OP CHECKSIG

From Bitcoin

OP_CHECKSIG is script opcode used to verify that the signature for a tx input is valid. OP_CHECKSIG expects two values to be on the stack, these are, in order of stack depth, the public key and the signature of the script. These two values are normally obtained by running the scriptSig script of the transaction input we are attempting to validate. After the scriptSig script is run the script is deleted but the stack is left as is, and then then scriptPubKey script from the previous transaction output that is now being spent is run, generally concluding in an OP_CHECKSIG.

The standard scriptPubKey checks that the public key (actually a hash of) is a particular value, and that OP_CHECKSIG passes.

For normal transaction inputs if the creator of the current transaction can successfully create a ScriptSig signature that uses the right public key for the ScriptPubKey of the transaction output they are attempting to spend, that transaction input is considered valid.

Contents

Parameters

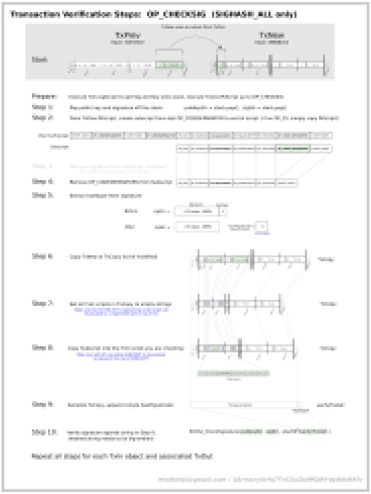
In addition to the script code itself and the stack parameters, to operate OP_CHECKSIG needs to know the current transaction and the index of current transaction input.

How it works

Firstly always this (the default) procedure is applied:

1. the public key and the signature are popped from the stack, in that order. If the hash-type value is 0, then it is replaced by the last_byte of the signature. Then the last byte of the signature is always deleted.
2. A new subscript is created from the instruction from the most recently parsed OP_CODESEPARATOR (last one in script) to the end of the script. If there is no OP_CODESEPARATOR the entire script becomes the subscript (hereby referred to as subScript)
3. The sig is deleted from subScript.

4. All OP_CODESEPARATORS are removed from subScript
5. The hashtype is removed from the last byte of the sig and stored
6. A copy is made of the current transaction (hereby referred to txCopy)
7. The scripts for all transaction inputs in txCopy are set to empty scripts (exactly 1 byte 0x00)
8. The script for the current transaction input in txCopy is set to subScript (lead in by its length as a var-integer encoded!)


Transaction Verification Steps: OP_CHECKSIG (SIGHASH_ALL only)

Signature verification process of the default procedure

Now depending on the hashtype various things can happen to txCopy, these will be discussed individually.

Hashtype Values (from script.h):

Name	Value
SIGHASH_ALL	0x00000001
SIGHASH_NONE	0x00000002
SIGHASH_SINGLE	0x00000003
SIGHASH_ANYONECANPAY	0x00000080

1. If (hashtype&31) = SIGHASH_NONE then apply the SIGHASH_NONE-procedure
2. If (hashtype&31) = SIGHASH_SINGLE then apply the SIGHASH_SINGLE-procedure
3. If hashtype & SIGHASH_ANYONECANPAY then apply the SIGHASH_ANYONECANPAY-procedure

Hence, hashtype SIGHASH_ANYONECANPAY may be applied also after any other hashtype-procedure[1]. Besides the four listed hashtypes only a hashtype of value 0 appears a few types in the (main) block chain (and is handled like SIGHASH_ALL).

Hashtype SIGHASH_ALL (default)

No special further handling occurs in the default case. Think of this as "sign **all** of the outputs." Which is already done by the default procedure.

Procedure for Hashtype SIGHASH_NONE

1. The output of txCopy is set to a vector of zero size.
2. All other inputs aside from the current input in txCopy have their nSequence index set to zero

Think of this as "sign **none** of the outputs-- I don't care where the bitcoins go."

Procedure for Hashtype SIGHASH_SINGLE

1. The output of txCopy is resized to the size of the current input index+1.
2. All other txCopy outputs aside from the output that is the same as the current input index are set to a blank script and a value of (long) -1.
3. All other txCopy inputs aside from the current input are set to have an nSequence index of zero.

Think of this as "sign **one** of the outputs-- I don't care where the other outputs go".

Note: The transaction that uses SIGHASH_SINGLE type of signature should not have more outputs than inputs. However if it does (because of the pre-existing implementation), it shall not be rejected, but instead for every "illegal" input (meaning: an input that has an index bigger than the maximum output index) the node should still verify it, though assuming the hash of 0000000000000000000000000000000000000000000000000000000000000001 [1] (https://bitcointalk.org/index.php?topic=260595.0)

Procedure for Hashtype SIGHASH_ANYONECANPAY

1. The txCopy input vector is resized to a length of one.
2. The subScript (lead in by its length as a var-integer encoded!) is set as the first and only member of this vector.

Think of this as "Let other people add inputs to this transaction, I don't care where the rest of the bitcoins come from."

Final signature check

An array of bytes is constructed from the serialized txCopy appended by four bytes for the hash type. This array is sha256 hashed twice, then the public key is used to check the supplied signature against the hash. The secp256k1 elliptic curve is used for the verification with the given public key.

Return values

OP_CHECKSIG will push true to the stack if the check passed, false otherwise. OP_CHECKSIG_VERIFY leaves nothing on the stack but will cause the script eval to fail immediately if the check does not pass.

Code samples and raw dumps

Taking the first transaction in Bitcoin which is in block number 170, we would get after serialising the transaction but before we hash+sign (or verify) it:

- http://blockexplorer.com/block/00000000d1145790a8694403d4063f323d499e655c83426834d4ce2f8dd4a2ee
- http://blockexplorer.com/tx/f4184fc596403b9d638783cf57adfe4c75c605f6356fbc91338530e9831e9e16

See also libbitcoin (https://gitorious.org/libbitcoin/libbitcoin) for code samples.

```
01 00 00 00              version
01                       number of inputs (var_uint)

input 0:
c9 97 a5 e5 6e 10 41 02  input address hash
fa 20 9c 6a 85 2d d9 06
60 a2 0b 2d 9c 35 24 23
ed ce 25 85 7f cd 37 04
00 00 00 00              input index

48                       size of script (var_uint)
47                       push 71 bytes to stack
30 44 02 20 4e 45 e1 69
32 b8 af 51 49 61 a1 d3
a1 a2 5f df 3f 4f 77 32
e9 d6 24 c6 c6 15 48 ab
5f b8 cd 41 02 20 18 15
22 ec 8e ca 07 de 48 60
a4 ac dd 12 90 9d 83 1c
c5 6c bb ac 46 22 08 22
```

```
21 a8 76 8d 1d 09 01
ff ff ff ff              sequence

02                       number of outputs (var_uint)

output 0:
00 ca 9a 3b 00 00 00 00  amount = 10.00000000
43                       size of script (var_uint)
script for output 0:
41                       push 65 bytes to stack
04 ae 1a 62 fe 09 c5 f5
1b 13 90 5f 07 f0 6b 99
a2 f7 15 9b 22 25 f3 74
cd 37 8d 71 30 2f a2 84
14 e7 aa b3 73 97 f5 54
a7 df 5f 14 2c 21 c1 b7
30 3b 8a 06 26 f1 ba de
d5 c7 2a 70 4f 7e 6c d8
4c
ac                       OP_CHECKSIG

output 1:
00 28 6b ee 00 00 00 00  amount = 40.00000000
43                       size of script (var_uint)
script for output 1:
41                       push 65 bytes to stack
04 11 db 93 e1 dc db 8a
01 6b 49 84 0f 8c 53 bc
1e b6 8a 38 2e 97 b1 48
2e ca d7 b1 48 a6 90 9a
5c b2 e0 ea dd fb 84 cc
f9 74 44 64 f8 2e 16 0b
fa 9b 8b 64 f9 d4 c0 3f
99 9b 86 43 f6 56 b4 12
a3
ac                       OP_CHECKSIG

00 00 00 00              locktime
01 00 00 00              hash_code_type (added on)

result =
01 00 00 00 01 c9 97 a5 e5 6e 10 41 02 fa 20 9c 6a 85 2d d9 06 60 a2 0b 2d 9c 35
24 23 ed ce 25 85 7f cd 37 04 00 00 00 00 43 41 04 11 db 93 e1 dc db 8a 01 6b 49
84 0f 8c 53 bc 1e b6 8a 38 2e 97 b1 48 2e ca d7 b1 48 a6 90 9a 5c b2 e0 ea dd fb
84 cc f9 74 44 64 f8 2e 16 0b fa 9b 8b 64 f9 d4 c0 3f 99 9b 86 43 f6 56 b4 12 a3
ac ff ff ff ff 02 00 ca 9a 3b 00 00 00 00 43 41 04 ae 1a 62 fe 09 c5 f5 1b 13 90
5f 07 f0 6b 99 a2 f7 15 9b 22 25 f3 74 cd 37 8d 71 30 2f a2 84 14 e7 aa b3 73 97
f5 54 a7 df 5f 14 2c 21 c1 b7 30 3b 8a 06 26 f1 ba de d5 c7 2a 70 4f 7e 6c d8 4c
ac 00 28 6b ee 00 00 00 00 43 41 04 11 db 93 e1 dc db 8a 01 6b 49 84 0f 8c 53 bc
1e b6 8a 38 2e 97 b1 48 2e ca d7 b1 48 a6 90 9a 5c b2 e0 ea dd fb 84 cc f9 74 44
64 f8 2e 16 0b fa 9b 8b 64 f9 d4 c0 3f 99 9b 86 43 f6 56 b4 12 a3 ac 00 00 00 00
01 00 00 00
```

To understand where that raw dump has come from, it may be useful to examine tests/ec-key.cpp in libbitcoin (https://gitorious.org/libbitcoin/libbitcoin) ,

libbitcoin (https://gitorious.org/libbitcoin/libbitcoin) has a unit test under tests/ec-key.cpp (make ec-key && ./bin/tests/ec-key). There is also a working OP_CHECKSIG implementation in src/script.cpp under script::op_checksig(). See also the unit test: tests/script-test.cpp

```cpp
#include <iostream>
#include <iomanip>
#include <bitcoin/util/serializer.hpp>
#include <bitcoin/util/elliptic_curve_key.hpp>
#include <bitcoin/util/sha256.hpp>
#include <bitcoin/util/assert.hpp>
#include <bitcoin/util/logger.hpp>
#include <bitcoin/types.hpp>
#include <openssl/ecdsa.h>
#include <openssl/obj_mac.h>
```

```
using libbitcoin::elliptic_curve_key;
using libbitcoin::serializer;
using libbitcoin::hash_digest;
using libbitcoin::data_chunk;
using libbitcoin::log_info;
using libbitcoin::log_fatal;

int main()
{
    serializer ss;
    // blk number 170, tx 1, input 0
    // version = 1
    ss.write_4_bytes(1);
    // 1 inputs
    ss.write_var_uint(1);

    // input 0
    // prevout hash
    ss.write_hash(hash_digest{0x04, 0x37, 0xcd, 0x7f, 0x85, 0x25, 0xce, 0xed, 0x23, 0x24, 0x35, 0x9c, 0x2
    // prevout index
    ss.write_4_bytes(0);

    // input script after running OP_CHECKSIG for this tx is a single
    // OP_CHECKSIG opcode
    data_chunk raw_data;
    raw_data = {0x04, 0x11, 0xdb, 0x93, 0xe1, 0xdc, 0xdb, 0x8a, 0x01, 0x6b, 0x49, 0x84, 0x0f, 0x8c, 0x53,
    data_chunk raw_script;
    raw_script = data_chunk();
    raw_script.push_back(raw_data.size());
    libbitcoin::extend_data(raw_script, raw_data);
    raw_script.push_back(172);
    ss.write_var_uint(raw_script.size());
    ss.write_data(raw_script);
    // sequence
    ss.write_4_bytes(0xffffffff);

    // 2 outputs for this tx
    ss.write_var_uint(2);

    // output 0
    ss.write_8_bytes(1000000000);
    // script for output 0
    raw_data = {0x04, 0xae, 0x1a, 0x62, 0xfe, 0x09, 0xc5, 0xf5, 0x1b, 0x13, 0x90, 0x5f, 0x07, 0xf0, 0x6b,
    // when data < 75, we can just write it's length as a single byte ('special'
    // opcodes)
    raw_script = data_chunk();
    raw_script.push_back(raw_data.size());
    libbitcoin::extend_data(raw_script, raw_data);
    // OP_CHECKSIG
    raw_script.push_back(172);
    // now actually write the script
    ss.write_var_uint(raw_script.size());
    ss.write_data(raw_script);

    // output 1
    ss.write_8_bytes(4000000000);
    // script for output 0
    raw_data = {0x04, 0x11, 0xdb, 0x93, 0xe1, 0xdc, 0xdb, 0x8a, 0x01, 0x6b, 0x49, 0x84, 0x0f, 0x8c, 0x53,
    // when data < 75, we can just write it's length as a single byte ('special'
    raw_script.push_back(raw_data.size());
    libbitcoin::extend_data(raw_script, raw_data);
    // OP_CHECKSIG
    raw_script.push_back(172);
    // now actually write the script
    ss.write_var_uint(raw_script.size());
    ss.write_data(raw_script);

    // End of 2 outputs

    // locktime
    ss.write_4_bytes(0);

    // write hash_type_code
    ss.write_4_bytes(1);

    // Dump hex to screen
    log_info() << "hashing:";
    {
        auto log_obj = log_info();
        log_obj << std::hex;
        for (int val: ss.get_data())
            log_obj << std::setfill('0') << std::setw(2) << val << ' ';
    }
    log_info();

    data_chunk raw_tx = {0x01, 0x00, 0x00, 0x00, 0x01, 0xc9, 0x97, 0xa5, 0xe5, 0x6e, 0x10, 0x41, 0x02, 0x
    BITCOIN_ASSERT(raw_tx == ss.get_data());

    hash_digest tx_hash = libbitcoin::generate_sha256_hash(ss.get_data());

    data_chunk pubkey{0x04, 0x11, 0xdb, 0x93, 0xe1, 0xdc, 0xdb, 0x8a, 0x01, 0x6b, 0x49, 0x84, 0x0f, 0x8c,
    // Leave out last byte since that's the hash_type_code (SIGHASH_ALL in this
    // case)
    data_chunk signature{0x30, 0x44, 0x02, 0x20, 0x4e, 0x45, 0xe1, 0x69, 0x32, 0xb8, 0xaf, 0x51, 0x49, 0x
    BITCOIN_ASSERT(signature.size() == 70);

    elliptic_curve_key key;
    if (!key.set_public_key(pubkey))
    {
        log_fatal() << "unable to set EC public key";
        return -1;
    }

    log_info() << "checksig returns: " << (key.verify(tx_hash, signature) ? "true" : "false");
    return 0;
}
```

References

1. ↑ file src/src/script.cpp in bitcoin-0.7.1 (http://sourceforge.net/projects/bitcoin/files/Bitcoin/bitcoin-0.7.1/bitcoin-0.7.1-linux.tar.gz)

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- This page was last modified on 6 November 2013, at 12:59.
- This page has been accessed 13,152 times.