PyTeal

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PyTeal is a Python language binding for Algorand Smart Contracts (ASC1s).

Algorand Smart Contracts are implemented using a new language that is stack-based, called Transaction Execution Approval Language (TEAL). This a non-Turing complete language that allows branch forwards but prevents recursive logic to maximize safety and performance.

However, TEAL is essentially an assembly language. With PyTeal, developers can express smart contract logic purely using Python. PyTeal provides high level, functional programming style abstactions over TEAL and does type checking at construction time.

The *User Guide* describes many useful features in PyTeal, and the complete documentation for every expression and operation can be found in the *PyTeal Package API documentation*.

PyTeal **hasn't been security audited**. Use it at your own risk.

CHAPTER 1

Overview

With PyTeal, developers can easily write Algorand Smart Contracts (ASC1s) in Python. PyTeal supports both stateless and statefull smart contracts.

Below is an example of writing a basic stateless smart contract that allows a specific receiver to withdraw funds from an account.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.

from pyteal import *

"""Basic Bank"""

def bank_for_account(receiver):
    """Only allow receiver to withdraw funds from this contract account.

    Args:
        receiver (str): Base 32 Algorand address of the receiver.
    """

    is_payment = Txn.type_enum() == TxnType.Payment
    is_single_tx = Global.group_size() == Int(1)
    is_correct_receiver = Txn.receiver() == Addr(receiver)
    no_close_out_addr = Txn.close_remainder_to() == Global.zero_address()
    no_rekey_addr = Txn.rekey_to() == Global.zero_address()
    acceptable_fee = Txn.fee() <= Int(1000)

    return And(
        is_payment,
        is_single_tx,
        is_correct_receiver,
        no_close_out_addr,
        no_rekey_addr,
        acceptable_fee
```

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```
    )

if __name__ == "__main__":
    program = bank_for_account(
↪"ZZAF5ARA4MEC5PVDOP64JM5O5MQST63Q2KOY2FLYFLXXD3PFSNJJBYAFZM")
    print(compileTeal(program, Mode.Signature))
```

As shown in this exmaple, the logic of smart contract is expressed using PyTeal expressions constructed in Python. PyTeal overloads Python's arithmetic operators such as < and == (more overloaded operators can be found in *Arithmetic Operators*), allowing Python developers express smart contract logic more naturally.

Lastly, *compileTeal* is called to convert an PyTeal expression to a TEAL program, consisting of a sequence of TEAL opcodes. The output of the above example is:

```
#pragma version 2
txn TypeEnum
int pay
==
global GroupSize
int 1
==
&&
txn Receiver
addr ZZAF5ARA4MEC5PVDOP64JM5O5MQST63Q2KOY2FLYFLXXD3PFSNJJBYAFZM
==
&&
txn CloseRemainderTo
global ZeroAddress
==
&&
txn RekeyTo
global ZeroAddress
==
&&
txn Fee
int 1000
<=
&&
```

CHAPTER 2

Install PyTeal

The easiest way of installing PyTeal is using `pip` :

```
$ pip3 install pyteal
```

Alternatively, choose a distribution file, and run

```
$ pip3 install [file name]
```

CHAPTER 3

PyTeal Examples

Here are some additional PyTeal example programs:

3.1 Signature Mode

3.1.1 Atomic Swap

Atomic Swap allows the transfer of Algos from a buyer to a seller in exchange for a good or service. This is done using a *Hashed Time Locked Contract*. In this scheme, the buyer and funds a TEAL account with the sale price. The buyer also picks a secret value and encodes a secure hash of this value in the TEAL program. The TEAL program will transfer its balance to the seller if the seller is able to provide the secret value that corresponds to the hash in the program. When the seller renders the good or service to the buyer, the buyer discloses the secret from the program. The seller can immediately verify the secret and withdraw the payment.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.

from pyteal import *

"""Atomic Swap"""

alice = Addr("6ZHGHH5Z5CTPCF5WCESXMGRSVK7QJETR63M3NY5FJCUYDHO57VTCMJOBGY")
bob = Addr("7Z5PWO2C6LFNQFGHWKSK5H47IQP5OJW2M3HA2QPXTY3WTNP5NU2MHBW27M")
secret = Bytes("base32", "23232323232323")
timeout = 3000

def htlc(tmpl_seller=alice,
         tmpl_buyer=bob,
         tmpl_fee=1000,
         tmpl_secret=secret,
         tmpl_hash_fn=Sha256,
         tmpl_timeout=timeout):
```

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```
    fee_cond = Txn.fee() < Int(tmpl_fee)
    type_cond = Txn.type_enum() == TxnType.Payment

    recv_cond = And(
        Txn.close_remainder_to() == Global.zero_address(),
        Txn.receiver() == tmpl_seller,
        tmpl_hash_fn(Arg(0)) == tmpl_secret
    )

    esc_cond = And(
        Txn.close_remainder_to() == Global.zero_address(),
        Txn.receiver() == tmpl_buyer,
        Txn.first_valid() > Int(tmpl_timeout)
    )

    return And(
        fee_cond,
        type_cond,
        Or(recv_cond, esc_cond)
    )

if __name__ == "__main__":
    print(compileTeal(htlc(), Mode.Signature))
```

3.1.2 Split Payment

Split Payment splits payment between `tmpl_rcv1` and `tmpl_rcv2` on the ratio of `tmpl_ratn / tmpl_ratd`.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.

from pyteal import *

"""Split Payment"""

tmpl_fee = Int(1000)
tmpl_rcv1 = Addr("6ZHGHH5Z5CTPCF5WCESXMGRSVK7QJETR63M3NY5FJCUYDHO57VTCMJOBGY")
tmpl_rcv2 = Addr("7Z5PWO2C6LFNQFGHWKSK5H47IQP5OJW2M3HA2QPXTY3WTNP5NU2MHBW27M")
tmpl_own = Addr("5MK5NGBRT5RL6IGUSYDIX5P7TNNZKRVXKT6FGVI6UVK6IZAWTYQGE4RZIQ")
tmpl_ratn  = Int(1)
tmpl_ratd = Int(3)
tmpl_min_pay = Int(1000)
tmpl_timeout = Int(3000)

def split(tmpl_fee=tmpl_fee,
              tmpl_rcv1=tmpl_rcv1,
              tmpl_rcv2=tmpl_rcv2,
              tmpl_own=tmpl_own,
              tmpl_ratn=tmpl_ratn,
              tmpl_ratd=tmpl_ratd,
              tmpl_min_pay=tmpl_min_pay,
              tmpl_timeout=tmpl_timeout):

    split_core = (Txn.type_enum() == TxnType.Payment).And(Txn.fee() < tmpl_fee)
```

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```
    split_transfer = And(
        Gtxn[0].sender() == Gtxn[1].sender(),
        Txn.close_remainder_to() == Global.zero_address(),
        Gtxn[0].receiver() == tmpl_rcv1,
        Gtxn[1].receiver() == tmpl_rcv2,
        Gtxn[0].amount() == ((Gtxn[0].amount() + Gtxn[1].amount()) * tmpl_ratn) /␣
↪tmpl_ratd,
        Gtxn[0].amount() == tmpl_min_pay
    )

    split_close = And(
        Txn.close_remainder_to() == tmpl_own,
        Txn.receiver() == Global.zero_address(),
        Txn.amount() == Int(0),
        Txn.first_valid() > tmpl_timeout
    )

    split = And(
        split_core,
        If(Global.group_size() == Int(2),
            split_transfer,
            split_close
        )
    )

    return split

if __name__ == "__main__":
    print(compileTeal(split, Mode.Signature))
```

3.1.3 Periodic Payment

Periodic Payment allows some account to execute periodic withdrawal of funds. This PyTeal program creates an contract account that allows `tmpl_rcv` to withdraw `tmpl_amt` every `tmpl_period` rounds for `tmpl_dur` after every multiple of `tmpl_period`.

After `tmpl_timeout`, all remaining funds in the escrow are available to `tmpl_rcv`.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.

from pyteal import *

"""Periodic Payment"""

tmpl_fee = Int(1000)
tmpl_period = Int(50)
tmpl_dur = Int(5000)
tmpl_lease = Bytes("base64", "023sdDE2")
tmpl_amt = Int(2000)
tmpl_rcv = Addr("6ZHGHH5Z5CTPCF5WCESXMGRSVK7QJETR63M3NY5FJCUYDHO57VTCMJOBGY")
tmpl_timeout = Int(30000)

def periodic_payment(tmpl_fee=tmpl_fee,
```

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```
                    tmpl_period=tmpl_period,
                    tmpl_dur=tmpl_dur,
                    tmpl_lease=tmpl_lease,
                    tmpl_amt=tmpl_amt,
                    tmpl_rcv=tmpl_rcv,
                    tmpl_timeout=tmpl_timeout):

    periodic_pay_core = And(
        Txn.type_enum() == TxnType.Payment,
        Txn.fee() < tmpl_fee,
        Txn.first_valid() % tmpl_period == Int(0),
        Txn.last_valid() == tmpl_dur + Txn.first_valid(),
        Txn.lease() == tmpl_lease
    )

    periodic_pay_transfer = And(
        Txn.close_remainder_to() == Global.zero_address(),
        Txn.receiver() == tmpl_rcv,
        Txn.amount() == tmpl_amt
    )

    periodic_pay_close = And(
        Txn.close_remainder_to() == tmpl_rcv,
        Txn.receiver() == Global.zero_address(),
        Txn.first_valid() == tmpl_timeout,
        Txn.amount() == Int(0)
    )

    periodic_pay_escrow = periodic_pay_core.And(periodic_pay_transfer.Or(periodic_pay_
↪close))

    return periodic_pay_escrow

if __name__ == "__main__":
    print(compileTeal(periodic_payment(), Mode.Signature))
```

3.2 Application Mode

3.2.1 Voting

Voting allows accounts to register and vote for arbitrary candiates. Here a *candiate* is any byte slice and anyone is allowed to register to vote.

This example has a configurable *registration period* defined by the global state `RegBegin` and `RegEnd` which restrict when accounts can register to vote. There is also a separate configurable *voting period* defined by the global state `VotingBegin` and `VotingEnd` which restrict when voting can take place.

An account must register in order to vote. Accounts cannot vote more than once, and if an account opts out of the application before the voting period has concluded, their vote is discarded. The results are visible in the global state of the application, and the winner is the candidate with the highest number of votes.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.
```

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```
from pyteal import *

def approval_program():
    on_creation = Seq([
        App.globalPut(Bytes("Creator"), Txn.sender()),
        Assert(Txn.application_args.length() == Int(4)),
        App.globalPut(Bytes("RegBegin"), Btoi(Txn.application_args[0])),
        App.globalPut(Bytes("RegEnd"), Btoi(Txn.application_args[1])),
        App.globalPut(Bytes("VoteBegin"), Btoi(Txn.application_args[2])),
        App.globalPut(Bytes("VoteEnd"), Btoi(Txn.application_args[3])),
        Return(Int(1))
    ])

    is_creator = Txn.sender() == App.globalGet(Bytes("Creator"))

    get_vote = App.localGetEx(Int(0), Txn.application_id(), Bytes("voted"))
    get_count = App.globalGetEx(Int(0), get_vote.value())

    decrement_existing = Seq([
        App.globalPut(get_vote.value(), get_count.value() - Int(1)),
        Return(Int(1))
    ])

    if_voted = Seq([
        get_count,
        If(get_count.hasValue(), decrement_existing, Return(Int(1)))
    ])

    on_closeout = If(
        Global.round() > App.globalGet(Bytes("VoteEnd")),
        Return(Int(1)),
        Seq([
            get_vote,
            If(get_vote.hasValue(), if_voted, Return(Int(1)))
        ])
    )

    on_register = Return(And(
        Global.round() >= App.globalGet(Bytes("RegBegin")),
        Global.round() <= App.globalGet(Bytes("RegEnd"))
    ))

    get_candidate = App.globalGetEx(Int(0), Txn.application_args[1])

    not_voted = Seq([
        get_candidate,
        App.globalPut(Txn.application_args[1], If(get_candidate.hasValue(), get_
↪candidate.value() + Int(1), Int(1))),
        App.localPut(Int(0), Bytes("voted"), Txn.application_args[1]),
        Return(Int(1))
    ])

    on_vote = Seq([
        Assert(And(Global.round() >= App.globalGet(Bytes("VoteBegin")), Global.
↪round() <= App.globalGet(Bytes("VoteEnd")))),
        get_vote,
        If(get_vote.hasValue(), Return(Int(1)), not_voted)
```

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```
    ])

    program = Cond(
        [Txn.application_id() == Int(0), on_creation],
        [Txn.on_completion() == OnComplete.DeleteApplication, Return(is_creator)],
        [Txn.on_completion() == OnComplete.UpdateApplication, Return(is_creator)],
        [Txn.on_completion() == OnComplete.CloseOut, on_closeout],
        [Txn.on_completion() == OnComplete.OptIn, on_register],
        [Bytes("vote") == Txn.application_args[0], on_vote]
    )

    return program

def close_out_program():
    get_voted = App.localGetEx(Int(0), Txn.application_id(), Bytes("voted"))
    get_candidate = App.globalGetEx(Int(0), get_voted.value())

    decrement_existing = Seq([
        App.globalPut(get_voted.value(), get_candidate.value() - Int(1)),
        Return(Int(1))
    ])

    voted = Seq([
        get_candidate,
        If(get_candidate.hasValue(), decrement_existing, Return(Int(1)))
    ])

    program = If(
        Global.round() > App.globalGet(Bytes("VoteEnd")),
        Return(Int(1)),
        Seq([
            get_voted,
            If(get_voted.hasValue(), voted, Return(Int(1)))
        ])
    )

    return program

with open('vote_approval.teal', 'w') as f:
    compiled = compileTeal(approval_program(), Mode.Application)
    f.write(compiled)

with open('vote_close_out.teal', 'w') as f:
    compiled = compileTeal(close_out_program(), Mode.Application)
    f.write(compiled)
```

3.2.2 Asset

Asset is an implementation of a custom asset type using smart contracts. While Algorand has ASAs, in some blockchains the only way to create a custom asset is through smart contracts.

At creation, the creator specifies the total supply of the asset. Initially this supply is placed in a reserve and the creator is made an admin. Any admin can move funds from the reserve into the balance of any account that has opted into the application using the *mint* argument. Additionally, any admin can move funds from any account's balance into the reserve using the *burn* argument.

Accounts are free to transfer funds in their balance to any other account that has opted into the application. When an account opts out of the application, their balance is added to the reserve.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.

from pyteal import *

def approval_program():
    on_creation = Seq([
        Assert(Txn.application_args.length() == Int(1)),
        App.globalPut(Bytes("total supply"), Btoi(Txn.application_args[0])),
        App.globalPut(Bytes("reserve"), Btoi(Txn.application_args[0])),
        App.localPut(Int(0), Bytes("admin"), Int(1)),
        App.localPut(Int(0), Bytes("balance"), Int(0)),
        Return(Int(1))
    ])

    is_admin = App.localGet(Int(0), Bytes("admin"))

    on_closeout = Seq([
        App.globalPut(
            Bytes("reserve"),
            App.globalGet(Bytes("reserve")) + App.localGet(Int(0), Bytes("balance"))
        ),
        Return(Int(1))
    ])

    register = Seq([
        App.localPut(Int(0), Bytes("balance"), Int(0)),
        Return(Int(1))
    ])

    # configure the admin status of the account Txn.accounts[0]
    # sender must be admin
    new_admin_status = Btoi(Txn.application_args[1])
    set_admin = Seq([
        Assert(And(is_admin, Txn.application_args.length() == Int(2))),
        App.localPut(Int(1), Bytes("admin"), new_admin_status),
        Return(Int(1))
    ])
    # NOTE: The above set_admin code is carefully constructed. If instead we used the␣
↪following code:
    # Seq([
    #     Assert(Txn.application_args.length() == Int(2)),
    #     App.localPut(Int(1), Bytes("admin"), new_admin_status),
    #     Return(is_admin)
    # ])
    # It would be vulnerable to the following attack: a sender passes in their own␣
↪address as
    # Txn.accounts[0], so then the line App.localPut(Int(1), Bytes("admin"), new_
↪admin_status)
    # changes the sender's admin status, meaning the final Return(is_admin) can␣
↪return anything the
    # sender wants. This allows anyone to become an admin!

    # move assets from the reserve to Txn.accounts[0]
    # sender must be admin
```

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```
    mint_amount = Btoi(Txn.application_args[1])
    mint = Seq([
        Assert(Txn.application_args.length() == Int(2)),
        Assert(mint_amount <= App.globalGet(Bytes("reserve"))),
        App.globalPut(Bytes("reserve"), App.globalGet(Bytes("reserve")) - mint_
↪amount),
        App.localPut(Int(1), Bytes("balance"), App.localGet(Int(1), Bytes("balance"))␣
↪+ mint_amount),
        Return(is_admin)
    ])

    # transfer assets from the sender to Txn.accounts[0]
    transfer_amount = Btoi(Txn.application_args[1])
    transfer = Seq([
        Assert(Txn.application_args.length() == Int(2)),
        Assert(transfer_amount <= App.localGet(Int(0), Bytes("balance"))),
        App.localPut(Int(0), Bytes("balance"), App.localGet(Int(0), Bytes("balance"))␣
↪- transfer_amount),
        App.localPut(Int(1), Bytes("balance"), App.localGet(Int(1), Bytes("balance"))␣
↪+ transfer_amount),
        Return(Int(1))
    ])

    program = Cond(
        [Txn.application_id() == Int(0), on_creation],
        [Txn.on_completion() == OnComplete.DeleteApplication, Return(is_admin)],
        [Txn.on_completion() == OnComplete.UpdateApplication, Return(is_admin)],
        [Txn.on_completion() == OnComplete.CloseOut, on_closeout],
        [Txn.on_completion() == OnComplete.OptIn, register],
        [Txn.application_args[0] == Bytes("set admin"), set_admin],
        [Txn.application_args[0] == Bytes("mint"), mint],
        [Txn.application_args[0] == Bytes("transfer"), transfer]
    )

    return program

def close_out_program():
    program = Seq([
        App.globalPut(
            Bytes("reserve"),
            App.globalGet(Bytes("reserve")) + App.localGet(Int(0), Bytes("balance"))
        ),
        Return(Int(1))
    ])

    return program

with open('asset_approval.teal', 'w') as f:
    compiled = compileTeal(approval_program(), Mode.Application)
    f.write(compiled)

with open('asset_close_out.teal', 'w') as f:
    compiled = compileTeal(close_out_program(), Mode.Application)
    f.write(compiled)
```

3.2.3 Security Token

Security Token is an extension of the *Asset* example with more features and restrictions. There are two types of admins, *contract admins* and *transfer admins*.

Contract admins can delete the smart contract if the entire supply is in the reserve. They can promote accounts to transfer or contract admins. They can also *mint* and *burn* funds.

Transfer admins can impose maximum balance limitations on accounts, temporarily lock accounts, assign accounts to transfer groups, and impose transaction restrictions between transaction groups.

Both contract and transfer admins can pause trading of funds and freeze individual accounts.

Accounts can only transfer funds if trading is not paused, both the sender and receive accounts are not frozen or temporarily locked, transfer group restrictions are not in place between them, and the receiver's account does not have a maximum balance restriction that would be invalidated.

```
# This example is provided for informational purposes only and has not been audited␣
↪for security.

from pyteal import *

def approval_program():
    on_creation = Seq([
        Assert(Txn.application_args.length() == Int(1)),
        App.globalPut(Bytes("total supply"), Btoi(Txn.application_args[0])),
        App.globalPut(Bytes("reserve"), Btoi(Txn.application_args[0])),
        App.globalPut(Bytes("paused"), Int(0)),
        App.localPut(Int(0), Bytes("contract admin"), Int(1)),
        App.localPut(Int(0), Bytes("transfer admin"), Int(1)),
        App.localPut(Int(0), Bytes("balance"), Int(0)),
        Return(Int(1))
    ])

    is_contract_admin = App.localGet(Int(0), Bytes("contract admin"))
    is_transfer_admin = App.localGet(Int(0), Bytes("transfer admin"))
    is_any_admin = is_contract_admin.Or(is_transfer_admin)

    can_delete = And(
        is_contract_admin,
        App.globalGet(Bytes("total supply")) == App.globalGet(Bytes("reserve"))
    )

    on_closeout = Seq([
        App.globalPut(
            Bytes("reserve"),
            App.globalGet(Bytes("reserve")) + App.localGet(Int(0), Bytes("balance"))
        ),
        Return(Int(1))
    ])

    register = Seq([
        App.localPut(Int(0), Bytes("balance"), Int(0)),
        Return(Int(1))
    ])

    # pause all transfers
    # sender must be any admin
    new_pause_value = Btoi(Txn.application_args[1])
```

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```
    pause = Seq([
        Assert(Txn.application_args.length() == Int(2)),
        App.globalPut(Bytes("paused"), new_pause_value),
        Return(is_any_admin)
    ])

    # configure the admin status of the account Txn.accounts[0]
    # sender must be contract admin
    new_admin_type = Txn.application_args[1]
    new_admin_status = Btoi(Txn.application_args[2])
    set_admin = Seq([
        Assert(And(
            is_contract_admin,
            Txn.application_args.length() == Int(3),
            Or(new_admin_type == Bytes("contract admin"), new_admin_type == Bytes(
↪"transfer admin")),
            Txn.accounts.length() == Int(1)
        )),
        App.localPut(Int(1), new_admin_type, new_admin_status),
        Return(Int(1))
    ])

    # freeze Txn.accounts[0]
    # sender must be any admin
    new_freeze_value = Btoi(Txn.application_args[1])
    freeze = Seq([
        Assert(And(
            Txn.application_args.length() == Int(2),
            Txn.accounts.length() == Int(1)
        )),
        App.localPut(Int(1), Bytes("frozen"), new_freeze_value),
        Return(is_any_admin)
    ])

    # modify the max balance of Txn.accounts[0]
    # if max_balance_value is 0, will delete the exisint max balance limitation on␣
↪the account
    # sender must be transfer admin
    max_balance_value = Btoi(Txn.application_args[1])
    max_balance = Seq([
        Assert(And(
            Txn.application_args.length() == Int(2),
            Txn.accounts.length() == Int(1)
        )),
        If(max_balance_value == Int(0),
            App.localDel(Int(1), Bytes("max balance")),
            App.localPut(Int(1), Bytes("max balance"), max_balance_value)
        ),
        Return(is_transfer_admin)
    ])

    # lock Txn.accounts[0] until a UNIX timestamp
    # sender must be transfer admin
    lock_until_value = Btoi(Txn.application_args[1])
    lock_until = Seq([
        Assert(And(
            Txn.application_args.length() == Int(2),
```

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```
            Txn.accounts.length() == Int(1)
        )),
        If(lock_until_value == Int(0),
            App.localDel(Int(1), Bytes("lock until")),
            App.localPut(Int(1), Bytes("lock until"), lock_until_value)
        ),
        Return(is_transfer_admin)
    ])

    set_transfer_group = Seq([
        Assert(And(
            Txn.application_args.length() == Int(3),
            Txn.accounts.length() == Int(1)
        )),
        App.localPut(Int(1), Bytes("transfer group"), Btoi(Txn.application_args[2]))
    ])

    def getRuleKey(sendGroup, receiveGroup):
        return Concat(Bytes("rule"), Itob(sendGroup), Itob(receiveGroup))

    lock_transfer_key = getRuleKey(Btoi(Txn.application_args[2]), Btoi(Txn.
↪application_args[3]))
    lock_transfer_until = Btoi(Txn.application_args[4])
    lock_transfer_group = Seq([
        Assert(Txn.application_args.length() == Int(5)),
        If(lock_transfer_until == Int(0),
            App.globalDel(lock_transfer_key),
            App.globalPut(lock_transfer_key, lock_transfer_until)
        )
    ])

    # sender must be transfer admin
    transfer_group = Seq([
        Assert(Txn.application_args.length() > Int(2)),
        Cond(
            [Txn.application_args[1] == Bytes("set"), set_transfer_group],
            [Txn.application_args[1] == Bytes("lock"), lock_transfer_group]
        ),
        Return(is_transfer_admin)
    ])

    # move assets from the reserve to Txn.accounts[0]
    # sender must be contract admin
    mint_amount = Btoi(Txn.application_args[1])
    mint = Seq([
        Assert(And(
            Txn.application_args.length() == Int(2),
            Txn.accounts.length() == Int(1),
            mint_amount <= App.globalGet(Bytes("reserve"))
        )),
        App.globalPut(Bytes("reserve"), App.globalGet(Bytes("reserve")) - mint_
↪amount),
        App.localPut(Int(1), Bytes("balance"), App.localGet(Int(1), Bytes("balance"))␣
↪+ mint_amount),
        Return(is_contract_admin)
    ])
```

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```
    # move assets from Txn.accounts[0] to the reserve
    # sender must be contract admin
    burn_amount = Btoi(Txn.application_args[1])
    burn = Seq([
        Assert(And(
            Txn.application_args.length() == Int(2),
            Txn.accounts.length() == Int(1),
            burn_amount <= App.localGet(Int(1), Bytes("balance"))
        )),
        App.globalPut(Bytes("reserve"), App.globalGet(Bytes("reserve")) + burn_
↪amount),
        App.localPut(Int(1), Bytes("balance"), App.localGet(Int(1), Bytes("balance"))␣
↪- burn_amount),
        Return(is_contract_admin)
    ])

    # transfer assets from the sender to Txn.accounts[0]
    transfer_amount = Btoi(Txn.application_args[1])
    receiver_max_balance = App.localGetEx(Int(1), App.id(), Bytes("max balance"))
    transfer = Seq([
        Assert(And(
            Txn.application_args.length() == Int(2),
            Txn.accounts.length() == Int(1),
            transfer_amount <= App.localGet(Int(0), Bytes("balance"))
        )),
        receiver_max_balance,
        If(
            Or(
                App.globalGet(Bytes("paused")),
                App.localGet(Int(0), Bytes("frozen")),
                App.localGet(Int(1), Bytes("frozen")),
                App.localGet(Int(0), Bytes("lock until")) >= Global.latest_
↪timestamp(),
                App.localGet(Int(1), Bytes("lock until")) >= Global.latest_
↪timestamp(),
                App.globalGet(getRuleKey(App.localGet(Int(0), Bytes("transfer group
↪")), App.localGet(Int(1), Bytes("transfer group")))) >= Global.latest_timestamp(),
                And(
                    receiver_max_balance.hasValue(),
                    receiver_max_balance.value() < App.localGet(Int(1), Bytes("balance
↪")) + transfer_amount
                )
            ),
            Return(Int(0))
        ),
        App.localPut(Int(0), Bytes("balance"), App.localGet(Int(0), Bytes("balance"))␣
↪- transfer_amount),
        App.localPut(Int(1), Bytes("balance"), App.localGet(Int(1), Bytes("balance"))␣
↪+ transfer_amount),
        Return(Int(1))
    ])

    program = Cond(
        [Txn.application_id() == Int(0), on_creation],
        [Txn.on_completion() == OnComplete.DeleteApplication, Return(can_delete)],
        [Txn.on_completion() == OnComplete.UpdateApplication, Return(is_contract_
↪admin)],
```

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```
        [Txn.on_completion() == OnComplete.CloseOut, on_closeout],
        [Txn.on_completion() == OnComplete.OptIn, register],
        [Txn.application_args[0] == Bytes("pause"), pause],
        [Txn.application_args[0] == Bytes("set admin"), set_admin],
        [Txn.application_args[0] == Bytes("freeze"), freeze],
        [Txn.application_args[0] == Bytes("max balance"), max_balance],
        [Txn.application_args[0] == Bytes("lock until"), lock_until],
        [Txn.application_args[0] == Bytes("transfer group"), transfer_group],
        [Txn.application_args[0] == Bytes("mint"), mint],
        [Txn.application_args[0] == Bytes("burn"), burn],
        [Txn.application_args[0] == Bytes("transfer"), transfer],
    )

    return program

def close_out_program():
    program = Seq([
        App.globalPut(
            Bytes("reserve"),
            App.globalGet(Bytes("reserve")) + App.localGet(Int(0), Bytes("balance"))
        ),
        Return(Int(1))
    ])

    return program

with open('security_token_approval.teal', 'w') as f:
    compiled = compileTeal(approval_program(), Mode.Application)
    f.write(compiled)

with open('security_token_close_out.teal', 'w') as f:
    compiled = compileTeal(close_out_program(), Mode.Application)
    f.write(compiled)
```

CHAPTER 4

Data Types and Constants

A PyTeal expression has one of the following two data types:

- *TealType.uint64*, 64 bit unsigned integer
- *TealType.bytes*, a slice of bytes

For example, all the transaction arguments (e.g. `Arg(0)`) are of type *TealType.bytes*. The first valid round of current transaction (*Txn.first_valid()*) is typed *TealType.uint64*.

4.1 Integers

`Int(n)` creates a `TealType.uint64` constant, where `n >= 0 and n < 2 ** 64`.

4.2 Bytes

A byte slice is a binary string. There are several ways to encode a byte slice in PyTeal:

4.2.1 UTF-8

Byte slices can be created from UTF-8 encoded strings. For example:

```
Bytes("hello world")
```

4.2.2 Base16

Byte slices can be created from a **RFC 4648#section-8** base16 encoded binary string, e.g. `"0xA21212EF"` or `"A21212EF"`. For example:

```
Bytes("base16", "0xA21212EF")
Bytes("base16", "A21212EF") # "0x" is optional
```

4.2.3 Base32

Byte slices can be created from a **RFC 4648#section-6** base32 encoded binary string **without padding**, e.g. `"7Z5PWO2C6LFNQFGHWKSK5H47IQP5OJW2M3HA2QPXTY3WTNP5NU2MHBW27M"`.

```
Bytes("base32", "7Z5PWO2C6LFNQFGHWKSK5H47IQP5OJW2M3HA2QPXTY3WTNP5NU2MHBW27M")
```

4.2.4 Base64

Byte slices can be created from a **RFC 4648#section-4** base64 encoded binary string, e.g. `"Zm9vYmE="`.

```
Bytes("base64", "Zm9vYmE=")
```

4.3 Type Checking

All PyTeal expressions are type checked at construction time, for example, running the following code triggers a `TealTypeError`:

```
Int(0) < Arg(0)
```

Since < (overloaded Python operator, see *Arithmetic Operators* for more details) requires both operands of type `TealType.uint64`, while `Arg(0)` is of type `TealType.bytes`.

4.4 Conversion

Converting a value to its corresponding value in the other data type is supported by the following two operators:

- `Itob(n)`: generate a `TealType.bytes` value from a `TealType.uint64` value `n`
- `Btoi(b)`: generate a `TealType.uint64` value from a `TealType.bytes` value `b`

CHAPTER 5

Arithmetic Operators

An arithmetic expression is an expression that results in a `TealType.uint64` value. In PyTeal, arithmetic expressions include integer arithmetics operators and boolean operators. We overloaded all integer arithmetics operator in Python.

Operator	Overloaded	Semantics	Example
`Lt(a, b)`	`<`	*1* if *a* is less than *b*, *0* otherwise	`Int(1) < Int(5)`
`Gt(a, b)`	`>`	*1* if *a* is greater than *b*, *0* otherwise	`Int(1) > Int(5)`
`Le(a, b)`	`<=`	*1* if *a* is no greater than *b*, *0* otherwise	`Int(1) <= Int(5)`
`Ge(a, b)`	`>=`	*1* if *a* is no less than *b*, *0* otherwise	`Int(1) >= Int(5)`
`Add(a, b)`	`+`	*a* + *b*, error (panic) if overflow	`Int(1) + Int(5)`
`Minus(a, b)`	`-`	*a* - *b*, error if underflow	`Int(5) - Int(1)`
`Mul(a, b)`	`*`	*a* * *b*, error if overflow	`Int(2) * Int(3)`
`Div(a, b)`	`/`	*a* / *b*, error if devided by zero	`Int(3) / Int(2)`
`Mod(a, b)`	`%`	*a* % *b*, modulo operation	`Int(7) % Int(3)`
`Eq(a, b)`	`==`	*1* if *a* equals *b*, *0* otherwise	`Int(7) == Int(7)`
`Neq(a, b)`	`!=`	*0* if *a* equals *b*, *1* otherwise	`Int(7) != Int(7)`
`And(a, b)`		*1* if *a* > *0* && *b* > *0*, *0* otherwise	`And(Int(1), Int(1))`
`Or(a, b)`		*1* if *a* > *0* || *b* > *0*, *0* otherwise	`Or(Int(1), Int(0))`
`Not(a)`		*1* if *a* equals *0*, *0* otherwise	`Not(Int(0))`
`BitwiseAnd(a,b)`	`&`	*a* & *b*, bitwise and operation	`Int(1) & Int(3)`
`BitwiseOr(a,b)`	`|`	*a* | *b*, bitwise or operation	`Int(2) | Int(5)`
`BitwiseXor(a,b)`	`^`	*a* ^ *b*, bitwise xor operation	`Int(3) ^ Int(7)`
`BitwiseNot(a)`	`~`	~*a*, bitwise complement operation	`~Int(1)`

All these operators takes two `TealType.uint64` values. In addition, `Eq(a, b)` (==) and `Neq(a, b)` (!=) also work for byte slices. For example, `Arg(0) == Arg(1)` and `Arg(0) != Arg(1)` are valid PyTeal expressions.

Both `And` and `Or` also support more than 2 arguements when called as functions:

- `And(a, b, ...)`
- `Or(a, b, ...)`

The associativity and precedence of the overloaded Python arithmatic operators are the same as the original python operators . For example:

- `Int(1) + Int(2) + Int(3)` is equivalent to `Add(Add(Int(1), Int(2)), Int(3))`
- `Int(1) + Int(2) * Int(3)` is equivalent to `Add(Int(1), Mul(Int(2), Int(3)))`

CHAPTER 6

Byte Operators

TEAL byte slices are similar to strings and can be manipulated in much the same way.

6.1 Concat

Byte slices can be combined using the *Concat* expression. This expression takes at least two arguments and produces a new byte slice consisting of each argument, one after another. For example:

```
Concat(Bytes("a"), Bytes("b"), Bytes("c")) # equivalent to Bytes("abc")
```

6.2 Substring

Byte slices can be extracted from other byte slices using the *Substring* expression. This expression can extract part of a byte slicing given start and end indices. For example:

```
Substring(Bytes("algorand"), Int(0), Int(4)) # equivalent to Bytes("algo")
```

CHAPTER 7

Transaction Fields and Global Parameters

PyTeal smart contracts can access properties of the current transaction and the state of the blockchain when they are running.

7.1 Transaction Fields

Information about the current transaction being evaluated can be obtained using the *Txn* object. Blow are the PyTeal expressions that refer to transaction fields:

Operator	Type	Notes
`Txn.sender()`	`TealType.bytes`	32 byte address
`Txn.fee()`	`TealType.uint64`	in microAlgos
`Txn.first_valid()`	`TealType.uint64`	round number
`Txn.last_valid()`	`TealType.uint64`	round number
`Txn.note()`	`TealType.bytes`	transaction note in bytes
`Txn.lease()`	`TealType.bytes`	transaction lease in bytes
`Txn.receiver()`	`TealType.bytes`	32 byte address
`Txn.amount()`	`TealType.uint64`	in microAlgos
`Txn.close_remainder_to()`	`TealType.bytes`	32 byte address
`Txn.vote_pk()`	`TealType.bytes`	32 byte address
`Txn.selection_pk()`	`TealType.bytes`	32 byte address
`Txn.vote_first()`	`TealType.uint64`	
`Txn.vote_last()`	`TealType.uint64`	
`Txn.vote_key_dilution()`	`TealType.uint64`	
`Txn.type()`	`TealType.bytes`	
`Txn.type_enum()`	`TealType.uint64`	see table below
`Txn.xfer_asset()`	`TealType.uint64`	asset ID
`Txn.asset_amount()`	`TealType.uint64`	value in Asset's units
`Txn.asset_sender()`	`TealType.bytes`	32 byte address, causes clawback of all value if sender
`Txn.asset_receiver()`	`TealType.bytes`	32 byte address

Continue

Table 1 – continued from previous page

Operator	Type	Notes
`Txn.asset_close_to()`	`TealType.bytes`	32 byte address
`Txn.group_index()`	`TealType.uint64`	position of this transaction within a transaction group
`Txn.tx_id()`	`TealType.bytes`	the computed ID for this transaction, 32 bytes
`Txn.application_id()`	`TealType.uint64`	
`Txn.on_completion()`	`TealType.uint64`	
`Txn.approval_program()`	`TealType.bytes`	
`Txn.clear_state_program()`	`TealType.bytes`	
`Txn.rekey_to()`	`TealType.bytes`	32 byte address
`Txn.config_asset()`	`TealType.uint64`	
`Txn.config_asset_total()`	`TealType.uint64`	
`Txn.config_asset_decimals()`	`TealType.uint64`	
`Txn.config_asset_default_frozen()`	`TealType.uint64`	
`Txn.config_asset_unit_name()`	`TealType.bytes`	
`Txn.config_asset_name()`	`TealType.bytes`	
`Txn.config_asset_url()`	`TealType.bytes`	
`Txn.config_asset_metadata_hash()`	`TealType.bytes`	
`Txn.config_asset_manager()`	`TealType.bytes`	32 byte address
`Txn.config_asset_reserve()`	`TealType.bytes`	32 byte address
`Txn.config_asset_freeze()`	`TealType.bytes`	32 byte address
`Txn.config_asset_clawback()`	`TealType.bytes`	32 byte address
`Txn.freeze_asset()`	`TealType.uint64`	
`Txn.freeze_asset_account()`	`TealType.bytes`	32 byte address
`Txn.freeze_asset_frozen()`	`TealType.uint64`	
`Txn.application_args()`	`TealType.bytes[]`	
`Txn.accounts()`	`TealType.bytes[]`	

The `Txn.type_enum()` values can be checked using the *TxnType* enum:

Value	Numerical Value	Type String	Description
TxnType.Unknown	0	unkown	unknown type, invalid
TxnType.Payment	1	pay	payment
TxnType.KeyRegistration	2	keyreg	key registration
TxnType.AssetConfig	3	acfg	asset config
TxnType.AssetTransfer	4	axfer	asset transfer
TxnType.AssetFreeze	5	afrz	asset freeze
TxnType.ApplicationCall	6	appl	application call

7.1.1 Atomic Tranfers

Atomic Transfers are irreducible batch transactions that allow groups of transactions to be submitted at one time. If any of the transactions fail, then all the transactions will fail. PyTeal allows programs to access information about the transactions in an atomic transfer group using the *Gtxn* object. This object acts like a list of *TxnObject*, meaning all of the above transaction fields on `Txn` are available on the elements of `Gtxn`. For example:

```
Gtxn[0].sender() # get the sender of the first transaction in the atomic transfer␣
↪group
Gtxn[1].receiver() # get the receiver of the second transaction in the atomic␣
↪transfer group
```

`Gtxn` is zero-indexed and the maximum size of an atomic transfer group is 16.

7.2 Global Parameters

Information about the current state of the blockchain can be obtained using the following *Global* expressions:

Operator	Type	Notes
Global.min_txn_fee()	TealType.uint64	in microAlgos
Global.min_balance()	TealType.uint64	in mircoAlgos
Global.max_txn_life()	TealType.uint64	number of rounds
Global.zero_address()	TealType.bytes	32 byte address of all zero bytes
Global.group_size()	TealType.uint64	number of txns in this atomic transaction group, At least 1
Global.logic_sig_version()	TealType.uint64	the maximum supported TEAL version
Global.round()	TealType.uint64	the current round number
Global.latest_timestamp()	TealType.uint64	the latest confirmed block UNIX timestamp
Global.current_application_id()	TealType.uint64	the ID of the current application executing

CHAPTER 8

Cryptographic Primitives

Algorand Smart Contracts support 4 cryptographic primitives, including 3 cryptographic hash functions and 1 digital signature verification. Each of these cryptographic primitives is associated with a cost, which is a number indicating its relative performance overhead comparing with simple teal operations such as addition and substraction. All TEAL opcodes except crypto primitives have cost *1*. Below is how you express cryptographic primitives in PyTeal:

Operator	Cost	Description
`Sha256(e)`	*7*	*SHA-256* hash function, produces 32 bytes
`Keccak256(e)`	*26*	*Keccak-256* hash funciton, produces 32 bytes
`Sha512_256(e)`	*9*	*SHA512-256* hash function, produces 32 bytes
`Ed25519Verify(d, s, p)`	*1900*	*1* if `s` is the signature of `d` signed by `p` (PK), else *0*

These cryptographic primitives cover the most used ones in blockchains and cryptocurrencies. For example, Bitcoin uses *SHA-256* for creating Bitcoin addresses; Alogrand uses *ed25519* signature scheme for authorization and uses *SHA512-256* hash function for creating contract account addresses from TEAL bytecode.

CHAPTER 9

Control Flow

PyTeal provides several control flow expressions to chain together multiple expressions and to conditionally evaluate expressions.

9.1 Exiting the Program: `Return`

The *Return* expression causes the program to exit immediately. It takes a single argument, which is the success value that the program should have. For example, `Return(Int(0))` causes the program to immediately fail, and `Return(Int(1))` causes the program to immediately succeed. Since the presence of a `Return` statement causes the program to exit, no operations after it will be executed.

9.2 Chaining Expressions: `Seq`

The *Seq* expression can be used to create a sequence of multiple expressions. It takes a single argument, which is a list of expressions to include in the sequence. For example:

```
Seq([
    App.globalPut(Bytes("creator"), Txn.sender()),
    Return(Int(1))
])
```

A `Seq` expression will take on the value of its last expression. Additionally, all expressions in a `Seq` expression, except the last one, must not return anything (e.g. evaluate to *TealType.none*). This restriction is in place because intermediate values must not add things to the TEAL stack. As a result, the following is an invalid sequence:

Listing 1: Invalid Seq expression

```
Seq([
    Txn.sender(),
    Return(Int(1))
])
```

If you must include an operation that returns a value in the earlier part of a sequence, you can wrap the value in a *Pop* expression to discard it. For example,

```
Seq([
    Pop(Txn.sender()),
    Return(Int(1))
])
```

9.3 Simple Branching: `If`

In an *If* expression,

```
If(test-expr, then-expr, else-expr)
```

the `test-expr` is always evaludated and needs to be typed `TealType.uint64`. If it results in a value greater than *0*, then the `then-expr` is evaluated. Otherwise, `else-expr` is evaluated. Note that `then-expr` and `else-expr` must evaluate to the same type (e.g. both `TealType.uint64`).

You may also invoke an *If* expression without an `else-expr`:

```
If(test-expr, then-expr)
```

In this case, `then-expr` must be typed `TealType.none`.

9.4 Checking Conditions: `Assert`

The *Assert* expression can be used to ensure that conditions are met before continuing the program. The syntax for `Assert` is:

```
Assert(test-expr)
```

If `test-expr` is always evaluated and must be typed `TealType.uint64`. If `test-expr` results in a value greater than *0*, the program continues. Otherwise, the program immediately exits an indicates that it encountered an error.

Example:

```
Assert(Txn.type_enum() == TxnType.Payment)
```

The above example will cause the program to immediately fail with an error if the transaction type is not a payment.

9.5 Chaining Tests: `Cond`

A *Cond* expression chians a series of tests to select a result expression. The syntax of *Cond* is:

```
Cond([test-expr body],
     . . . )
```

Each `test-expr` is evaluated in order. If it produces *0*, the paired `body` is ignored, and evaluation proceeds to the next `test-expr`. As soon as a `test-expr` produces a true value (> *0*), its `body` is evaluated to produce the value for this `Cond` expression. If none of `test-expr` s evaluates to a true value, the `Cond` expression will be evaluated to `err`, a TEAL opcode that causes the runtime panic.

In a `Cond` expression, each `test-expr` needs to be typed `TealType.uint64`. A `body` could be typed either `TealType.uint64` or `TealType.bytes`. However, all `body` s must have the same data type. Otherwise, a `TealTypeError` is triggered.

Example:

```
Cond([Global.group_size() == Int(5), bid],
     [Global.group_size() == Int(4), redeem],
     [Global.group_size() == Int(1), wrapup])
```

This PyTeal code branches on the size of the atomic transaction group.

CHAPTER 10

State Access and Manipulation

PyTeal can be used to write Stateful Algorand Smart Contracts as well. Stateful contracts, also known as applications, can access and manipulate state on the Algorand blockchain.

State consists of key-value pairs, where keys are byte slices and values can be integers or byte slices. There are multiple types of state that an application can use.

10.1 State Operation Table

Context	Write	Read	Delete	Check If Exists
Current App Global	*App.globalPut*	*App.globalGet*	*App.globalDel*	*App.globalGetEx*
Current App Local	*App.localPut*	*App.localGet*	*App.localDel*	*App.localGetEx*
Other App Global		*App.globalGetEx*		*App.globalGetEx*
Other App Local		*App.localGetEx*		*App.localGetEx*

10.2 Global State

Global state consists of key-value pairs that are stored in the application's global context. It can be manipulated as follows:

10.2.1 Writing

To write to global state, use the *App.globalPut* function. The first argument is the key to write to, and the second argument is the value to write. For example:

```
App.globalPut(Bytes("status"), Bytes("active")) # write a byte slice
App.globalPut(Bytes("total supply"), Int(100)) # write a uint64
```

10.2.2 Reading

To read from global state, use the *App.globalGet* function. The only argument it takes it the key to read from. For example:

```
App.globalGet(Bytes("status"))
App.globalGet(Bytes("total supply"))
```

If you try to read from a key that does not exist in your app's global state, the integer *0* is returned.

10.2.3 Deleting

To delete a key from global state, use the *App.globalDel* function. The only argument it takes is the key to delete. For example:

```
App.globalDel(Bytes("status"))
App.globalDel(Bytes("total supply"))
```

If you try to delete a key that does not exist in your app's global state, nothing happens.

10.3 Local State

Local state consists of key-value pairs that are stored in a unique context for each account that has opted into your application. As a result, you will need to specify an account when manipulating local state. This is done by passing in an integer that corresponds to an account. The integer *0* is a special case that refers to the sender of the application call transaction. The integer *1* refers to the first element in *Txn.accounts*, *2* refers to the second element, and so on.

10.3.1 Writing

To write to the local state of an account, use the *App.localPut* function. The first argument is an integers corresponding to the account to write to, the second argument is the key to write to, and the third argument is the value to write. For example:

```
App.localPut(Int(0), Bytes("role"), Bytes("admin")) # write a byte slice to the sender
↪'s account
App.localPut(Int(0), Bytes("balance"), Int(10)) # write a uint64 to the sender's␣
↪account
App.localPut(Int(1), Bytes("balance"), Int(10)) # write a uint64 to Txn.accounts[0]
```

Note: It is only possible to write to the local state of an account if that account has opted into your application. If the account has not opted in, the program will fail with an error. The function *App.optedIn* can be used to check if an account has opted into an app.

10.3.2 Reading

To read from the local state of an account, use the *App.localGet* function. The first argument is an integer corresponding to the account to read from and the second argument is the key to read. For example:

```
App.localGet(Int(0), Bytes("role")) # read from the sender's account
App.localGet(Int(0), Bytes("balance")) # read from the the sender's account
App.localGet(Int(1), Bytes("balance")) # read from Txn.accounts[0]
```

If you try to read from a key that does not exist in your app's global state, the integer *0* is returned.

10.3.3 Deleting

To delete a key from local state of an account, use the *App.localDel* function. The first argument is an integer corresponding to the account and the second argument is the key to delete. For example:

```
App.localDel(Int(0), Bytes("role")) # delete "role" from the sender's account
App.localDel(Int(0), Bytes("balance")) # delete "balance" from the the sender's␣
↪account
App.localDel(Int(1), Bytes("balance")) # delete "balance" from Txn.accounts[0]
```

If you try to delete a key that does not exist in the account's local state, nothing happens.

10.4 External State

The above functions allow an app to read and write state in its own context. Additionally, it's possible for applications to read state written by other applications. This is possible using the *App.globalGetEx* and *App.localGetEx* functions.

Similar to local state access, to use these functions you need to pass in an integer that represents which application to read from. The integer *0* is a special case that refers to the current application. The integer *1* refers to the first element in Txn.ForeignApps, *2* refers to the second element, and so on. Note that the transaction field *ForeignApps* is not accessible from TEAL at this time.

Unlike the other state access functions, *App.globalGetEx* and *App.localGetEx* return a *MaybeValue*. This value cannot be used directly, but has methods *MaybeValue.hasValue()* and *MaybeValue.value()*. If the key being accessed exists in the global context of the app being read, `hasValue()` will return *1* and `value()` will return its value. Otherwise, `hasValue()` and `value()` will return *0*.

Note: Even though the *MaybeValue* returned by *App.globalGetEx* and *App.localGetEx* cannot be used directly, it **must** be included in the application before `hasValue()` and `value()` are called on it. You will probably want to use *Seq* to do this.

Since these functions are the only way to check whether a key exists, it can be useful to use them in the current application's context too.

10.4.1 External Global

To read a value from the global state of another application, use the *App.globalGetEx* function. The first argument is an integer corresponding to the application to read from and the second argument is the key to read. For example:

```
# get "status" from the current global context
# if "status" has not been set, returns "none"
myStatus = App.globalGetEx(Int(0), Bytes("status"))
Seq([
    myStatus,
    If(myStatus.hasValue(), myStatus.value(), Bytes("none"))
])
```

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```
# get "status" from the global context of Txn.ForeignApps[0]
# if "status" has not been set, returns "none"
otherStatus = App.globalGetEx(Int(1), Bytes("status"))
Seq([
    otherStatus,
    If(otherStatus.hasValue(), otherStatus.value(), Bytes("none"))
])

# get "total supply" from the global context of Txn.ForeignApps[0]
# if "total supply" has not been set, returns the default value of 0
otherSupply = App.globalGetEx(Int(1), Bytes("status"))
Seq([
    otherSupply,
    otherSupply.value()
])
```

10.4.2 External Local

To read a value from an account's local state for another application, use the *App.localGetEx* function. The first argument is an integer corresponding to the account to read from (in the same format as *App.localGet*), the second argument is an integer corresponding to the application to read from, and the third argument is the key to read. For example:

```
# get "role" from the sender's local state for the current account
# if "role" has not been set, returns "none"
myAppSenderRole = App.localGetEx(Int(0), Int(0), Bytes("role"))
Seq([
    myAppSenderRole,
    If(myAppSenderRole.hasValue(), myAppSenderRole.value(), Bytes("none"))
])

# get "role" from the local state of Txn.accounts[0] for the current account
# if "role" has not been set, returns "none"
myAppOtherAccountRole = App.localGetEx(Int(1), Int(0), Bytes("role"))
Seq([
    myAppOtherAccountRole,
    If(myAppOtherAccountRole.hasValue(), myAppOtherAccountRole.value(), Bytes("none"))
])

# get "role" from the sender's local state for Txn.ForeignApps[0]
# if "role" has not been set, returns "none"
otherAppSenderRole = App.localGetEx(Int(0), Int(1), Bytes("role"))
Seq([
    otherAppSenderRole,
    If(otherAppSenderRole.hasValue(), otherAppSenderRole.value(), Bytes("none"))
])

# get "role" from the local state of Txn.accounts[0] for Txn.ForeignApps[0]
# if "role" has not been set, returns "none"
otherAppOtherAccountRole = App.localGetEx(Int(1), Int(1), Bytes("role"))
Seq([
    otherAppOtherAccountRole,
    If(otherAppOtherAccountRole.hasValue(), otherAppOtherAccountRole.value(), Bytes(
↪"none"))
```

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```
])
```

CHAPTER 11

PyTeal Package

pyteal.**Txn = <pyteal.TxnObject object>**
The current transaction being evaluated.

pyteal.**Gtxn = <pyteal.TxnGroup object>**
The current group of transactions being evaluated.

pyteal.**Add**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Add two numbers.

Produces left + right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**Addr**(*address: str*)
Bases: *pyteal.LeafExpr*

An expression that represents an Algorand address.

__init__(*address: str*) → None
Create a new Addr expression.

Parameters **address** – A string containing a valid base32 Algorand address

type_of()
Get the return type of this expression.

pyteal.**And**(**args*) → pyteal.NaryExpr
Logical and expression.

Produces 1 if all arguments are nonzero. Otherwise produces 0.

All arguments must be PyTeal expressions that evaluate to uint64, and there must be at least two arguments.

Example

```
And(Txn.amount() == Int(500), Txn.fee() <= Int(10))
```

class pyteal.**App**(*field: pyteal.AppField*, *args*)
Bases: *pyteal.LeafExpr*

An expression related to applications.

classmethod globalDel(*key: pyteal.Expr*) → pyteal.App
Delete a key from the global state of the current application.

Parameters **key** – The key to delete from the global application state. Must evaluate to bytes.

classmethod globalGet(*key: pyteal.Expr*) → pyteal.App
Read from the global state of the current application.

Parameters **key** – The key to read from the global application state. Must evaluate to bytes.

classmethod globalGetEx(*app: pyteal.Expr*, *key: pyteal.Expr*) → pyteal.MaybeValue
Read from the global state of an application.

Parameters

- **app** – An index into Txn.ForeignApps that corresponds to the application to read from. Must evaluate to uint64.
- **key** – The key to read from the global application state. Must evaluate to bytes.

classmethod globalPut(*key: pyteal.Expr*, *value: pyteal.Expr*) → pyteal.App
Write to the global state of the current application.

Parameters

- **key** – The key to write in the global application state. Must evaluate to bytes.
- **value** – THe value to write in the global application state. Can evaluate to any type.

classmethod id() → pyteal.Global
Get the ID of the current running application.

This is the same as *Global.current_application_id()*.

classmethod localDel(*account: pyteal.Expr*, *key: pyteal.Expr*) → pyteal.App
Delete a key from an account's local state for the current application.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account from which the key should be deleted. Must evaluate to uint64.
- **key** – The key to delete from the account's local state. Must evaluate to bytes.

classmethod localGet(*account: pyteal.Expr*, *key: pyteal.Expr*) → pyteal.App
Read from an account's local state for the current application.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account to read from. Must evaluate to uint64.
- **key** – The key to read from the account's local state. Must evaluate to bytes.

classmethod localGetEx(*account: pyteal.Expr*, *app: pyteal.Expr*, *key: pyteal.Expr*) → pyteal.MaybeValue
Read from an account's local state for an application.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account to read from. Must evaluate to uint64.
- **app** – The ID of the application being checked. Must evaluate to uint64.
- **key** – The key to read from the account's local state. Must evaluate to bytes.

classmethod localPut(*account: pyteal.Expr*, *key: pyteal.Expr*, *value: pyteal.Expr*) → pyteal.App

Write to an account's local state for the current application.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account to write to. Must evaluate to uint64.
- **key** – The key to write in the account's local state. Must evaluate to bytes.
- **value** – The value to write in the account's local state. Can evaluate to any type.

classmethod optedIn(*account: pyteal.Expr*, *app: pyteal.Expr*) → pyteal.App

Check if an account has opted in for an application.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account to check. Must evaluate to uint64.
- **app** – The ID of the application being checked. Must evaluate to uint64.

type_of()

Get the return type of this expression.

class pyteal.**AppField**(*op: pyteal.Op*, *type: pyteal.TealType*)

Bases: enum.Enum

Enum of app fields used to create *App* objects.

get_op() → pyteal.Op

globalDel = (<Op.app_global_del: 'app_global_del'>, <TealType.none: 3>)

globalGet = (<Op.app_global_get: 'app_global_get'>, <TealType.anytype: 2>)

globalGetEx = (<Op.app_global_get_ex: 'app_global_get_ex'>, <TealType.none: 3>)

globalPut = (<Op.app_global_put: 'app_global_put'>, <TealType.none: 3>)

localDel = (<Op.app_local_del: 'app_local_del'>, <TealType.none: 3>)

localGet = (<Op.app_local_get: 'app_local_get'>, <TealType.anytype: 2>)

localGetEx = (<Op.app_local_get_ex: 'app_local_get_ex'>, <TealType.none: 3>)

localPut = (<Op.app_local_put: 'app_local_put'>, <TealType.none: 3>)

optedIn = (<Op.app_opted_in: 'app_opted_in'>, <TealType.uint64: 0>)

type_of() → pyteal.TealType

class pyteal.**Arg**(*index: int*)

Bases: *pyteal.LeafExpr*

An expression to get an argument when running in signature verification mode.

__init__(*index: int*) → None
Get an argument for this program.

Should only be used in signature verification mode. For application mode arguments, see *TxnObject.application_args*.

Parameters **index** – The integer index of the argument to get. Must be between 0 and 255 inclusive.

type_of()
Get the return type of this expression.

class pyteal.**Array**
Bases: abc.ABC

Represents a variable length array of objects.

__getitem__(*index: int*)
Get the value at a given index in this array.

length() → pyteal.Expr
Get the length of the array.

class pyteal.**Assert**(*cond: pyteal.Expr*)
Bases: *pyteal.Expr*

A control flow expression to verify that a condition is true.

__init__(*cond: pyteal.Expr*) → None
Create an assert statement that raises an error if the condition is false.

Parameters **cond** – The condition to check. Must evaluate to a uint64.

type_of()
Get the return type of this expression.

class pyteal.**AssetHolding**
Bases: object

classmethod balance(*account: pyteal.Expr*, *asset: pyteal.Expr*) → pyteal.MaybeValue
Get the amount of an asset held by an account.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account to check. Must evaluate to uint64.
- **asset** – The ID of the asset to get. Must evaluate to uint64.

classmethod frozen(*account: pyteal.Expr*, *asset: pyteal.Expr*) → pyteal.MaybeValue
Check if an asset is frozen for an account.

Parameters

- **account** – An index into Txn.Accounts that corresponds to the account to check. Must evaluate to uint64.
- **asset** – The ID of the asset to check. Must evaluate to uint64.

class pyteal.**AssetParam**
Bases: object

classmethod clawback(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the clawback address for an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod decimals(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the number of decimals for an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod defaultFrozen(*asset: pyteal.Expr*) → pyteal.MaybeValue
Check if an asset is frozen by default.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod freeze(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the freeze address for an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod manager(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the manager commitment for an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod metadataHash(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the arbitrary commitment for an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod name(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the name of an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod reserve(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the reserve address for an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod total(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the total number of units of an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod unitName(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the unit name of an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

classmethod url(*asset: pyteal.Expr*) → pyteal.MaybeValue
Get the URL of an asset.

Parameters **asset** – An index into Txn.ForeignAssets that corresponds to the asset to check. Must evaluate to uint64.

pyteal.**Balance**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the balance of a user in micro Algos.

Argument must be an index into Txn.Accounts that corresponds to the account to read from. It must evaluate to uint64.

This operation is only permitted in application mode.

class pyteal.**BinaryExpr**(*op: pyteal.Op*, *inputType: pyteal.TealType*, *outputType: pyteal.TealType*, *argLeft: pyteal.Expr*, *argRight: pyteal.Expr*)
Bases: *pyteal.Expr*

An expression with two arguments.

type_of()
Get the return type of this expression.

pyteal.**BitwiseAnd**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Bitwise and expression.

Produces left & right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

pyteal.**BitwiseNot**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the bitwise inverse of a uint64.

Produces ~arg.

pyteal.**BitwiseOr**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Bitwise or expression.

Produces left | right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

pyteal.**BitwiseXor**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Bitwise xor expression.

Produces left ^ right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

pyteal.**Btoi**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Convert a byte string to a uint64.

class pyteal.**Bytes**(**args*)
Bases: *pyteal.LeafExpr*

An expression that represents a byte string.

__init__(**args*) → None
Create a new byte string.

Depending on the encoding, there are different arguments to pass:

For UTF-8 strings: Pass the string as the only argument. For example, `Bytes("content")`.

For base16, base32, or base64 strings: Pass the base as the first argument and the string as the second argument. For example, `Bytes("base16", "636F6E74656E74")`, `Bytes("base32", "ORFDPQ6ARJK")`, `Bytes("base64", "Y29udGVudA==")`.

Special case for base16: The prefix "0x" may be present in a base16 byte string. For example, `Bytes("base16", "0x636F6E74656E74")`.

type_of()
Get the return type of this expression.

pyteal.**Concat**(**args*) → pyteal.NaryExpr
Concatenate byte strings.

Produces a new byte string consisting of the contents of each of the passed in byte strings joined together.

All arguments must be PyTeal expressions that evaluate to bytes, and there must be at least two arguments.

Example

```
Concat(Bytes("hello"), Bytes(" "), Bytes("world"))
```

class pyteal.**Cond**(**argv*)
Bases: *pyteal.Expr*

A chainable branching expression that supports an arbitrary number of conditions.

__init__(**argv*)
Create a new Cond expression.

At least one argument must be provided, and each argument must be a list with two elements. The first element is a condition which evalutes to uint64, and the second is the body of the condition, which will execute if that condition is true. All condition bodies must have the same return type. During execution, each condition is tested in order, and the first condition to evaluate to a true value will cause its associated body to execute and become the value for this Cond expression. If no condition evalutes to a true value, the Cond expression produces an error and the TEAL program terminates.

Example

```
Cond([Global.group_size() == Int(5), bid],
    [Global.group_size() == Int(4), redeem],
    [Global.group_size() == Int(1), wrapup])
```

type_of()
Get the return type of this expression.

pyteal.**Div**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Divide two numbers.

Produces left / right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**Ed25519Verify**(*data: pyteal.Expr*, *sig: pyteal.Expr*, *key: pyteal.Expr*)
Bases: *pyteal.Expr*

An expression to verify ed25519 signatures.

__init__(*data: pyteal.Expr*, *sig: pyteal.Expr*, *key: pyteal.Expr*) → None
Verify the ed25519 signature of ("ProgData" || program_hash || data).

Parameters

- **data** – The data signed by the public. Must evalutes to bytes.
- **sig** – The proposed 64 byte signature of ("ProgData" || program_hash || data). Must evalute to bytes.
- **key** – The 32 byte public key that produced the signature. Must evaluate to bytes.

type_of()
Get the return type of this expression.

class pyteal.**EnumInt**(*name: str*)
Bases: *pyteal.LeafExpr*

An expression that represents uint64 enum values.

__init__(*name: str*) → None
Create an expression to reference a uint64 enum value.

Parameters **name** – The name of the enum value.

type_of()
Get the return type of this expression.

pyteal.**Eq**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Equality expression.

Checks if left == right.

Parameters

- **left** – A value to check.
- **right** – The other value to check. Must evaluate to the same type as left.

class pyteal.**Err**
Bases: *pyteal.LeafExpr*

Expression that causes the program to immediately fail when executed.

type_of()
Get the return type of this expression.

class pyteal.**Expr**
Bases: abc.ABC

Abstract base class for PyTeal expressions.

And(*other: pyteal.Expr*) → pyteal.Expr
Take the logical And of this expression and another one.

This expression must evaluate to uint64.

This is the same as using *And()* with two arguments.

Or(*other: pyteal.Expr*) → pyteal.Expr
Take the logical Or of this expression and another one.

This expression must evaluate to uint64.

This is the same as using *Or()* with two arguments.

type_of() → pyteal.TealType
Get the return type of this expression.

pyteal.**Ge**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Greater than or equal to expression.

Checks if left >= right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**Global**(*field: pyteal.GlobalField*)
Bases: *pyteal.LeafExpr*

An expression that accesses a global property.

classmethod current_application_id() → pyteal.Global
Get the ID of the current application executing.

Fails if no application is executing.

classmethod group_size() → pyteal.Global
Get the number of transactions in this atomic transaction group.

This will be at least 1.

classmethod latest_timestamp() → pyteal.Global
Get the latest confirmed block UNIX timestamp.

Fails if negative.

classmethod logic_sig_version() → pyteal.Global
Get the maximum supported TEAL version.

classmethod max_txn_life() → pyteal.Global
Get the maximum number of rounds a transaction can have.

classmethod min_balance() → pyteal.Global
Get the minumum balance in micro Algos.

classmethod min_txn_fee() → pyteal.Global
Get the minumum transaction fee in micro Algos.

classmethod round() → pyteal.Global
Get the current round number.

type_of()
Get the return type of this expression.

classmethod zero_address() → pyteal.Global
Get the 32 byte zero address.

class pyteal.**GlobalField**(*id: int*, *name: str*, *type: pyteal.TealType*)
Bases: enum.Enum

An enumeration.

current_app_id = (8, 'CurrentApplicationID', <TealType.uint64: 0>)

group_size = (4, 'GroupSize', <TealType.uint64: 0>)

latest_timestamp = (7, 'LatestTimestamp', <TealType.uint64: 0>)

logic_sig_version = (5, 'LogicSigVersion', <TealType.uint64: 0>)

max_txn_life = (2, 'MaxTxnLife', <TealType.uint64: 0>)

min_balance = (1, 'MinBalance', <TealType.uint64: 0>)

min_txn_fee = (0, 'MinTxnFee', <TealType.uint64: 0>)

round = (6, 'Round', <TealType.uint64: 0>)

type_of() → pyteal.TealType

zero_address = (3, 'ZeroAddress', <TealType.bytes: 1>)

pyteal.**Gt**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Greater than expression.

Checks if left > right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**GtxnExpr**(*txnIndex: int*, *field: pyteal.TxnField*)
Bases: *pyteal.TxnExpr*

An expression that accesses a transaction field from a transaction in the current group.

class pyteal.**GtxnaExpr**(*txnIndex: int*, *field: pyteal.TxnField*, *index: int*)
Bases: *pyteal.TxnaExpr*

An expression that accesses a transaction array field from a transaction in the current group.

class pyteal.**If**(*cond: pyteal.Expr*, *thenBranch: pyteal.Expr*, *elseBranch: pyteal.Expr = None*)
Bases: *pyteal.Expr*

Simple two-way conditional expression.

__init__(*cond: pyteal.Expr*, *thenBranch: pyteal.Expr*, *elseBranch: pyteal.Expr = None*) → None
Create a new If expression.

When this If expression is executed, the condition will be evaluated, and if it produces a true value, thenBranch will be executed and used as the return value for this expression. Otherwise, elseBranch will be executed and used as the return value, if it is provided.

Parameters

- **cond** – The condition to check. Must evaluate to uint64.
- **thenBranch** – Expression to evaluate if the condition is true.
- **elseBranch** (*optional*) – Expression to evaluate if the condition is false. Must evaluate to the same type as thenBranch, if provided. Defaults to None.

type_of()
Get the return type of this expression.

class pyteal.**Int**(*value: int*)
Bases: *pyteal.LeafExpr*

An expression that represents a uint64.

__init__(*value: int*) → None
Create a new uint64.

Parameters **value** – The integer value this uint64 will represent. Must be a positive value less than 2**64.

type_of()
Get the return type of this expression.

pyteal.**Itob**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Convert a uint64 string to a byte string.

pyteal.**Keccak256**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the KECCAK-256 hash of a byte string.

pyteal.**Le**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Less than or equal to expression.

Checks if left <= right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**LeafExpr**
Bases: *pyteal.Expr*

Leaf expression base class.

pyteal.**Len**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the length of a byte string.

pyteal.**Lt**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Less than expression.

Checks if left < right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**MaybeValue**(*op: pyteal.Op*, *type: pyteal.TealType*, ***, *immediate_args: List[Union[int, str]] = None*, *args: List[pyteal.Expr] = None*)
Bases: *pyteal.LeafExpr*

Represents a get operation returning a value that may not exist.

__init__(*op: pyteal.Op*, *type: pyteal.TealType*, ***, *immediate_args: List[Union[int, str]] = None*, *args: List[pyteal.Expr] = None*)
Create a new MaybeValue.

Parameters

- **op** – The operation that returns values.
- **type** – The type of the returned value.
- **immediate_args** (*optional*) – Immediate arguments for the op. Defaults to None.
- **args** (*optional*) – Stack arguments for the op. Defaults to None.

hasValue() → pyteal.ScratchLoad
Check if the value exists.

This will return 1 if the value exists, otherwise 0.

type_of()
Get the return type of this expression.

value() → pyteal.ScratchLoad
Get the value.

If the value exists, it will be returned. Otherwise, the zero value for this type will be returned (i.e. either 0 or an empty byte string, depending on the type).

pyteal.**Minus**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Subtract two numbers.

Produces left - right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

pyteal.**Mod**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Modulo expression.

Produces left % right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**Mode**
Bases: enum.Flag

Enum of program running modes.

Application = 2

Signature = 1

pyteal.**Mul**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Multiply two numbers.

Produces left * right.

Parameters

- **left** – Must evaluate to uint64.
- **right** – Must evaluate to uint64.

class pyteal.**NaryExpr**(*op: pyteal.Op, inputType: pyteal.TealType, outputType: pyteal.TealType, args: Sequence[pyteal.Expr]*)
Bases: *pyteal.Expr*

N-ary expression base class.

This type of expression takes an arbitrary number of arguments.

type_of()
Get the return type of this expression.

pyteal.**Neq**(*left: pyteal.Expr*, *right: pyteal.Expr*) → pyteal.BinaryExpr
Difference expression.

Checks if left != right.

Parameters

- **left** – A value to check.
- **right** – The other value to check. Must evaluate to the same type as left.

class pyteal.**Nonce**(*base: str*, *nonce: str*, *child: pyteal.Expr*)
Bases: *pyteal.Expr*

A meta expression only used to change the hash of a TEAL program.

__init__(*base: str*, *nonce: str*, *child: pyteal.Expr*) → None
Create a new Nonce.

The Nonce expression behaves exactly like the child expression passed into it, except it uses the provided nonce string to alter its structure in a way that does not affect execution.

Parameters

- **base** – The base of the nonce. Must be one of utf8, base16, base32, or base64.
- **nonce** – An arbitrary nonce string that conforms to base.
- **child** – The expression to wrap.

type_of()
Get the return type of this expression.

pyteal.**Not**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the logical inverse of a uint64.

If the argument is 0, then this will produce 1. Otherwise this will produce 0.

class pyteal.**OnComplete**
Bases: object

An enum of values that *TxnObject.on_completion()* may return.

ClearState = <pyteal.EnumInt object>

CloseOut = <pyteal.EnumInt object>

DeleteApplication = <pyteal.EnumInt object>

NoOp = <pyteal.EnumInt object>

OptIn = <pyteal.EnumInt object>

UpdateApplication = <pyteal.EnumInt object>

class pyteal.**Op**(*value: str*, *mode: pyteal.Mode*)
Bases: enum.Enum

Enum of program opcodes.

add = '+'

addr = 'addr'

addw = 'addw'

app_global_del = 'app_global_del'

app_global_get = 'app_global_get'

app_global_get_ex = 'app_global_get_ex'

app_global_put = 'app_global_put'

app_local_del = 'app_local_del'

```
app_local_get = 'app_local_get'
app_local_get_ex = 'app_local_get_ex'
app_local_put = 'app_local_put'
app_opted_in = 'app_opted_in'
arg = 'arg'
asset_holding_get = 'asset_holding_get'
asset_params_get = 'asset_params_get'
b = 'b'
balance = 'balance'
bitwise_and = '&'
bitwise_not = '~'
bitwise_or = '|'
bitwise_xor = '^'
bnz = 'bnz'
btoi = 'btoi'
byte = 'byte'
bz = 'bz'
concat = 'concat'
div = '/'
dup = 'dup'
dup2 = 'dup2'
ed25519verify = 'ed25519verify'
eq = '=='
err = 'err'
ge = '>='
global_ = 'global'
gt = '>'
gtxn = 'gtxn'
gtxna = 'gtxna'
int = 'int'
itob = 'itob'
keccak256 = 'keccak256'
le = '<='
len = 'len'
load = 'load'
logic_and = '&&'
```

logic_not = '!'

logic_or = '||'

lt = '<'

minus = '-'

mod = '%'

mul = '*'

mulw = 'mulw'

neq = '!='

pop = 'pop'

return_ = 'return'

sha256 = 'sha256'

sha512_256 = 'sha512_256'

store = 'store'

substring = 'substring'

substring3 = 'substring3'

txn = 'txn'

txna = 'txna'

pyteal.**Or**(**args*) → pyteal.NaryExpr
Logical or expression.

Produces 1 if any argument is nonzero. Otherwise produces 0.

All arguments must be PyTeal expressions that evaluate to uint64, and there must be at least two arguments.

pyteal.**Pop**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Pop a value from the stack.

pyteal.**Return**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Immediately exit the program with the given success value.

class pyteal.**ScratchLoad**(*slot: pyteal.ScratchSlot*, *type: pyteal.TealType* = <*TealType.anytype: 2*>)
Bases: *pyteal.Expr*

Expression to load a value from scratch space.

__init__(*slot: pyteal.ScratchSlot*, *type: pyteal.TealType* = <*TealType.anytype: 2*>)
Create a new ScratchLoad expression.

Parameters

- **slot** – The slot to load the value from.
- **type** (*optional*) – The type being loaded from this slot, if known. Defaults to TealType.anytype.

type_of()
Get the return type of this expression.

class pyteal.**ScratchSlot**
Bases: object

Represents the allocation of a scratch space slot.

load(*type: pyteal.TealType = <TealType.anytype: 2>*)
Get an expression to load a value from this slot.

Parameters **type** (*optional*) – The type being loaded from this slot, if known. Defaults to TealType.anytype.

slotId = 0

store()
Get an expression to store a value in this slot.

class pyteal.**ScratchStore**(*slot: pyteal.ScratchSlot*)
Bases: *pyteal.Expr*

Expression to store a value in scratch space.

__init__(*slot: pyteal.ScratchSlot*)
Create a new ScratchStore expression.

Parameters **slot** – The slot to store the value in.

type_of()
Get the return type of this expression.

class pyteal.**Seq**(*exprs: List[pyteal.Expr]*)
Bases: *pyteal.Expr*

A control flow expression to represent a sequence of expressions.

__init__(*exprs: List[pyteal.Expr]*)
Create a new Seq expression.

The new Seq expression will take on the return value of the final expression in the sequence.

Parameters **exprs** – The expressions to include in this sequence. All expressions that are not the final one in this list must not return any values.

Example

```
Seq([
    App.localPut(Bytes("key"), Bytes("value")),
    Int(1)
])
```

type_of()
Get the return type of this expression.

pyteal.**Sha256**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the SHA-256 hash of a byte string.

pyteal.**Sha512_256**(*arg: pyteal.Expr*) → pyteal.UnaryExpr
Get the SHA-512/256 hash of a byte string.

class pyteal.**Substring**(*string: pyteal.Expr*, *start: pyteal.Expr*, *end: pyteal.Expr*)
Bases: *pyteal.Expr*

Take a substring of a byte string.

__init__(*string: pyteal.Expr*, *start: pyteal.Expr*, *end: pyteal.Expr*) → None
Create a new Substring expression.

Produces a new byte string consisting of the bytes starting at start up to but not including end.

Parameters

- **string** – The byte string.
- **start** – The starting index for the substring.
- **end** – The ending index for the substring.

type_of()
Get the return type of this expression.

class pyteal.**TealComponent**
Bases: abc.ABC

assemble() → str

assignSlot(*slot: ScratchSlot*, *location: int*)

getSlots() → List[ScratchSlot]

exception pyteal.**TealInputError**(*msg*)
Bases: Exception

exception pyteal.**TealInternalError**(*message: str*)
Bases: Exception

class pyteal.**TealLabel**(*label: str*)
Bases: *pyteal.TealComponent*

assemble() → str

class pyteal.**TealOp**(*op: pyteal.Op*, **args*)
Bases: *pyteal.TealComponent*

assemble() → str

assignSlot(*slot: ScratchSlot*, *location: int*)

getOp() → pyteal.Op

getSlots() → List[ScratchSlot]

class pyteal.**TealType**
Bases: enum.Enum

Teal type enum.

anytype = 2

bytes = 1

none = 3

uint64 = 0

exception pyteal.**TealTypeError**(*actual*, *expected*)
Bases: Exception

class pyteal.**Tmpl**(*op: pyteal.Op*, *type: pyteal.TealType*, *name: str*)
Bases: *pyteal.LeafExpr*

Template expression for creating placeholder values.

classmethod Addr(*placeholder: str*)
Create a new Addr template.

Parameters **placeholder** – The name to use for this template variable. Must start with *TMPL_* and only consist of uppercase alphanumeric characters and underscores.

classmethod Bytes(*placeholder: str*)
Create a new Bytes template.

Parameters placeholder – The name to use for this template variable. Must start with *TMPL_* and only consist of uppercase alphanumeric characters and underscores.

classmethod Int(*placeholder: str*)
Create a new Int template.

Parameters placeholder – The name to use for this template variable. Must start with *TMPL_* and only consist of uppercase alphanumeric characters and underscores.

type_of()
Get the return type of this expression.

class pyteal.**TxnArray**(*txnObject: pyteal.TxnObject*, *accessField: pyteal.TxnField*, *lengthField: pyteal.TxnField*)
Bases: *pyteal.Array*

Represents a transaction array field.

__getitem__(*index: int*) → pyteal.TxnaExpr
Get the value at a given index in this array.

length() → pyteal.TxnExpr
Get the length of the array.

class pyteal.**TxnExpr**(*field: pyteal.TxnField*)
Bases: *pyteal.LeafExpr*

An expression that accesses a transaction field from the current transaction.

type_of()
Get the return type of this expression.

class pyteal.**TxnField**(*id: int*, *name: str*, *type: pyteal.TealType*)
Bases: enum.Enum

An enumeration.

accounts = (28, 'Accounts', <TealType.bytes: 1>)

amount = (8, 'Amount', <TealType.uint64: 0>)

application_args = (26, 'ApplicationArgs', <TealType.bytes: 1>)

application_id = (24, 'ApplicationID', <TealType.uint64: 0>)

approval_program = (30, 'ApprovalProgram', <TealType.bytes: 1>)

asset_amount = (18, 'AssetAmount', <TealType.uint64: 0>)

asset_close_to = (21, 'AssetCloseTo', <TealType.bytes: 1>)

asset_receiver = (20, 'AssetReceiver', <TealType.bytes: 1>)

asset_sender = (19, 'AssetSender', <TealType.bytes: 1>)

clear_state_program = (31, 'ClearStateProgram', <TealType.bytes: 1>)

close_remainder_to = (9, 'CloseRemainderTo', <TealType.bytes: 1>)

config_asset = (33, 'ConfigAsset', <TealType.uint64: 0>)

config_asset_clawback = (44, 'ConfigAssetClawback', <TealType.bytes: 1>)

config_asset_decimals = (35, 'ConfigAssetDecimals', <TealType.uint64: 0>)

config_asset_default_frozen = (36, 'ConfigAssetDefaultFrozen', <TealType.uint64: 0>)

config_asset_freeze = (43, 'ConfigAssetFreeze', <TealType.bytes: 1>)

config_asset_manager = (41, 'ConfigAssetManager', <TealType.bytes: 1>)

config_asset_metadata_hash = (40, 'ConfigAssetMetadataHash', <TealType.bytes: 1>)

config_asset_name = (38, 'ConfigAssetName', <TealType.bytes: 1>)

config_asset_reserve = (42, 'ConfigAssetReserve', <TealType.bytes: 1>)

config_asset_total = (34, 'ConfigAssetTotal', <TealType.uint64: 0>)

config_asset_unit_name = (37, 'ConfigAssetUnitName', <TealType.bytes: 1>)

config_asset_url = (39, 'ConfigAssetURL', <TealType.bytes: 1>)

fee = (1, 'Fee', <TealType.uint64: 0>)

first_valid = (2, 'FirstValid', <TealType.uint64: 0>)

first_valid_time = (3, 'FirstValidTime', <TealType.uint64: 0>)

freeze_asset = (45, 'FreezeAsset', <TealType.uint64: 0>)

freeze_asset_account = (46, 'FreezeAssetAccount', <TealType.bytes: 1>)

freeze_asset_frozen = (47, 'FreezeAssetFrozen', <TealType.uint64: 0>)

group_index = (22, 'GroupIndex', <TealType.uint64: 0>)

last_valid = (4, 'LastValid', <TealType.uint64: 0>)

lease = (6, 'Lease', <TealType.bytes: 1>)

note = (5, 'Note', <TealType.bytes: 1>)

num_accounts = (2, 'NumAccounts', <TealType.uint64: 0>)

num_app_args = (27, 'NumAppArgs', <TealType.uint64: 0>)

on_completion = (25, 'OnCompletion', <TealType.uint64: 0>)

receiver = (7, 'Receiver', <TealType.bytes: 1>)

rekey_to = (32, 'RekeyTo', <TealType.bytes: 1>)

selection_pk = (11, 'SelectionPK', <TealType.bytes: 1>)

sender = (0, 'Sender', <TealType.bytes: 1>)

tx_id = (23, 'TxID', <TealType.bytes: 1>)

type = (15, 'Type', <TealType.bytes: 1>)

type_enum = (16, 'TypeEnum', <TealType.uint64: 0>)

type_of() → pyteal.TealType

vote_first = (12, 'VoteFirst', <TealType.uint64: 0>)

vote_key_dilution = (14, 'VoteKeyDilution', <TealType.uint64: 0>)

vote_last = (13, 'VoteLast', <TealType.uint64: 0>)

vote_pk = (10, 'VotePK', <TealType.bytes: 1>)

xfer_asset = (17, 'XferAsset', <TealType.uint64: 0>)

class pyteal.**TxnGroup**
Bases: object

Represents a group of transactions.

__getitem__(*txnIndex: int*) → pyteal.TxnObject

class pyteal.**TxnObject**(*txnType: Callable[[pyteal.TxnField], pyteal.TxnExpr], txnaType: Callable[[pyteal.TxnField, int], pyteal.TxnaExpr]*)
Bases: object

Represents a transaction and its fields.

accounts
Application call accounts array.

Type *TxnArray*

amount() → pyteal.TxnExpr
Get the amount of the transaction in micro Algos.

Only set when *type_enum()* is *TxnType.Payment*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#amount

application_args
Application call arguments array.

Type *TxnArray*

application_id() → pyteal.TxnExpr
Get the application ID from the ApplicationCall portion of the current transaction.

Only set when *type_enum()* is *TxnType.ApplicationCall*.

approval_program() → pyteal.TxnExpr
Get the approval program.

Only set when *type_enum()* is *TxnType.ApplicationCall*.

asset_amount() → pyteal.TxnExpr
Get the amount of the asset being transferred, measured in the asset's units.

Only set when *type_enum()* is *TxnType.AssetTransfer*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#assetamount

asset_close_to() → pyteal.TxnExpr
Get the closeout address of the asset transfer.

Only set when *type_enum()* is *TxnType.AssetTransfer*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#assetcloseto

asset_receiver() → pyteal.TxnExpr
Get the recipient of the asset transfer.

Only set when *type_enum()* is *TxnType.AssetTransfer*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#assetreceiver

asset_sender() → pyteal.TxnExpr
Get the 32 byte address of the subject of clawback.

Only set when *type_enum()* is *TxnType.AssetTransfer*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#assetsender

clear_state_program() → pyteal.TxnExpr
Get the clear state program.

Only set when *type_enum()* is *TxnType.ApplicationCall*.

close_remainder_to() → pyteal.TxnExpr
Get the 32 byte address of the CloseRemainderTo field.

Only set when *type_enum()* is *TxnType.Payment*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#closeremainderto

config_asset() → pyteal.TxnExpr
Get the asset ID in asset config transaction.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#configasset

config_asset_clawback() → pyteal.TxnExpr
Get the 32 byte asset clawback address.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#clawbackaddr

config_asset_decimals() → pyteal.TxnExpr
Get the number of digits to display after the decimal place when displaying the asset.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#decimals

config_asset_default_frozen() → pyteal.TxnExpr
Check if the asset's slots are frozen by default or not.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#defaultfrozen

config_asset_freeze() → pyteal.TxnExpr
Get the 32 byte asset freeze address.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#freezeaddr

config_asset_manager() → pyteal.TxnExpr
Get the 32 byte asset manager address.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#manageraddr

config_asset_metadata_hash() → pyteal.TxnExpr
Get the 32 byte commitment to some unspecified asset metdata.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#metadatahash

config_asset_name() → pyteal.TxnExpr
Get the asset name.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#assetname

config_asset_reserve() → pyteal.TxnExpr
Get the 32 byte asset reserve address.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#reserveaddr

config_asset_total() → pyteal.TxnExpr
Get the total number of units of this asset created.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#total

config_asset_unit_name() → pyteal.TxnExpr
Get the unit name of the asset.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#unitname

config_asset_url() → pyteal.TxnExpr
Get the asset URL.

Only set when *type_enum()* is *TxnType.AssetConfig*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#url

fee() → pyteal.TxnExpr
Get the transaction fee in micro Algos.

For more information, see https://developer.algorand.org/docs/reference/transactions/#fee

first_valid() → pyteal.TxnExpr
Get the first valid round number.

For more information, see https://developer.algorand.org/docs/reference/transactions/#firstvalid

freeze_asset() → pyteal.TxnExpr
Get the asset ID being frozen or un-frozen.

Only set when *type_enum()* is *TxnType.AssetFreeze*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#freezeasset

freeze_asset_account() → pyteal.TxnExpr
Get the 32 byte address of the account whose asset slot is being frozen or un-frozen.

Only set when *type_enum()* is *TxnType.AssetFreeze*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#freezeaccount

freeze_asset_frozen() → pyteal.TxnExpr
Get the new frozen value for the asset.

Only set when *type_enum()* is *TxnType.AssetFreeze*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#assetfrozen

group_index() → pyteal.TxnExpr
Get the position of the transaction within the atomic transaction group.

A stand-alone transaction is implictly element 0 in a group of 1.

For more information, see https://developer.algorand.org/docs/reference/transactions/#group

last_valid() → pyteal.TxnExpr
Get the last valid round number.

For more information, see https://developer.algorand.org/docs/reference/transactions/#lastvalid

lease() → pyteal.TxnExpr
Get the transaction lease.

For more information, see https://developer.algorand.org/docs/reference/transactions/#lease

note() → pyteal.TxnExpr
Get the transaction note.

For more information, see https://developer.algorand.org/docs/reference/transactions/#note

on_completion() → pyteal.TxnExpr
Get the on completion action from the ApplicationCall portion of the transaction.

Only set when *type_enum()* is *TxnType.ApplicationCall*.

receiver() → pyteal.TxnExpr
Get the 32 byte address of the receiver.

Only set when *type_enum()* is *TxnType.Payment*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#receiver

rekey_to() → pyteal.TxnExpr
Get the sender's new 32 byte AuthAddr.

For more information, see https://developer.algorand.org/docs/reference/transactions/#rekeyto

selection_pk() → pyteal.TxnExpr
Get the VRF public key.

Only set when *type_enum()* is *TxnType.KeyRegistration*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#selectionpk

sender() → pyteal.TxnExpr
Get the 32 byte address of the sender.

For more information, see https://developer.algorand.org/docs/reference/transactions/#sender

tx_id() → pyteal.TxnExpr
Get the 32 byte computed ID for the transaction.

type() → pyteal.TxnExpr
Get the type of this transaction as a byte string.

In most cases it is preferable to use *type_enum()* instead.

For more information, see https://developer.algorand.org/docs/reference/transactions/#type

type_enum() → pyteal.TxnExpr
Get the type of this transaction.

See *TxnType* for possible values.

vote_first() → pyteal.TxnExpr
Get the first round that the participation key is valid.

Only set when *type_enum()* is *TxnType.KeyRegistration*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#votefirst

vote_key_dilution() → pyteal.TxnExpr
Get the dilution for the 2-level participation key.

Only set when *type_enum()* is *TxnType.KeyRegistration*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#votekeydilution

vote_last() → pyteal.TxnExpr
Get the last round that the participation key is valid.

Only set when *type_enum()* is *TxnType.KeyRegistration*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#votelast

vote_pk() → pyteal.TxnExpr
Get the root participation public key.

Only set when *type_enum()* is *TxnType.KeyRegistration*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#votepk

xfer_asset() → pyteal.TxnExpr
Get the ID of the asset being transferred.

Only set when *type_enum()* is *TxnType.AssetTransfer*.

For more information, see https://developer.algorand.org/docs/reference/transactions/#xferasset

class pyteal.**TxnType**
Bases: object

Enum of all possible transaction types.

ApplicationCall = <pyteal.EnumInt object>

AssetConfig = <pyteal.EnumInt object>

AssetFreeze = <pyteal.EnumInt object>

AssetTransfer = <pyteal.EnumInt object>

KeyRegistration = <pyteal.EnumInt object>

Payment = <pyteal.EnumInt object>

Unknown = <pyteal.EnumInt object>

class pyteal.**TxnaExpr**(*field: pyteal.TxnField*, *index: int*)
Bases: *pyteal.LeafExpr*

An expression that accesses a transaction array field from the current transaction.

type_of()
Get the return type of this expression.

class pyteal.**UnaryExpr**(*op: pyteal.Op*, *inputType: pyteal.TealType*, *outputType: pyteal.TealType*, *arg: pyteal.Expr*)
Bases: *pyteal.Expr*

An expression with a single argument.

type_of()
Get the return type of this expression.

pyteal.**compileTeal**(*ast: pyteal.Expr*, *mode: pyteal.Mode*) → str
Compile a PyTeal expression into TEAL assembly.

Parameters **ast** – The PyTeal expression to assemble.

Returns A TEAL assembly program compiled from the input expression.

Return type str

pyteal.**execute**(*args*)

Execute in bash, return stdout and stderr in string

Arguments: args: command and arguments to run, e.g. [‘ls’, ‘-l’]

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