

REWRITING PYC FILES FOR FUN AND REPRODUCIBILITY

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About me

- RedHatter working on systemd and various open source things
- Fedora contributor working on package build reproducibility
- Long time ago some small contributions to CPython



What is build reproducibility?

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Two angles of motivation:

- Security (independent verification of supply chain security)
- Quality (issues in hardware, build systems, packaging, software)

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- packages are built in a container with no network access
- dependencies are installed as packages
- build process must be deterministic
- operation independent of the environment (e.g. time clamped to `$SOURCE_DATE_EPOCH`)

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To solve issues that cannot be resolved by changing individual packages or tools, we apply a post-build cleanup...

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Fedora now has **add-determinism**

add-determinism runs after the install phase of the package build

```
+ /usr/bin/add-determinism --brp -j2 /builddir/build/BUILD/python-tables-3.10.1-build/BUILDROOT
/.../BUILDROOT/.../tables/misc/__pycache__/__init__.cpython-313.pyc:
    rewriting with normalized contents
/.../BUILDROOT/.../tables/misc/__pycache__/enum.cpython-313.pyc:
    rewriting with normalized contents
...
Scanned 36 directories and 362 files,
    processed 94 inodes,
    94 modified (30 replaced + 64 rewritten),
    0 unsupported format, 0 errors
```

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```

- ~~ownership and mtimes in *.zip, *.jar, and *.a archives~~
- ~~timestamps in javadoc *.html~~
- python *.pyc files

The intro is finally over, phew!

pyc files

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- CPython will (attempt to) write .pyc files every time it loads a .py file
- writing may fail
- Fedora packages include .pyc files for speed and reliability

pyc contents

basic objects

pyc contents

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[VERSION1 VERSION2 MAGIC1 MAGIC2 4–12 byte header]
[object1] [object2] ... [object...]

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an 32-bit integer: ['i' BYTE4 BYTE3 BYTE2 BYTE1]

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[object1] [object2] ... [object...]

Object can be:

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an 64-bit float: ['g' BYTE8 BYTE7 ... BYTE2 BYTE1]

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Object can be:

an 32-bit integer: ['i' BYTE4 BYTE3 BYTE2 BYTE1]

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an 2×64-bit complex: ['y' REAL8 ... REAL1 IMAG8 ... IMAG1]

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a Python integer: ['l' SIZE4 SIZE3 SIZE2 SIZE1

DIGIT1_4 DIGIT1_3 DIGIT1_2 DIGIT1_1
... DIGITn_1]

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DIGIT1_4 DIGIT1_3 DIGIT1_2 DIGIT1_1
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normal string: ['s'/'t'/'u'/'a'/'A' SIZE4 ... SIZE1 CHAR1 ... CHARn]

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normal string: ['s'/'t'/'u'/'a'/'A' SIZE4 ... SIZE1 CHAR1 ... CHARn]

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special Python stuff: ['N'/'F'/'T'/'.'/ 'S']

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New in Python 3.14 — slice objects: [':' [start] [stop] [step]]

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very complex objects

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```
code object: ['c' [ARGCOUNT] [POSONLYARGCOUNT]  
[KWONLYARGCOUNT] ... [FLAGS] [code] [consts] [names] ...  
[filename] [name] [qualname] ...]
```

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code object: ['c' [ARGCOUNT] [POSONLYARGCOUNT]
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[filename] [name] [qualname] ...]

the whole pyc file:

[VERSION1 VERSION2 MAGIC1 MAGIC2 4–12 byte header]
[code]

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[filename] [name] [qualname] ...]

the whole pyc file:

[VERSION1 VERSION2 MAGIC1 MAGIC2 4–12 byte header]
[code [string1] [string2] ... [list ...]]

pyc contents

reference objects

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reference: ['r' BYTE4 ... BYTE1]

pyc contents

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reference: ['r' BYTE4 ... BYTE1]

[HEADER] [object1] [object2 

...

pyc contents

reference objects

reference: ['r' BYTE4 ... BYTE1]

[HEADER] [object1] [object2 

...

[REF 0] ... [object] ... [REF 1]

```

Code "<module>" ▶204/(ref to 204)"<module>" ▶0
  (ref to 22)"/usr/lib/python3.12/site-packages/elftools/construct/adapters.py":1
  argcount=0 posonlyargcount=0 kwnonlyargcount=0 stacksize=5 flags=0
  -code: [560 bytes]
  -consts: (
    1 ▶2,
    ("Adapter" ▶3, "AdaptationError" ▶4, "Pass" ▶5),
    ("int_to_bin" ▶6, "bin_to_int" ▶7, "swap_bytes" ▶8),
    ("FlagsContainer" ▶9, "HexString" ▶10),
    ("BytesIO" ▶11, "decodebytes" ▶12),
  Code (ref to 14)"BitIntegerError"/(ref to 14)"BitIntegerError"
    "/usr/lib/python3.12/site-packages/elftools/construct/adapters.py" ▶22:10
    argcount=0 posonlyargcount=0 kwnonlyargcount=0 stacksize=1 flags=0
    -code: [16 bytes]
    -consts: ("BitIntegerError" ▶14, None)
    -names: ("__name__" ▶16, "__module__" ▶17, "__qualname__" ▶18, "__slots__" ▶19) ▶15
    -locals+names: () ▶20
    -locals+kinds: [] ▶21
    -linetable: [7 bytes]
    -exceptiontable: (ref to 21)[] ▶21,
  (ref to 14)"BitIntegerError",
  Code (ref to 25)"MappingError"/(ref to 25)"MappingError"
    (ref to 22)"/usr/lib/python3.12/site-packages/elftools/construct/adapters.py":12
    argcount=0 posonlyargcount=0 kwnonlyargcount=0 stacksize=1 flags=0
    -code: [16 bytes]
    -consts: ("MappingError" ▶25, None)
    -names: (ref to 15)("__name__" ▶16, "__module__" ▶17, "__qualname__" ▶18, "__slots__" ▶19)
    -locals+names: (ref to 20)()
    -locals+kinds: (ref to 21)[]
    -linetable: (ref to 23)[7 bytes]
    -exceptiontable: (ref to 21)[] ▶21,
  (ref to 25)"MappingError",
  Code (ref to 27)"ConstError"/(ref to 27)"ConstError"
    (ref to 22)"/usr/lib/python3.12/site-packages/elftools/construct/adapters.py":14
    argcount=0 posonlyargcount=0 kwnonlyargcount=0 stacksize=1 flags=0
    -code: [16 bytes]
    -consts: ("ConstError" ▶27, None)
    -names: (ref to 15)("__name__" ▶16, "__module__" ▶17, "__qualname__" ▶18, "__slots__" ▶19) 12 / 16

```

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Solution:

- rewrite the object stream with minimal number of flags and maximal number of references

```

-Code "<module>" ▶204/(ref to 204)"<module>" ▶0
- (ref to 22)"/usr/lib/python3.12/site-packages/elftools/construct/adapters.py":1
+Code "<module>" ▶118/(ref to 118)"<module>"
+ (ref to 20)"/usr/lib/python3.12/site-packages/elftools/construct/adapters.py":1
  argcount=0 posonlyargcount=0 kwonlyargcount=0 stacksize=5 flags=0
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-   ("FlagsContainer" ▶9, "HexString" ▶10),
-   ("BytesIO" ▶11, "decodebytes" ▶12),
-   Code (ref to 14)"BitIntegerError"/(ref to 14)"BitIntegerError"
-     "/usr/lib/python3.12/site-packages/elftools/construct/adapters.py" ▶22:10
+   1 ▶0,
+   ("Adapter" ▶1, "AdaptationError" ▶2, "Pass" ▶3),
+   ("int_to_bin" ▶4, "bin_to_int" ▶5, "swap_bytes" ▶6),
+   ("FlagsContainer" ▶7, "HexString" ▶8),
+   ("BytesIO" ▶9, "decodebytes" ▶10),
+   Code (ref to 12)"BitIntegerError"/(ref to 12)"BitIntegerError"
+     "/usr/lib/python3.12/site-packages/elftools/construct/adapters.py" ▶20:10
    argcount=0 posonlyargcount=0 kwonlyargcount=0 stacksize=1 flags=0
    -code: [16 bytes]
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    -names: ("__name__" ▶16, "__module__" ▶17, "__qualname__" ▶18, "__slots__" ▶19) ▶15
    -locals+names: () ▶20
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    -linetable: []
    -exceptiontable: (ref to 21)[] ▶21,
  (ref to 14)"BitIntegerError",
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+   -linetable: (ref to 19)[]
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- Can we change '[' ←→ '('/')'? (more references, less bytes)
- `add-determinism -p` is useful, but no bytecode decoder
- `diffoscope` should use `marshalparser -p/`
`marshal-parser -p/add-determinism -p`

Links and references

For more info:

- reproducible-builds.org
- [Fedora ReproduciblePackageBuilds Change](#)
- [Flock 2024 Reproducible builds in Fedora](#) talk

Tools:

- github.com/keszybz/add-determinism
- packages.debian.org/sid/dh-strip-nondeterminism
- github.com/fedora-python/marshalparser
- crates.io/crates/marshal-parser