	Less than or equal to
$x == y$	Equals
$x \neq y$	Does not equal
$x \geq y$	Greater than or equal to
$x > y$	Greater than

$x$  and  $y$  must be of the type `uint256`.

## Arithmetic Operators

Operator	Description
$x + y$	Addition
$x - y$	Subtraction
<code>uint256_addmod(x, y, z)</code>	Addition modulo $z$
$x * y$	Multiplication
<code>uint256_mulmod(x, y, z)</code>	Multiplication modulo $z$
$x / y$	Division
$x ** y$	Exponentiation
$x \% y$	Modulo
<code>min(x, y)</code>	Minimum
<code>max(x, y)</code>	Maximum

$x$ ,  $y$  and  $z$  must be of the type `uint256`.

## Bitwise Operators

Operator	Description
<code>bitwise_and(x, y)</code>	AND
<code>bitwise_not(x, y)</code>	NOT
<code>bitwise_or(x, y)</code>	OR
<code>bitwise_xor(x, y)</code>	XOR
<code>shift(x, _shift)</code>	Bitwise Shift

$x$  and  $y$  must be of the type `uint256`. `_shift` must be of the type `int128`.

---

**Note:** Positive `_shift` equals a left shift; negative `_shift` equals a right shift. Values shifted above/below the most/least significant bit get discarded.

---

## Decimals

**Keyword:** `decimal`

A decimal is a type to store a decimal fixed point value.

## Values

A value with a precision of 10 decimal places between  $-2^{127}$  and  $(2^{127} - 1)$ .

## Operators

### Comparisons

Comparisons return a boolean value.

Operator	Description
$x < y$	Less than
$x \leq y$	Less or equal
$x == y$	Equals
$x != y$	Does not equal
$x \geq y$	Greater or equal
$x > y$	Greater than

$x$  and  $y$  must be of the type `decimal`.

### Arithmetic Operators

Operator	Description
$x + y$	Addition
$x - y$	Subtraction
$-x$	Unary minus/Negation
$x * y$	Multiplication
$x / y$	Division
$x \% y$	Modulo
$\min(x, y)$	Minimum
$\max(x, y)$	Maximum
$\text{floor}(x)$	Largest integer $\leq x$ . Returns <code>int128</code> .
$\text{ceil}(x)$	Smallest integer $\geq x$ . Returns <code>int128</code> .

$x$  and  $y$  must be of the type `decimal`.

## Address

**Keyword:** `address`

The address type holds an Ethereum address.

## Values

An address type can hold an Ethereum address which equates to 20 bytes or 160 bits. It returns in hexadecimal notation with a leading `0x`.

### Members

Member	Description
balance	Query the balance of an address. Returns <code>wei_value</code> .
codesize	Query the code size of an address. Returns <code>int128</code> .
is_contract	Query whether it is a contract address. Returns <code>bool</code> .

Syntax as follows: `_address.<member>`, where `_address` is of the type `address` and `<member>` is one of the above keywords.

### Unit Types

Vyper allows the definition of types with discrete units e.g. meters, seconds, wei, ... . These types may only be based on either `uint256`, `int128` or `decimal`. Vyper has 3 unit types built in, which are the following:

#### Time

Keyword	Unit	Base type	Description
<code>timestamp</code>	1 sec	<code>uint256</code>	This represents a point in time.
<code>timedelta</code>	1 sec	<code>uint256</code>	This is a number of seconds.

---

**Note:** Two `timedelta` can be added together, as can a `timedelta` and a `timestamp`, but not two `timestamps`.

---

#### Wei

Keyword	Unit	Base type	Description
<code>wei_value</code>	1 wei	<code>uint256</code>	This is an amount of <a href="#">Ether</a> in wei.

### Custom Unit Types

Vyper allows you to add additional not-provided unit label to either `uint256`, `int128` or `decimal`.

#### Custom units example:

```
# specify units used in the contract.
units: {
    cm: "centimeter",
    km: "kilometer"
}
```

Having defined the units they can be defined on variables as follows.

#### Custom units usage:

```
a: int128(cm)
b: uint256(km)
```

### 32-bit-wide Byte Array

**Keyword:** `bytes32` This is a 32-bit-wide byte array that is otherwise similar to byte arrays.

**Example:**

```
# Declaration
hash: bytes32
# Assignment
self.hash = _hash
```

### Operators

Keyword	Description
<code>keccak256(x)</code>	Return the keccak256 hash as bytes32.
<code>concat(x, ...)</code>	Concatenate multiple inputs.
<code>slice(x, start=_start, len=_len)</code>	Return a slice of <code>_len</code> starting at <code>_start</code> .

Where `x` is a byte array and `_start` as well as `_len` are integer values.

### Fixed-size Byte Arrays

**Keyword:** `bytes`

A byte array with a fixed size. The syntax being `bytes[maxLen]`, where `maxLen` is an integer which denotes the maximum number of bytes. On the ABI level the Fixed-size bytes array is annotated as `bytes`.

**Example:**

```
example_bytes: bytes[100] = b"\x01\x02\x03"
```

### Fixed-size Strings

**Keyword:** `string` Fixed-size strings can hold strings with equal or fewer characters than the maximum length of the string. On the ABI level the Fixed-size bytes array is annotated as `string`.

**Example:**

```
example_str: string[100] = "Test String"
```

### Operators

Keyword	Description
<code>len(x)</code>	Return the length as an integer.
<code>keccak256(x)</code>	Return the keccak256 hash as bytes32.
<code>concat(x, ...)</code>	Concatenate multiple inputs.
<code>slice(x, start=_start, len=_len)</code>	Return a slice of <code>_len</code> starting at <code>_start</code> .

Where `x` is a byte array or string while `_start` and `_len` are integers. The `len`, `keccak256`, `concat`, `slice` operators can be used with `string` and `bytes` types.

### 2.12.2 Reference Types

Reference types do not fit into 32 bytes. Because of this, copying their value is not as feasible as with value types. Therefore only the location, i.e. the reference, of the data is passed.

#### Fixed-size Lists

Fixed-size lists hold a finite number of elements which belong to a specified type.

#### Syntax

Lists can be declared with `_name: _ValueType[_Integer]`. Multidimensional lists are also possible.

#### Example:

```
#Defining a list
exampleList: int128[3]
#Setting values
exampleList = [10, 11, 12]
exampleList[2] = 42
#Returning a value
return exampleList[0]
```

#### Structs

Structs are custom defined types that can group several variables.

#### Syntax

Structs can be accessed via `struct.argname`. **Example:**

```
#Defining a struct
struct MyStruct:
    value1: int128
    value2: decimal
exampleStruct: MyStruct
#Constructing a struct
exampleStruct = MyStruct({value1: 1, value2: 2})
#Accessing a value
exampleStruct.value1 = 1
```

#### Mappings

Mappings in Vyper can be seen as [hash tables](#) which are virtually initialized such that every possible key exists and is mapped to a value whose byte-representation is all zeros: a type's default value. The similarity ends here, though: The key data is not actually stored in a mapping, only its `keccak256` hash used to look up the value. Because of this, mappings do not have a length or a concept of a key or value being "set".

It is possible to mark mappings `public` and have Vyper create a getter. The `_KeyType` will become a required parameter for the getter and it will return `_ValueType`.

**Note:** Mappings are only allowed as state variables.

### Syntax

Mapping types are declared as `map(_KeyType, _ValueType)`. Here `_KeyType` can be any base or bytes type. Mappings, contract or structs are not support as key types. `_ValueType` can actually be any type, including mappings.

**Example:**

```
#Defining a mapping
exampleMapping: map(int128, decimal)
#Accessing a value
exampleMapping[0] = 10.1
```

**Note:** Mappings can only be accessed, not iterated over.

### 2.12.3 Built In Constants

Vyper has a few convenience constants builtin.

Type	Name	Value
address	ZERO_ADDRESS	0x00000000000000000000000000000000
bytes32	EMPTY_BYTES32	0x00
int128	MAX_INT128	2**127 - 1
int128	MIN_INT128	-2**127
decimal	MAX_DECIMAL	(2**127 - 1)
decimal	MIN_DECIMAL	(-2**127)
uint256	MAX_UINT256	2**256 - 1

### 2.12.4 Custom Constants

Custom constants can be defined at a global level in Vyper. To define a constant make use of the `constant` keyword.

**Example:**

```
TOTAL_SUPPLY: constant(uint256) = 10000000
total_supply: public(uint256)

@public
def __init__():
    self.total_supply = TOTAL_SUPPLY
```

**Advanced Example:**

```

units: {
    share: "Share unit"
}

MAX_SHARES: constant(uint256(share)) = 1000
SHARE_PRICE: constant(uint256(wei/share)) = 5

@public
def market_cap() -> uint256(wei):
    return MAX_SHARES * SHARE_PRICE
    
```

### 2.12.5 Initial Values

In Vyper, there is no `null` option like most programming languages have. Thus, every variable type has a default value. In order to check if a variable is empty, you will need to compare it to its type's default value. If you would like to reset a variable to its type's default value, use the built-in `clear()` function.

Here you can find a list of all types and default values:

Table 1: Default Variable Values

Type	Default Value
bool	False
int128	0
uint256	0
decimal	0.0
address	0x00
bytes32	\x00

**Note:** In `bytes` the array starts with the bytes all set to '`\x00`'

**Note:** In reference types all the type's members are set to their initial values.

### 2.12.6 Type Conversions

All type conversions in Vyper must be made explicitly using the built-in `convert(a, b)` function. Currently, the following type conversions are supported:

Table 2: Basic Type Conversions

Destination Type (b)	Input Type (a.type)	Allowed Inputs Values (a)	Additional Notes
bool	bool	—	Do not allow converting to/from the same type
bool	decimal	MINNUM...MAXNUM	Has the effective conversion logic of: <code>return bool(a)</code>
bool	int128	MINNUM...MAXNUM	Has the effective conversion logic of: <code>return bool(a)</code>
bool	uint256	0...MAX_UINT256	Has the effective conversion logic of: <code>return bool(a)</code>
bool	bytes32	(0x00 * 32)...(0xFF * 32)	Has the effective conversion logic of: <code>return bool(a)</code>
bool	bytes	(0x00 * 1)...(0xFF * 32)	Has the effective conversion logic of: <code>return bool(a)</code>

Table 2 – continued from

Destination Type (b)	Input Type (a.type)	Allowed Inputs Values (a)	Additional Notes
decimal	bool	True / False	Result will be 0.0 or 1.0
decimal	decimal	—	Do not allow converting to/from the same type
decimal	int128	MINNUM...MAXNUM	
decimal	uint256	0...MAXDECIMAL	
decimal	bytes32	(0x00 * 32) ... (0xFF * 32)	
decimal	bytes	(0x00 * 1) ... (0xFF * 32)	
int128	bool	True / False	Result will be 0 or 1
int128	decimal	MINNUM...MAXNUM	Only allow input within int128 supported range
int128	int128	—	Do not allow converting to/from the same type
int128	uint256	0...MAXNUM	
int128	bytes32	(0x00 * 32) ... (0xFF * 32)	
int128	bytes	(0x00 * 1) ... (0xFF * 32)	
uint256	bool	True / False	Result will be 0 or 1
uint256	decimal	0...MAXDECIMAL	Truncates the decimal value
uint256	int128	0...MAXNUM	
uint256	uint256	—	Do not allow converting to/from the same type
uint256	bytes32	(0x00 * 32) ... (0xFF * 32)	
uint256	bytes	(0x00 * 1) ... (0xFF * 32)	
bytes32	bool	True / False	Result will be either (0x00 * 32) or (0xFF * 32)
bytes32	decimal	MINDECIMAL...MAXDECIMAL	Has the effective behavior of multiplying the decimal value by 2 <sup>32</sup>
bytes32	int128	MINNUM...MAXNUM	
bytes32	uint256	0...MAX_UINT256	
bytes32	bytes32	—	Do not allow converting to/from the same type
bytes32	bytes	(0x00 * 1) ... (0xFF * 32)	Left-pad input bytes to size of 32

## 2.13 Release Notes

### 2.13.1 v0.1.0-beta.12

Date released: 27-08-2019

The following VIPs were implemented for Beta 12:

- Support for relative imports (VIP #1367)
- Restricted use of environment variables in private functions (VIP #1199)

Some of the bug and stability fixes:

- @nonreentrant/@constant logical inconsistency (#1544)
- Struct passthrough issue (#1551)
- Private underflow issue (#1470)
- Constancy check issue (#1480)
- Prevent use of conflicting method IDs (#1530)
- Missing arg check for private functions (#1579)

- Zero padding issue (#1563)
- `vyper.cli` rearchitecture of scripts (#1574)
- AST end offsets and Solidity-compatible compressed sourcemap (#1580)

Special thanks to (@iamdefinitelyahuman) for lots of updates this release!

### 2.13.2 v0.1.0-beta.11

Date released: 23-07-2019

Beta 11 brings some performance and stability fixes.

- Using `calldata` instead of memory parameters. (#1499)
- Reducing of contract size, for large parameter functions. (#1486)
- Improvements for Windows users (#1486) (#1488)
- Array copy optimisation (#1487)
- Fixing `@nonreentrant` decorator for return statements (#1532)
- `sha3` builtin function removed (#1328)
- Disallow conflicting method IDs (#1530)
- Additional `convert()` supported types (#1524) (#1500)
- Equality operator for strings and bytes (#1507)
- Change in `compile_codes` interface function (#1504)

Thanks to all the contributors!

### 2.13.3 v0.1.0-beta.10

Date released: 24-05-2019

- Lots of linting and refactoring!
- Bugfix with regards to using arrays as parameters to private functions (#1418). Please check your contracts, and upgrade to latest version, if you do use this.
- Slight shrinking in init produced bytecode. (#1399)
- Additional constancy protection in the `for .. range` expression. (#1397)
- Improved bug report (#1394)
- Fix returning of External Contract from functions (#1376)
- Interface unit fix (#1303)
- Not Equal (!=) optimisation (#1303) 1386
- New `assert <condition>`, `UNREACHABLE` statement. (#711)

Special thanks to (Charles Cooper), for some excellent contributions this release.

## 2.13.4 v0.1.0-beta.9

Date released: 12-03-2019

- Add support for list constants (#1211)
- Add sha256 function (#1327)
- Renamed `create_with_code_of` to `create_forwarder_to` (#1177)
- `@nonreentrant` Decorator (#1204)
- Add opcodes and `opcodes_runtime` flags to compiler (#1255)
- Improved External contract call interfaces (#885)

## 2.13.5 Prior to v0.1.0-beta.9

Prior to this release, we managed our change log in a different fashion. Here is the old changelog:

- **2019.04.05:** Add stricter checking of unbalanced return statements. (#590)
- **2019.03.04:** `create_with_code_of` has been renamed to `create_forwarder_to`. (#1177)
- **2019.02.14:** Assigning a persistent contract address can only be done using the `bar_contact = ERC20(<address>)` syntax.
- **2019.02.12:** ERC20 interface has to be imported using `from vyper.interfaces import ERC20` to use.
- **2019.01.30:** Byte array literals need to be annotated using `b""`, strings are represented as `""`.
- **2018.12.12:** Disallow use of `None`, disallow use of `del`, implemented `clear()` built-in function.
- **2018.11.19:** Change mapping syntax to use `map()`. (VIP564)
- **2018.10.02:** Change the convert style to use types instead of string. (VIP1026)
- **2018.09.24:** Add support for custom constants.
- **2018.08.09:** Add support for default parameters.
- **2018.06.08:** Tagged first beta.
- **2018.05.23:** Changed `wei_value` to be `uint256`.
- **2018.04.03:** Changed bytes declaration from `'bytes <= n'` to `'bytes[n]'`.
- **2018.03.27:** Renaming `signed256` to `int256`.
- **2018.03.22:** Add modifiable and static keywords for external contract calls.
- **2018.03.20:** Renaming `__log__` to `event`.
- **2018.02.22:** Renaming `num` to `int128`, and `num256` to `uint256`.
- **2018.02.13:** Ban functions with payable and constant decorators.
- **2018.02.12:** Division by `num` returns decimal type.
- **2018.02.09:** Standardize type conversions.
- **2018.02.01:** Functions cannot have the same name as globals.
- **2018.01.27:** Change getter from `get_var` to `var`.
- **2018.01.11:** Change version from 0.0.2 to 0.0.3
- **2018.01.04:** Types need to be specified on assignment (VIP545).

- **2017.01.02** Change `as_wei_value` to use quotes for units.
- **2017.12.25**: Change name from Viper to Vyper.
- **2017.12.22**: Add `continue` for loops
- **2017.11.29**: `@internal` renamed to `@private`.
- **2017.11.15**: Functions require either `@internal` or `@public` decorators.
- **2017.07.25**: The `def foo() -> num(const): ...` syntax no longer works; you now need to do `def foo() -> num: ...` with a `@constant` decorator on the previous line.
- **2017.07.25**: Functions without a `@payable` decorator now fail when called with nonzero wei.
- **2017.07.25**: A function can only call functions that are declared above it (that is, A can call B only if B appears earlier in the code than A does). This was introduced

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