BITCOIN IMPROVEMENT PROPOSAL 39 · APPLICATIONS · SPECIFICATION · 10 SEPTEMBER 2013

Mnemonic code for generating *deterministic keys*

Marek Palatinus · Pavol Rusnak · Aaron Voisine · Sean Bowe

slush@satoshilabs.com · stick@satoshilabs.com · voisine@gmail.com · ewillbefull@gmail.com

39

Abstract

This BIP describes the implementation of a mnemonic code or mnemonic sentence -- a group of easy to remember words -- for the generation of deterministic wallets.

It consists of two parts: generating the mnemonic and converting it into a binary seed. This seed can be later used to generate deterministic wallets using BIP-0032 or similar methods.

Copyright

This BIP falls under the MIT License.

Motivation

A mnemonic code or sentence is superior for human interaction compared to the handling of raw binary or hexadecimal representations of a wallet seed. The sentence could be written on paper or spoken over the telephone.

This guide is meant to be a way to transport computer-generated randomness with a human-readable transcription. It's not a way to process user-created sentences (also known as brainwallets) into a wallet seed.

Generating the mnemonic

The mnemonic must encode entropy in a multiple of 32 bits. With more entropy security is improved but the sentence length increases. We refer to the initial entropy length as ENT. The allowed size of ENT is 128-256 bits.

First, an initial entropy of ENT bits is generated. A checksum is generated by taking the first `ENT / 32` bits of its SHA256 hash. This checksum is appended to the end of the initial entropy. Next, these concatenated bits are split into groups of 11 bits, each encoding a number from 0-2047, serving as an index into a wordlist. Finally, we convert these numbers into words and use the joined words as a mnemonic sentence.

The following table describes the relation between the initial entropy length (ENT), the checksum length (CS), and the length of the generated mnemonic sentence (MS) in words.

```
CS = ENT / 32
MS = (ENT + CS) / 11

|  ENT  | CS | ENT+CS |  MS  |
+-------+----+--------+------+
|  128  |  4 |   132  |  12  |
|  160  |  5 |   165  |  15  |
|  192  |  6 |   198  |  18  |
|  224  |  7 |   231  |  21  |
|  256  |  8 |   264  |  24  |
```

Wordlist

An ideal wordlist has the following characteristics:

a) smart selection of words

- the wordlist is created in such a way that it's enough to type the first four letters to unambiguously identify the word

b) similar words avoided

- word pairs like "build" and "built", "woman" and "women", or "quick" and "quickly" not only make remembering the sentence difficult but are also more error prone and more difficult to guess

c) sorted wordlists

- the wordlist is sorted which allows for more efficient lookup of the code words (i.e. implementations can use binary search instead of linear search)
- this also allows trie (a prefix tree) to be used, e.g. for better compression

The wordlist can contain native characters, but they must be encoded in UTF-8 using Normalization Form Compatibility Decomposition (NFKD).

From mnemonic to seed

A user may decide to protect their mnemonic with a passphrase. If a passphrase is not present, an empty string "" is used instead.

To create a binary seed from the mnemonic, we use the PBKDF2 function with a mnemonic sentence (in UTF-8 NFKD) used as the password and the string "mnemonic" + passphrase (again in UTF-8 NFKD) used as the salt. The iteration count is set to 2048 and HMAC-SHA512 is used as the pseudo-random function. The length of the derived key is 512 bits (= 64 bytes).

This seed can be later used to generate deterministic wallets using BIP-0032 or similar methods.

The conversion of the mnemonic sentence to a binary seed is completely independent from generating the sentence. This results in a rather simple code; there are no constraints on sentence structure and clients are free to implement their own wordlists or even whole sentence generators, allowing for flexibility in wordlists for typo detection or other purposes.

Although using a mnemonic not generated by the algorithm described in "Generating the mnemonic" section is possible, this is not advised and software must compute a checksum for the mnemonic sentence using a wordlist and issue a warning if it is invalid.

The described method also provides plausible deniability, because every passphrase generates a valid seed (and thus a deterministic wallet) but only the correct one will make the desired wallet available.

Wordlists

Since the vast majority of BIP39 wallets supports only the English wordlist, it is **strongly discouraged** to use non-English wordlists for generating the mnemonic sentences.

If you still feel your application really needs to use a localized wordlist, use one of the following instead of inventing your own.

- Wordlists

Test vectors

The test vectors include input entropy, mnemonic and seed. The passphrase "TREZOR" is used for all vectors.

`https://github.com/trezor/python-mnemonic/blob/master/vectors.json`

Also see `https://github.com/bip32JP/bip32JP.github.io/blob/master/test_JP_BIP39.json`

(Japanese wordlist test with heavily normalized symbols as passphrase)

Shortcomings

Some shortcomings have been identified with this proposal:

- Generated seed depends on the wordlist that was used for the mnemonic. Because the "mnemonic to seed" process uses the mnemonic sentence directly rather than the original entropy, translating the mnemonic to a different wordlist necessarily creates a completely different seed. This is not an issue if you only support the English wordlist, as recommended above.
- Because the seed is generated by hashing the mnemonic, it is not possible to represent an arbitrary BIP-0032 seed via a BIP-0039 sentence: the conversion is one-way only (from BIP-0039 sentence to BIP-0032 seed).
- The checksum is short. This means it only gives modest odds of catching random errors (1-in-256 errors will be missed). It is also not able to provide any assistance in correcting errors.
- No versioning scheme. When originally introduced, there was no way to distinguish the address format that should be used for a BIP-0039 key. This is now largely mitigated by use of descriptor wallets (BIP-0380) in addition to a seed however.

Related Work

The authors of BIP-0039 proposed the SLIP-0039 scheme as an intended successor to BIP-0039 improving on the above shortcomings.

Reference Implementation

Reference implementation including wordlists is available from

`http://github.com/trezor/python-mnemonic`

bip-0039/english.txt

```
abandon   another   basic     broken    champion  convince  decorate  dream     equal     few       gallery   hammer    improve   knee      lunar     model     object    pave      prison    region    safe      shy       speed     surround  tomato    unique    warfare
ability   answer    basket    bronze    change    cook      decrease  dress     equip     fiber     game      hamster   impulse   knife     lunch     modify    oblige    payment   private   regret    sail      sibling   spell     survey    tomorrow  unit      warm
able      antenna   battle    broom     chaos     cool      deer      drift     era       fiction   gap       hand      inch      knock     luxury    mom       obscure   peace     prize     regular   salad     sick      spend     suspect   tone      universe  warrior
about     antique   beach     brother   chapter   copper    defense   drill     erase     field     garage    happy     include   know      lyrics    moment    observe   peanut    problem   reject    salmon    side      sphere    sustain   tongue    unknown   wash
above     anxiety   bean      brown     charge    copy      define    drink     erode     figure    garbage   harbor    income    lab       machine   monitor   obtain    pear      process   relax     salon     siege     spice     swallow   tonight   unlock    wasp
absent    any       beauty    brush     chase     coral     defy      drip      erosion   file      garden    hard      increase  label     mad       monkey    obvious   peasant   produce   release   salt      sight     spider    swamp     tool      until     waste
absorb    apart     because   bubble    chat      core      degree    drive     error     film      garlic    harsh     index     labor     magic     monster   occur     pelican   profit    relief    salute    sign      spike     swap      tooth     unusual   water
abstract  apology   become    buddy     cheap     corn      delay     drop      erupt     filter    garment   harvest   indicate  ladder    magnet    month     ocean     pen       program   rely      same      silent    spin      swarm     top       unveil    wave
absurd    appear    beef      budget    check     correct   deliver   drum      escape    final     gas       hat       indoor    lady      maid      moon      october   penalty   project   remain    sample    silk      spirit    swear     topic     update    way
abuse     apple     before    buffalo   cheese    cost      demand    dry       essay     find      gasp      have      industry  lake      mail      moral     odor      pencil    promote   remember  sand      silly     split     sweet     topple    upgrade   wealth
access    approve   begin     build     chef      cotton    demise    duck      essence   fine      gate      hawk      infant    lamp      main      more      off       people    proof     remind    satisfy   silver    spoil     swift     torch     uphold    weapon
accident  april     behave    bulb      cherry    couch     denial    dumb      estate    finger    gather    hazard    inflict   language  major     morning   offer     pepper    property  remove    satoshi   similar   sponsor   swim      tornado   upon      wear
account   arch      behind    bulk      chest     country   dentist   dune      eternal   finish    gauge     head      inform    laptop    make      mosquito  office    perfect   prosper   render    sauce     simple    spoon     swing     tortoise  upper     weasel
accuse    arctic    believe   bullet    chicken   couple    deny      during    ethics    fire      gaze      health    inhale    large     mammal    mother    often     permit    protect   renew     sausage   since     sport     switch    toss      upset     weather
achieve   area      below     bundle    chief     course    depart    dust      evidence  firm      general   heart     inherit   later     man       motion    oil       person    proud     rent      save      sing      spot      sword     total     urban     web
acid      arena     belt      bunker    child     cousin    depend    dutch     evil      first     genius    heavy     initial   latin     manage    motor     okay      pet       provide   reopen    say       siren     spray     symbol    tourist   urge      wedding
acoustic  argue     bench     burden    chimney   cover     deposit   duty      evoke     fiscal    genre     hedgehog  inject    laugh     mandate   mountain  old       phone     public    repair    scale     sister    spread    symptom   toward    usage     weekend
acquire   arm       benefit   burger    choice    coyote    depth     dwarf     evolve    fish      gentle    height    injury    laundry   mango     mouse     olive     photo     pudding   repeat    scan      situate   spring    syrup     tower     use       weird
across    armed     best      burst     choose    crack     deputy    dynamic   exact     fit       genuine   hello     inmate    lava      mansion   move      olympic   phrase    pull      replace   scare     six       spy       system    town      used      welcome
act       armor     betray    bus       chronic   cradle    derive    eager     example   fitness   gesture   helmet    inner     law       manual    movie     omit      physical  pulp      report    scatter   size      square    table     toy       useful    west
action    army      better    business  chuckle   craft     describe  eagle     excess    fix       ghost     help      innocent  lawn      maple     much      once      piano     pulse     require   scene     skate     squeeze   tackle    track     useless   wet
actor     around    between   busy      chunk     cram      desert    early     exchange  flag      giant     hen       input     lawsuit   marble    muffin    one       picnic    pumpkin   rescue    scheme    sketch    squirrel  tag       trade     usual     whale
actress   arrange   beyond    butter    churn     crane     design    earn      excite    flame     gift      hero      inquiry   layer     march     mule      onion     picture   punch     resemble  school    ski       stable    tail      traffic   utility   what
actual    arrest    bicycle   buyer     cigar     crash     desk      earth     exclude   flash     giggle    hidden    insane    lazy      margin    multiply  online    piece     pupil     resist    science   skill     stadium   talent    tragic    vacant    wheat
adapt     arrive    bid       buzz      cinnamon  crater    despair   easily    excuse    flat      ginger    high      insect    leader    marine    muscle    only      pig       puppy     resource  scissors  skin      staff     talk      train     vacuum    wheel
add       arrow     bike      cabbage   circle    crawl     destroy   east      execute   flavor    giraffe   hill      inside    leaf      market    museum    open      pigeon    purchase  response  scorpion  skirt     stage     tank      transfer  vague     when
addict    art       bind      cabin     citizen   crazy     detail    easy      exercise  flee      girl      hint      inspire   learn     marriage  mushroom  opera     pill      purity    result    scout     skull     stairs    tape      trap      valid     where
address   artefact  biology   cable     city      cream     detect    echo      exhaust   flight    give      hip       install   leave     mask      music     opinion   pilot     purpose   retire    scrap     slab      stamp     target    trash     valley    whip
adjust    artist    bird      cactus    civil     credit    develop   ecology   exhibit   flip      glad      hire      intact    lecture   mass      must      oppose    pink      purse     retreat   screen    slam      stand     task      travel    valve     whisper
admit     artwork   birth     cage      claim     creek     device    economy   exile     float     glance    history   interest  left      master    mutual    option    pioneer   push      return    script    sleep     start     taste     tray      van       wide
adult     ask       bitter    cake      clap      crew      devote    edge      exist     flock     glare     hobby     into      leg       match     myself    orange    pipe      put       reunion   scrub     slender   state     tattoo    treat     vanish    width
advance   aspect    black     call      clarify   cricket   diagram   edit      exit      floor     glass     hockey    invest    legal     material  mystery   orbit     pistol    puzzle    reveal    sea       slice     stay      taxi      tree      vapor     wife
advice    assault   blade     calm      claw      crime     dial      educate   exotic    flower    glide     hold      invite    legend    math      myth      orchard   pitch     pyramid   review    search    slide     steak     teach     trend     various   wild
aerobic   asset     blame     camera    clay      crisp     diamond   effort    expand    fluid     glimpse   hole      involve   leisure   matrix    naive     order     pizza     quality   reward    season    slight    steel     team      trial     vast      will
affair    assist    blanket   camp      clean     critic    diary     egg       expect    flush     globe     holiday   iron      lemon     matter    name      ordinary  place     quantum   rhythm    seat      slim      stem      tell      tribe     vault     win
afford    assume    blast     can       clerk     crop      dice      eight     expire    fly       gloom     hollow    island    lend      maximum   napkin    organ     planet    quarter   rib       second    slogan    step      ten       trick     vehicle   window
afraid    asthma    bleak     canal     clever    cross     diesel    either    explain   foam      glory     home      isolate   length    maze      narrow    orient    plastic   question  ribbon    secret    slot      stereo    tenant    trigger   velvet    wine
again     athlete   bless     cancel    click     crouch    diet      elbow     expose    focus     glove     honey     issue     lens      meadow    nasty     original  plate     quick     rice      section   slow      stick     tennis    trim      vendor    wing
age       atom      blind     candy     client    crowd     differ    elder     express   fog       glow      hood      item      leopard   mean      nation    orphan    play      quit      rich      security  slush     still     tent      trip      venture   wink
agent     attack    blood     cannon    cliff     crucial   digital   electric  extend    foil      glue      hope      ivory     lesson    measure   nature    ostrich   please    quiz      ride      seed      small     sting     term      trophy    venue     winner
agree     attend    blossom   canoe     climb     cruel     dignity   elegant   extra     fold      goat      horn      jacket    letter    meat      near      other     pledge    quote     ridge     seek      smart     stock     test      trouble   verb      winter
ahead     attitude  blouse    canvas    clinic    cruise    dilemma   element   eye       follow    goddess   horror    jaguar    level     mechanic  neck      outdoor   pluck     rabbit    rifle     segment   smile     stomach   text      truck     verify    wire
aim       attract   blue      canyon    clip      crumble   dinner    elephant  eyebrow   food      gold      horse     jar       liar      medal     need      outer     plug      raccoon   right     select    smoke     stone     thank     true      version   wisdom
air       auction   blur      capable   clock     crunch    dinosaur  elevator  fabric    foot      good      hospital  jazz      liberty   media     negative  output    plunge    race      rigid     sell      smooth    stool     that      truly     very      wise
airport   audit     blush     capital   clog      crush     direct    elite     face      force     goose     host      jealous   library   melody    neglect   outside   poem      rack      ring      seminar   snack     story     theme     trumpet   vessel    wish
aisle     august    board     captain   close     cry       dirt      else      faculty   forest    gorilla   hotel     jeans     license   melt      neither   oval      poet      radar     riot      senior    snake     stove     then      trust     veteran   witness
alarm     aunt      boat      car       cloth     crystal   disagree  embark    fade      forget    gospel    hour      jelly     life      member    nephew    oven      point     radio     ripple    sense     snap      strategy  theory    truth     viable    wolf
album     author    body      carbon    cloud     cube      discover  embody    faint     fork      gossip    hover     jewel     lift      memory    nerve     over      polar     rail      risk      sentence  sniff     street    there     try       vibrant   woman
alcohol   auto      boil      card      clown     culture   disease   embrace   faith     fortune   govern    hub       job       light     mention   nest      own       pole      rain      ritual    series    snow      strike    they      tube      vicious   wonder
alert     autumn    bomb      cargo     club      cup       dish      emerge    fall      forum     gown      huge      join      like      menu      net       owner     police    raise     rival     service   soap      strong    thing     tuition   victory   wood
alien     average   bone      carpet    clump     cupboard  dismiss   emotion   false     forward   grab      human     joke      limb      mercy     network   oxygen    pond      rally     river     session   soccer    struggle  this      tumble    video     wool
all       avocado   bonus     carry     cluster   curious   disorder  employ    fame      fossil    grace     humble    journey   limit     merge     neutral   oyster    pony      ramp      road      settle    social    student   thought   tuna      view      word
alley     avoid     book      cart      clutch    current   display   empower   family    foster    grain     humor     joy       link      merit     never     ozone     pool      ranch     roast     setup     sock      stuff     three     tunnel    village   work
allow     awake     boost     case      coach     curtain   distance  empty     famous    found     grant     hundred   judge     lion      merry     news      pact      popular   random    robot     seven     soda      stumble   thrive    turkey    vintage   world
almost    aware     border    cash      coast     curve     divert    enable    fan       fox       grape     hungry    juice     liquid    mesh      next      paddle    portion   range     robust    shadow    soft      style     throw     turn      violin    worry
alone     away      boring    casino    coconut   cushion   divide    enact     fancy     fragile   grass     hunt      jump      list      message   nice      page      position  rapid     rocket    shaft     solar     subject   thumb     turtle    virtual   worth
alpha     awesome   borrow    castle    code      custom    divorce   end       fantasy   frame     gravity   hurdle    jungle    little    metal     night     pair      possible  rare      romance   shallow   soldier   submit    thunder   twelve    virus     wrap
already   awful    boss      casual    coffee    cute      dizzy     endless   farm      frequent  great     hurry     junior    live      method    noble     palace    post      rate      roof      share     solid     subway    ticket    twenty    visa      wreck
also      awkward  bottom    cat       coil      cycle     doctor    endorse   fashion   fresh     green     hurt      junk      lizard    middle    noise     palm      potato    rather    rookie    shed      solution  success   tide      twice     visit     wrestle
alter     axis      bounce    catalog   coin      dad       document  enemy     fat       friend    grid      husband   just      load      midnight  nominee   panda     pottery   raven     room      shell     solve     such      tiger     twin      visual    wrist
always    baby      box       catch     collect   damage    dog       energy    fatal     fringe    grief     hybrid    kangaroo  loan      milk      noodle    panel     poverty   raw       rose      sheriff   someone   sudden    tilt      twist     vital     write
amateur   bachelor  boy       category  color     damp      doll      enforce   father    frog      grit      ice       keen      lobster   million   normal    panic     powder    razor     rotate    shield    song      suffer    timber    two       vivid     wrong
amazing   bacon     bracket   cattle    column    dance     dolphin   engage    fatigue   front     grocery   icon      keep      local     mimic     north     panther   power     ready     rough     shift     soon      sugar     time      type      vocal     yard
among     badge     brain     caught    combine   danger    domain    engine    fault     frost     group     idea      ketchup   lock      mind      nose      paper     practice  real      round     shine     sorry     suggest   tiny      typical   voice     year
amount    bag       brand     cause     come      daring    donate    enhance   favorite  frown     grow      identify  key       logic     minimum   notable   parade    praise    reason    route     ship      sort      suit      tip       ugly      void      yellow
amused    balance   brass     caution   comfort   dash      donkey    enjoy     feature   frozen    grunt     idle      kick      lonely    minor     note      parent    predict   rebel     royal     shiver    soul      summer    tired     umbrella  volcano   you
analyst   balcony   brave     cave      comic     daughter  donor     enlist    february  fruit     guard     ignore    kid       long      minute    nothing   park      prefer    rebuild   rubber    shock     sound     sun       tissue    unable    volume    young
anchor    ball      bread     ceiling   common    dawn      door      enough    federal   fuel      guess     ill       kidney    loop      miracle   notice    parrot    prepare   recall    rude      shoe      soup      sunny     title     unaware   vote      youth
ancient   bamboo    breeze    celery    company   day       dose      enrich    fee       fun       guide     illegal   kind      lottery   mirror    novel     party     present   receive   rug       shoot     source    sunset    toast     uncle     voyage    zebra
anger     banana    brick     cement    concert   deal      double    enroll    feed      funny     guilt     illness   kingdom   loud      misery    now       pass      pretty    recipe    rule      shop      south     super     tobacco   uncover   wage      zero
angle     banner    bridge    census    conduct   debate    dove      ensure    feel      furnace   guitar    image     kiss      lounge    miss      nuclear   patch     prevent   record    run       short     space     supply    today     under     wagon     zone
angry     bar       brief     century   confirm   debris    draft     enter     female    fury      gun       imitate   kit       love      mistake   number    path      price     recycle   runway    shoulder  spare     supreme   toddler   undo      wait      zoo
animal    barely    bright    cereal    congress  decade    dragon    entire    fence     future    gym       immense   kitchen   loyal     mix       nurse     patient   pride     reduce    rural     shove     spatial   sure      toe       unfair    walk
ankle     bargain   bring     certain   connect   december  drama     entry     festival  gadget    habit     immune    kite      lucky     mixed     nut       patrol    primary   reflect   sad       shrimp    spawn     surface   together  unfold    wall
announce  barrel    brisk     chair     consider  decide    drastic   envelope  fetch     gain      hair      impact    kitten    luggage   mixture   oak       pattern   print     reform    saddle    shrug     speak     surge     toilet    unhappy   walnut
annual    base      broccoli  chalk     control   decline   draw      episode   fever     galaxy    half      impose    kiwi      lumber    mobile    obey      pause     priority  refuse    sadness   shuffle   special   surprise  token     uniform   want
```

MIT License, Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions: The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software. THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.