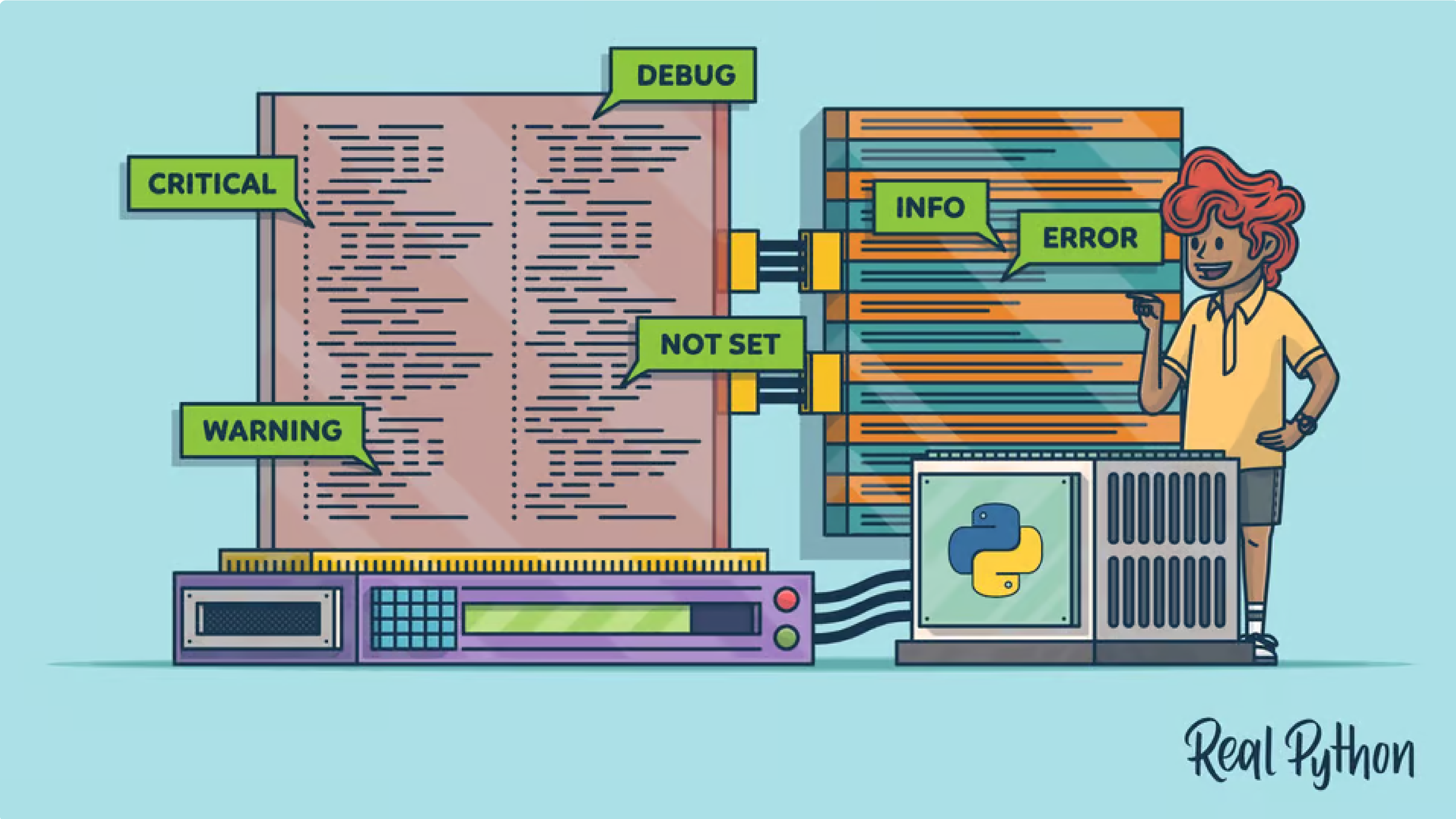

Python Logging: A Stroll Through the Source Code

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Help

The Python `logging` package is a a lightweight but extensible package for keeping better track of what your own code does. Using it gives you much more flexibility than just littering your code with superfluous `print()` calls.

However, Python's `logging` package can be complicated in certain spots. Handlers, loggers, levels, namespaces, filters: it's not easy to keep track of all of these pieces and how they interact.

One way to tie up the loose ends in your understanding of `logging` is to peek under the hood to its CPython source code. The Python code behind `logging` is concise and modular, and reading through it can help you get that *aha* moment.

This article is meant to complement the logging HOWTO document as well as Logging in Python, which is a walkthrough on how to use the package.

By the end of this article, you'll be familiar with the following:

- `logging` levels and how they work
- Thread-safety versus process-safety in `logging`
- The design of `logging` from an OOP perspective
- Logging in libraries vs applications
- Best practices and design patterns for using `logging`

For the most part, we'll go line-by-line down the core module in Python's `logging` package in order to build a picture of how it's laid out.

How to Follow Along

Because the `logging` source code is central to this article, you can assume that any code block or link is based on a specific commit in the Python 3.7 CPython repository, namely commit `d730719`. You can find the `logging` package itself in the `Lib/` directory within the CPython source.

Within the `logging` package, most of the heavy lifting occurs within `logging/__init__.py`, which is the file you'll spend the most time on here:

```
cpython/
│
├── Lib/
│   ├── logging/
│   │   ├── __init__.py
│   │   ├── config.py
│   │   └── handlers.py
│   ├── ...
├── Modules/
├── Include/
...
... [truncated]
```

With that, let's jump in.

Preliminaries

Before we get to the heavyweight classes, the top hundred lines or so of `__init__.py` introduce a few subtle but important concepts.

Preliminary #1: A Level Is Just an `int`!

Objects like `logging.INFO` or `logging.DEBUG` can seem a bit opaque. What are these variables internally, and how are they defined?

In fact, the uppercase constants from Python's `logging` are just integers, forming an enum-like collection of numerical levels:

Python

```python
CRITICAL = 50
FATAL = CRITICAL
ERROR = 40
WARNING = 30
WARN = WARNING
INFO = 20
DEBUG = 10
NOTSET = 0
```

Why not just use the strings `"INFO"` or `"DEBUG"`? Levels are `int` constants to allow for the simple, unambiguous comparison of one level with another. They are given names as well to lend them semantic meaning. Saying that a message has a severity of 50 may not be immediately clear, but saying that it has a level of `CRITICAL` lets you know that you've got a flashing red light somewhere in your program.

Now, technically, you can pass just the `str` form of a level in some places, such as `logger.setLevel("DEBUG")`. Internally, this will call `_checkLevel()`, which ultimately does a `dict` lookup for the corresponding `int`:

Python

```python
_nameToLevel = {
    'CRITICAL': CRITICAL,
    'FATAL': FATAL,
    'ERROR': ERROR,
    'WARN': WARNING,
    'WARNING': WARNING,
    'INFO': INFO,
    'DEBUG': DEBUG,
    'NOTSET': NOTSET,
}

def _checkLevel(level):
    if isinstance(level, int):
        rv = level
    elif str(level) == level:
        if level not in _nameToLevel:
            raise ValueError("Unknown level: %r" % level)
        rv = _nameToLevel[level]
    else:
        raise TypeError("Level not an integer or a valid string: %r" % level)
    return rv
```

Which should you prefer? I'm not too opinionated on this, but it's notable that the `logging` docs consistently use the form `logging.DEBUG` rather than `"DEBUG"` or `10`. Also, passing the `str` form isn't an option in Python 2, and some `logging` methods such as `logger.isEnabledFor()` will accept only an `int`, not its `str` cousin.

Preliminary #2: Logging Is Thread-Safe, but Not Process-Safe

A few lines down, you'll find the following short code block, which is sneakily critical to the whole package:

Python

```python
import threading

_lock = threading.RLock()

def _acquireLock():
     if _lock:
        _lock.acquire()

def _releaseLock():
    if _lock:
        _lock.release()
```

The `_lock` object is a reentrant lock that sits in the global namespace of the `logging/__init__.py` module. It makes pretty much every object and operation in the entire `logging` package thread-safe, enabling threads to do read and write operations without the threat of a race condition. You can see in the module source code that `_acquireLock()` and `_releaseLock()` are ubiquitous to the module and its classes.

There's something not accounted for here, though: what about process safety? The short answer is that the `logging` module is *not* process safe. This isn't inherently a fault of `logging`—generally, two processes can't write to same file without a lot of proactive effort on behalf of the programmer first.

This means that you'll want to be careful before using classes such as a `logging.FileHandler` with multiprocessing involved. If two processes want to read from and write to the same underlying file concurrently, then you can run into a nasty bug halfway through a long-running routine.

If you want to get around this limitation, there's a thorough recipe in the official Logging Cookbook. Because this entails a decent amount of setup, one alternative is to have each process log to a separate file based on its process ID, which you can grab with `os.getpid()`.

Package Architecture: Logging's MRO

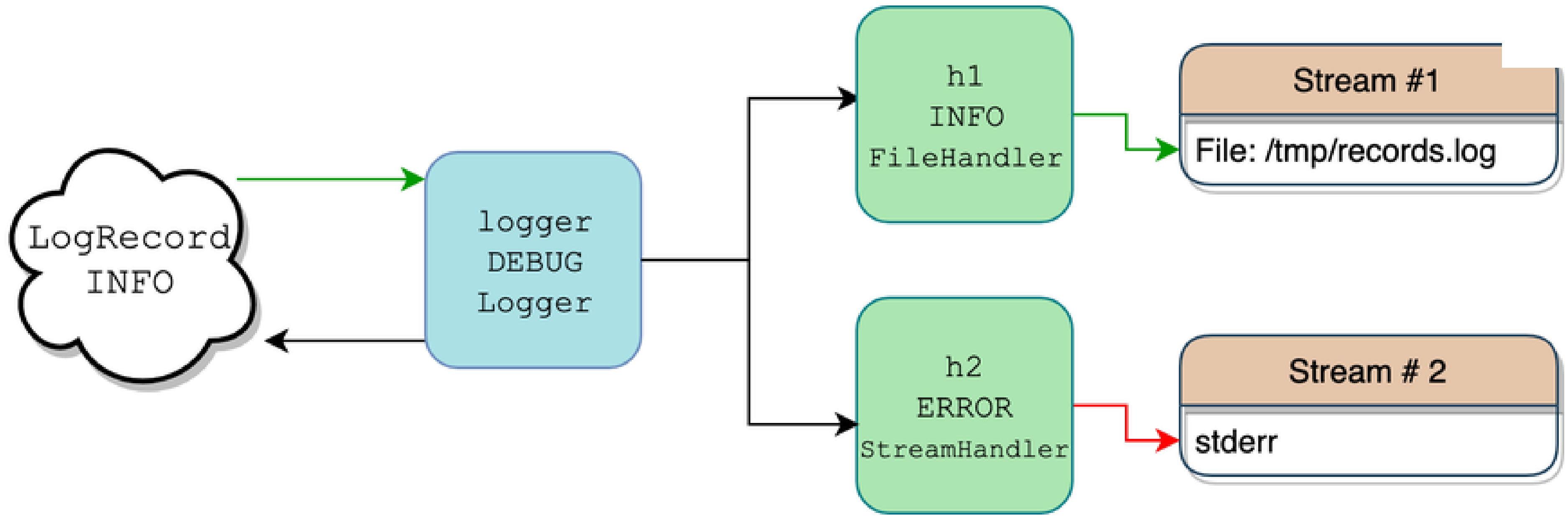
Now that we've covered some preliminary setup code, let's take a high-level look at how `logging` is laid out. The `logging` package uses a healthy dose of OOP and inheritance. Here's a partial look at the method resolution order (MRO) for some of the most important classes in the package:

```
object
│
├── LogRecord
├── Filterer
│   ├── Logger
│   │   └── RootLogger
│   └── Handler
│       ├── StreamHandler
│       └── NullHandler
├── Filter
└── Manager
```

The tree diagram above doesn't cover all of the classes in the module, just those that are most worth highlighting.

> **Note**: You can use the dunder attribute `logging.StreamHandler.__mro__` to see the chain of inheritance. A definitive guide to the MRO can be found in the Python 2 docs, though it is applicable to Python 3 as well.

This litany of classes is typically one source of confusion because there's a lot going on, and it's all jargon-heavy. `Filter` versus `Filterer`? `Logger` versus `Handler`? It can be challenging to keep track of everything, much less visualize how it fits together. A picture is worth a thousand words, so here's a diagram of a scenario where one logger with two handlers attached to it writes a log message with level `logging.INFO`:



Flow of logging objects (Image: Real Python)

In Python code, everything above would look like this:

Python

```
import logging
import sys

logger = logging.getLogger("pylog")
logger.setLevel(logging.DEBUG)
h1 = logging.FileHandler(filename="/tmp/records.log")
h1.setLevel(logging.INFO)
h2 = logging.StreamHandler(sys.stderr)
h2.setLevel(logging.ERROR)
logger.addHandler(h1)
logger.addHandler(h2)
logger.info("testing %d.. %d.. %d..", 1, 2, 3)
```

There's a more detailed map of this flow in the Logging HOWTO. What's shown above is a simplified scenario.

Your code defines just one `Logger` instance, `logger`, along with two `Handler` instances, `h1` and `h2`.

When you call `logger.info("testing %d.. %d.. %d..", 1, 2, 3)`, the `logger` object serves as a filter because it also has a `level` associated with it. Only if the message level is severe enough will the logger do anything with the message. Because the logger has level `DEBUG`, and the message carries a higher `INFO` level, it gets the go-ahead to move on.

Internally, `logger` calls `logger.makeRecord()` to put the message string `"testing %d.. %d.. %d.."` and its arguments `(1, 2, 3)` into a bona fide class instance of a `LogRecord`, which is just a container for the message and its metadata.

The `logger` object looks around for its handlers (instances of `Handler`), which may be tied directly to `logger` itself or to its parents (a concept that we'll touch on later). In this example, it finds two handlers:

1. One with level `INFO` that dumps log data to a file at `/tmp/records.log`
2. One that writes to `sys.stderr` but only if the incoming message is at level `ERROR` or higher

At this point, there's another round of tests that kicks in. Because the `LogRecord` and its message only carry level `INFO`, the record gets written to Handler 1 (green arrow), but not to Handler 2's `stderr` stream (red arrow). For Handlers, writing the `LogRecord` to their stream is called **emitting** it, which is captured in their `.emit()`.

Next, let's further dissect everything from above.

The `LogRecord` Class

What is a `LogRecord`? When you log a message, an instance of the `LogRecord` class is the object you send to be logged. It's created for you by a `Logger` instance and encapsulates all the pertinent info about that event. Internally, it's little more than a wrapper around a `dict` that contains attributes for the record. A `Logger` instance sends a `LogRecord` instance to zero or more `Handler` instances.

The `LogRecord` contains some metadata, such as the following:

1. A name
2. The creation time as a Unix timestamp
3. The message itself
4. Information on what function made the logging call

Here's a peek into the metadata that it carries with it, which you can introspect by stepping through a `logging.error()` call with the [`pdb` module](https://realpython.com/python-debugging-pdb/):

Python

```python
>>> import logging
>>> import pdb

>>> def f(x):
...     logging.error("bad vibes")
...     return x / 0
...
>>> pdb.run("f(1)")
```

After stepping through some higher-level functions, you end up at line 1517:

Shell

```
(Pdb) l
1514                    exc_info = (type(exc_info), exc_info, exc_info.__traceback__)
1515                elif not isinstance(exc_info, tuple):
1516                    exc_info = sys.exc_info()
1517            record = self.makeRecord(self.name, level, fn, lno, msg, args,
1518                                     exc_info, func, extra, sinfo)
1519 ->         self.handle(record)
1520
1521        def handle(self, record):
1522            """
1523            Call the handlers for the specified record.
1524
(Pdb) from pprint import pprint
(Pdb) pprint(vars(record))
{'args': (),
 'created': 1550671851.660067,
 'exc_info': None,
 'exc_text': None,
 'filename': '<stdin>',
 'funcName': 'f',
 'levelname': 'ERROR',
 'levelno': 40,
 'lineno': 2,
 'module': '<stdin>',
 'msecs': 660.067081451416,
 'msg': 'bad vibes',
 'name': 'root',
 'pathname': '<stdin>',
 'process': 2360,
 'processName': 'MainProcess',
 'relativeCreated': 295145.5490589142,
 'stack_info': None,
 'thread': 4372293056,
 'threadName': 'MainThread'}
```

A `LogRecord`, internally, contains a trove of metadata that's used in one way or another.

You'll rarely need to deal with a `LogRecord` directly, since the `Logger` and `Handler` do this for you. It's still worthwhile to know what information is wrapped up in a `LogRecord`, because this is where all that useful info, like the timestamp, come from when you see record log messages.

> **Note**: Below the `LogRecord` class, you'll also find the `setLogRecordFactory()`, `getLogRecordFactory()`, and `makeLogRecord()` factory functions. You won't need these unless you want to use a custom class instead of `LogRecord` to encapsulate log messages and their metadata.

The `Logger` and `Handler` Classes

The `Logger` and `Handler` classes are both central to how `logging` works, and they interact with each other frequently. A `Logger`, a `Handler`, and a `LogRecord` each have a `.level` associated with them.

The `Logger` takes the `LogRecord` and passes it off to the `Handler`, but only if the effective level of the `LogRecord` is equal to or higher than that of the `Logger`. The same goes for the `LogRecord` versus `Handler` test. This is called **level-based filtering**, which `Logger` and `Handler` implement in slightly different ways.

In other words, there is an (at least) two-step test applied before the message that you log gets to go anywhere. In order to be fully passed from a logger to handler and then logged to the end stream (which could be `sys.stdout`, a file, or an email via SMTP), a `LogRecord` must have a level at least as high as *both* the logger and handler.

PEP 282 describes how this works:

> Each `Logger` object keeps track of a log level (or threshold) that it is interested in, and discards log requests below that level. (Source)

So where does this level-based filtering actually occur for both `Logger` and `Handler`?

For the `Logger` class, it's a reasonable first assumption that the logger would compare its `.level` attribute to the level of the `LogRecord`, and be done there. However, it's slightly more involved than that.

Level-based filtering for loggers occurs in `.isEnabledFor()`, which in turn calls `.getEffectiveLevel()`. *Always* use `logger.getEffectiveLevel()` rather than just consulting `logger.level`. The reason has to do with the organization of `Logger` objects in a hierarchical namespace. (You'll see more on this later.)

By default, a `Logger` instance has a level of `0` (`NOTSET`). However, loggers also have **parent loggers**, one of which is the root logger, which functions as the parent of all other loggers. A `Logger` will walk upwards in its hierarchy and get its effective level vis-à-vis its parent (which ultimately may be `root` if no other parents are found).

Here's where this happens in the `Logger` class:

Python

```python
class Logger(Filterer):
    # ...
    def getEffectiveLevel(self):
        logger = self
        while logger:
            if logger.level:
                return logger.level
            logger = logger.parent
        return NOTSET

    def isEnabledFor(self, level):
        try:
            return self._cache[level]
        except KeyError:
            _acquireLock()
            if self.manager.disable >= level:
                is_enabled = self._cache[level] = False
            else:
                is_enabled = self._cache[level] = level >= self.getEffectiveLevel()
            _releaseLock()
        return is_enabled
```

Correspondingly, here's an example that calls the source code you see above:

Python

```python
>>> import logging
>>> logger = logging.getLogger("app")
>>> logger.level  # No!
0
>>> logger.getEffectiveLevel()
30
>>> logger.parent
<RootLogger root (WARNING)>
>>> logger.parent.level
30
```

Here's the takeaway: don't rely on `.level`. If you haven't explicitly set a level on your `logger` object, and you're depending on `.level` for some reason, then your logging setup will likely behave differently than you expected it to.

What about `Handler`? For handlers, the level-to-level comparison is simpler, though it actually happens [in `.callHandlers()`] from the `Logger` class:

Python

```python
class Logger(Filterer):
    # ...
    def callHandlers(self, record):
        c = self
        found = 0
        while c:
            for hdlr in c.handlers:
                found = found + 1
                if record.levelno >= hdlr.level:
                    hdlr.handle(record)
```

For a given `LogRecord` instance (named `record` in the source code above), a logger checks with each of its registered handlers and does a quick check on the `.level` attribute of that `Handler` instance. If the `.levelno` of the `LogRecord` is greater than or equal to that of the handler, only then does the record get passed on. A docstring in `logging` refers to this as "conditionally emit[ting] the specified logging record."

Handlers and the Places They Go Show/Hide

The `Filter` and `Filterer` Classes

Above, we asked the question, "Where does level-based filtering happen?" In answering this question, it's easy to get distracted by the `Filter` and `Filterer` classes. Paradoxically, level-based filtering for `Logger` and `Handler` instances occurs without the help of either of the `Filter` or `Filterer` classes.

`Filter` and `Filterer` are designed to let you add additional function-based filters on top of the level-based filtering that is done by default. I like to think of it as *à la carte* filtering.

`Filterer` is the base class for `Logger` and `Handler` because both of these classes are eligible for receiving additional custom filters that you specify. You add instances of `Filter` to them with `logger.addFilter()` or `handler.addFilter()`, which is what `self.filters` refers to in the following method:

Python

```
class Filterer(object):
    # ...
    def filter(self, record):
        rv = True
        for f in self.filters:
            if hasattr(f, 'filter'):
                result = f.filter(record)
            else:
                result = f(record)
            if not result:
                rv = False
                break
        return rv
```

Given a `record` (which is a `LogRecord` instance), `.filter()` returns `True` or `False` depending on whether that record gets the okay from this class's filters.

Here is `.handle()` in turn, for the `Logger` and `Handler` classes:

Python

```
class Logger(Filterer):
    # ...
    def handle(self, record):
        if (not self.disabled) and self.filter(record):
            self.callHandlers(record)

# ...

class Handler(Filterer):
    # ...
    def handle(self, record):
        rv = self.filter(record)
        if rv:
            self.acquire()
            try:
                self.emit(record)
            finally:
                self.release()
        return rv
```

Neither `Logger` nor `Handler` come with any additional filters by default, but here's a quick example of how you could add one:

Python

```
>>> import logging

>>> logger = logging.getLogger("rp")
>>> logger.setLevel(logging.INFO)
>>> logger.addHandler(logging.StreamHandler())
>>> logger.filters  # Initially empty
[]
>>> class ShortMsgFilter(logging.Filter):
...     """Only allow records that contain long messages (> 25 chars)."""
...     def filter(self, record):
...         msg = record.msg
...         if isinstance(msg, str):
...             return len(msg) > 25
...         return False
...
>>> logger.addFilter(ShortMsgFilter())
>>> logger.filters
[<__main__.ShortMsgFilter object at 0x10c28b208>]
>>> logger.info("Reeeeaaaaallllllly long message")  # Length: 31
Reeeeaaaaallllllly long message
>>> logger.info("Done")  # Length: <25, no output
```

Above, you define a class `ShortMsgFilter` and override its `.filter()`. In `.addHandler()`, you could also just pass a callable, such as a function or lambda or a class that defines `.__call__()`.

The `Manager` Class

There's one more behind-the-scenes actor of `logging` that is worth touching on: the `Manager` class. What matters most is not the `Manager` class but a single instance of it that acts as a container for the growing hierarchy of loggers that are defined across packages. You'll see in the next section how just a single instance of this class is central to gluing the module together and allowing its parts to talk to each other.

The All-Important Root Logger

When it comes to `Logger` instances, one stands out. It's called the root logger:

Python

```
class RootLogger(Logger):
    def __init__(self, level):
        Logger.__init__(self, "root", level)

# ...

root = RootLogger(WARNING)
Logger.root = root
Logger.manager = Manager(Logger.root)
```

The last three lines of this code block are one of the ingenious tricks employed by the `logging` package. Here are a few points:

- The root logger is just a no-frills Python object with the identifier `root`. It has a level of `logging.WARNING` and a `.name` of `"root"`. As far as the class `RootLogger` is concerned, this unique name is all that's special about it.
- The `root` object in turn becomes a class attribute for the `Logger` class. This means that all instances of `Logger`, and the `Logger` class itself, all have a `.root` attribute that is the root logger. This is another example of a singleton-like pattern being enforced in the `logging` package.
- A `Manager` instance is set as the `.manager` class attribute for `Logger`. This eventually comes into play in `logging.getLogger("name")`. The `.manager` does all the facilitation of searching for existing loggers with the name `"name"` and creating them if they don't exist.

The Logger Hierarchy

Everything is a child of `root` in the logger namespace, and I mean everything. That includes loggers that you specify yourself as well as those from third-party libraries that you import.

Remember earlier how the `.getEffectiveLevel()` for our `logger` instances was 30 (`WARNING`) even though we had not explicitly set it? That's because the root logger sits at the top of the hierarchy, and its level is a fallback if any nested loggers have a null level of `NOTSET`:

Python

```python
>>> root = logging.getLogger()  # Or getLogger("")
>>> root
<RootLogger root (WARNING)>
>>> root.parent is None
True
>>> root.root is root  # Self-referential
True
>>> root is logging.root
True
>>> root.getEffectiveLevel()
30
```

The same logic applies to the search for a logger's handlers. The search is effectively a reverse-order search up the tree of a logger's parents.

A Multi-Handler Design

The logger hierarchy may seem neat in theory, but how beneficial is it in practice?

Let's take a break from exploring the `logging` code and foray into writing our own mini-application—one that takes advantage of the logger hierarchy in a way that reduces boilerplate code and keeps things scalable if the project's codebase grows.

Here's the project structure:

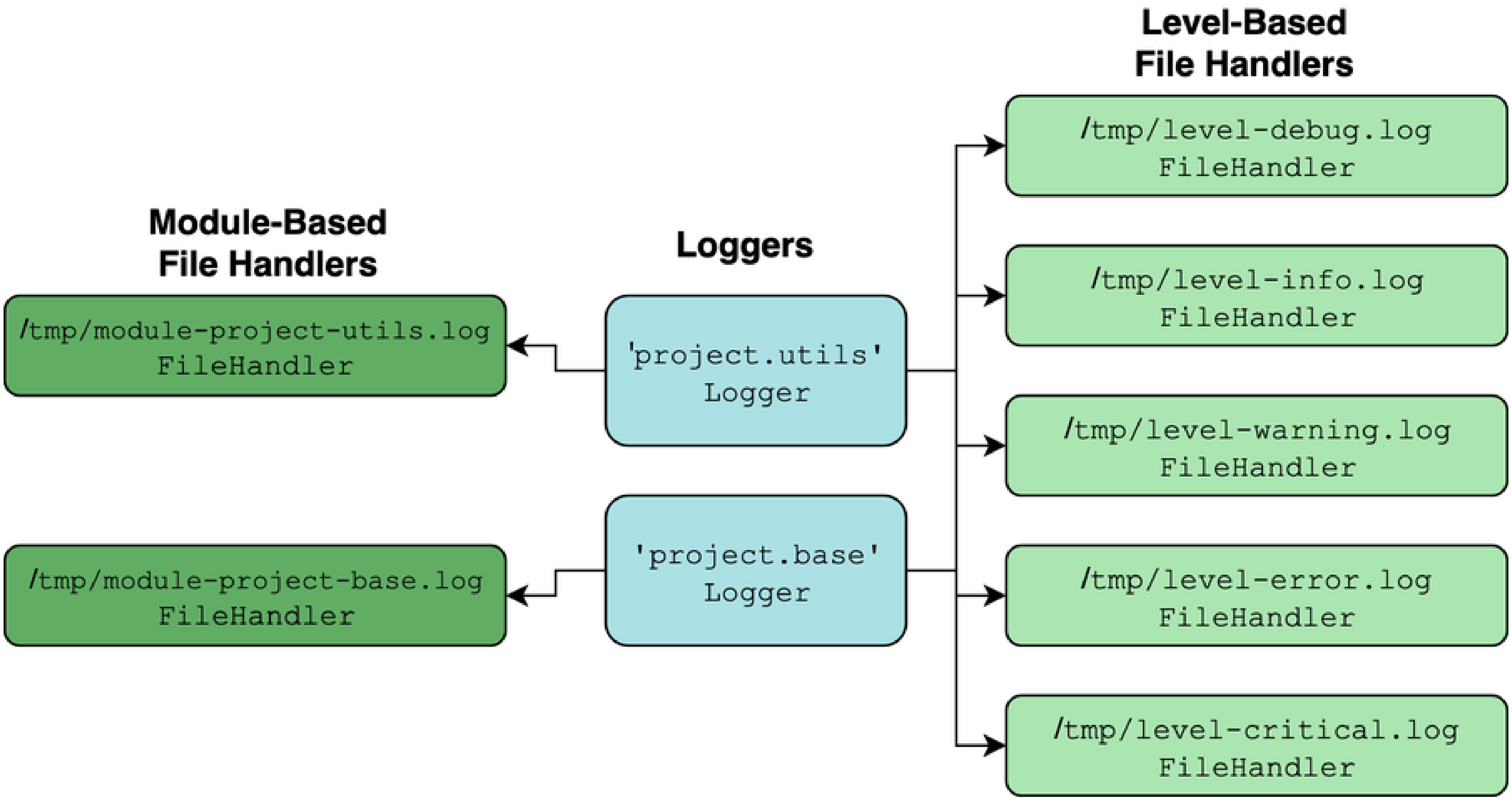
```
project/
│
└── project/
    ├── __init__.py
    ├── utils.py
    └── base.py
```

Don't worry about the application's main functions in `utils.py` and `base.py`. What we're paying more attention to here is the interaction in `logging` objects between the modules in `project/`.

In this case, say that you want to design a multipronged logging setup:

- Each module gets a `logger` with multiple handlers.
- Some of the handlers are shared between different `logger` instances in different modules. These handlers only care about level-based filtering, not the module where the log record emanated from. There is a handler for `DEBUG` messages, one for `INFO`, one for `WARNING`, and so on.
- Each `logger` is also tied to one more additional handler that only receives `LogRecord` instances from that lone `logger`. You can call this a module-based file handler.

Visually, what we're shooting for would look something like this:



A multipronged logging design (Image: Real Python)

The two turquoise objects are instances of `Logger`, established with `logging.getLogger(__name__)` for each module in a package. Everything else is a `Handler` instance.

The thinking behind this design is that it's neatly compartmentalized. You can conveniently look at messages coming from a single logger, or look at messages of a certain level and above coming from any logger or module.

The properties of the logger hierarchy make it suitable for setting up this multipronged logger-handler layout. What does that mean? Here's a concise explanation from the Django documentation:

> Why is the hierarchy important? Well, because loggers can be set to propagate their logging calls to their parents. In this way, you can define a single set of handlers at the root of a logger tree, and capture all logging calls in the subtree of loggers. A logging handler defined in the `project` namespace will catch all logging messages issued on the `project.interesting` and `project.interesting.stuff` loggers. (Source)

The term **propagate** refers to how a logger keeps walking up its chain of parents looking for handlers. The `.propagate` attribute is `True` for a `Logger` instance by default:

Python

```
>>> logger = logging.getLogger(__name__)
>>> logger.propagate
True
```

In `.callHandlers()`, if `propagate` is `True`, each successive parent gets reassigned to the local variable `c` until the hierarchy is exhausted:

Python

```python
class Logger(Filterer):
    # ...
    def callHandlers(self, record):
        c = self
        found = 0
        while c:
            for hdlr in c.handlers:
                found = found + 1
                if record.levelno >= hdlr.level:
                    hdlr.handle(record)
            if not c.propagate:
                c = None
            else:
                c = c.parent
```

Here's what this means: because the `__name__` dunder variable within a package's `__init__.py` module is just the name of the package, a logger there becomes a parent to any loggers present in other modules in the same package.

Here are the resulting `.name` attributes from assigning to `logger` with `logging.getLogger(__name__)`:

Module	`.name` Attribute
`project/__init__.py`	`'project'`
`project/utils.py`	`'project.utils'`
`project/base.py`	`'project.base'`

Because the `'project.utils'` and `'project.base'` loggers are children of `'project'`, they will latch onto not only their own direct handlers but whatever handlers are attached to `'project'`.

Let's build out the modules. First comes `__init__.py`:

Python

```python
# __init__.py
import logging

logger = logging.getLogger(__name__)
logger.setLevel(logging.DEBUG)

levels = ("DEBUG", "INFO", "WARNING", "ERROR", "CRITICAL")
for level in levels:
    handler = logging.FileHandler(f"/tmp/level-{level.lower()}.log")
    handler.setLevel(getattr(logging, level))
    logger.addHandler(handler)

def add_module_handler(logger, level=logging.DEBUG):
    handler = logging.FileHandler(
        f"/tmp/module-{logger.name.replace('.', '-')}.log"
    )
    handler.setLevel(level)
    logger.addHandler(handler)
```

This module is imported when the `project` package is imported. You add a handler for each level in `DEBUG` through `CRITICAL`, then attach it to a single logger at the top of the hierarchy.

You also define a utility function that adds one more `FileHandler` to a logger, where the `filename` of the handler corresponds to the module name where the logger is defined. (This assumes the logger is defined with `__name__`.)

You can then add some minimal boilerplate logger setup in `base.py` and `utils.py`. Notice that you only need to add one additional handler with `add_module_handler()` from `__init__.py`. You don't need to worry about the level-oriented handlers because they are already added to their parent logger named `'project'`:

Python

```python
# base.py
import logging

from project import add_module_handler

logger = logging.getLogger(__name__)
add_module_handler(logger)

def func1():
    logger.debug("debug called from base.func1()")
    logger.critical("critical called from base.func1()")
```

Here's `utils.py`:

Python

```python
# utils.py
import logging

from project import add_module_handler

logger = logging.getLogger(__name__)
add_module_handler(logger)

def func2():
    logger.debug("debug called from utils.func2()")
    logger.critical("critical called from utils.func2()")
```

Let's see how all of this works together from a fresh Python session:

Python

```python
>>> from pprint import pprint
>>> import project
>>> from project import base, utils

>>> project.logger
<Logger project (DEBUG)>
>>> base.logger, utils.logger
(<Logger project.base (DEBUG)>, <Logger project.utils (DEBUG)>)
>>> base.logger.handlers
[<FileHandler /tmp/module-project-base.log (DEBUG)>]
>>> pprint(base.logger.parent.handlers)
[<FileHandler /tmp/level-debug.log (DEBUG)>,
 <FileHandler /tmp/level-info.log (INFO)>,
 <FileHandler /tmp/level-warning.log (WARNING)>,
 <FileHandler /tmp/level-error.log (ERROR)>,
 <FileHandler /tmp/level-critical.log (CRITICAL)>]
>>> base.func1()
>>> utils.func2()
```

You'll see in the resulting log files that our filtration system works as intended. Module-oriented handlers direct one logger to a specific file, while level-oriented handlers direct multiple loggers to a different file:

Shell

```
$ cat /tmp/level-debug.log
debug called from base.func1()
critical called from base.func1()
debug called from utils.func2()
critical called from utils.func2()

$ cat /tmp/level-critical.log
critical called from base.func1()
critical called from utils.func2()

$ cat /tmp/module-project-base.log
debug called from base.func1()
critical called from base.func1()

$ cat /tmp/module-project-utils.log
debug called from utils.func2()
critical called from utils.func2()
```

A drawback worth mentioning is that this design introduces a lot of redundancy. One `LogRecord` instance may go to no less than six files. That's also a non-negligible amount of file I/O that may add up in a performance-critical application.

Now that you've seen a practical example, let's switch gears and delve into a possible source of confusion in `logging`.

The "Why Didn't My Log Message Go Anywhere?" Dilemma

There are two common situations with `logging` when it's easy to get tripped up:

1. You logged a message that seemingly went nowhere, and you're not sure why.
2. Instead of being suppressed, a log message appeared in a place that you didn't expect it to.

Each of these has a reason or two commonly associated with it.

You logged a message that seemingly went nowhere, and you're not sure why.

Don't forget that the **effective** level of a logger for which you don't otherwise set a custom level is `WARNING`, because a logger will walk up its hierarchy until it finds the root logger with its own `WARNING` level:

Python

```python
>>> import logging
>>> logger = logging.getLogger("xyz")
>>> logger.debug("mind numbing info here")
>>> logger.critical("storm is coming")
storm is coming
```

Because of this default, the `.debug()` call goes nowhere.

Instead of being suppressed, a log message appeared in a place that you didn't expect it to.

When you defined your `logger` above, you didn't add any handlers to it. So, why is it writing to the console?

The reason for this is that `logging` sneakily uses a handler called `lastResort` that writes to `sys.stderr` if no other handlers are found:

Python

```python
class _StderrHandler(StreamHandler):
    # ...
    @property
    def stream(self):
        return sys.stderr

_defaultLastResort = _StderrHandler(WARNING)
lastResort = _defaultLastResort
```

This kicks in when a logger goes to find its handlers:

Python

```python
class Logger(Filterer):
    # ...
    def callHandlers(self, record):
        c = self
        found = 0
        while c:
            for hdlr in c.handlers:
                found = found + 1
                if record.levelno >= hdlr.level:
                    hdlr.handle(record)
            if not c.propagate:
                c = None
            else:
                c = c.parent
        if (found == 0):
            if lastResort:
                if record.levelno >= lastResort.level:
                     lastResort.handle(record)
```

If the logger gives up on its search for handlers (both its own direct handlers and attributes of parent loggers), then it picks up the `lastResort` handler and uses that.

There's one more subtle detail worth knowing about. This section has largely talked about the instance methods (methods that a class defines) rather than the module-level functions of the `logging` package that carry the same name.

If you use the functions, such as `logging.info()` rather than `logger.info()`, then something slightly different happens internally. The function calls `logging.basicConfig()`, which adds a `StreamHandler` that writes to `sys.stderr`. In the end, the behavior is virtually the same:

Python

```python
>>> import logging
>>> root = logging.getLogger("")
>>> root.handlers
[]
>>> root.hasHandlers()
False
>>> logging.basicConfig()
>>> root.handlers
[<StreamHandler <stderr> (NOTSET)>]
>>> root.hasHandlers()
True
```

Taking Advantage of Lazy Formatting

It's time to switch gears and take a closer look at how messages themselves are joined with their data. While it's been supplanted by `str.format()` and f-strings, you've probably used Python's percent-style formatting to do something like this:

Python

```python
>>> print("To iterate is %s, to recurse %s" % ("human", "divine"))
To iterate is human, to recurse divine
```

As a result, you may be tempted to do the same thing in a `logging` call:

Python

```
>>> # Bad!  Check out a more efficient alternative below.
>>> logging.warning("To iterate is %s, to recurse %s" % ("human", "divine"))
WARNING:root:To iterate is human, to recurse divine
```

This uses the entire format string and its arguments as the `msg` argument to `logging.warning()`.

Here is the recommended alternative, [straight from the `logging` docs](#):

Python

```
>>> # Better: formatting doesn't occur until it really needs to.
>>> logging.warning("To iterate is %s, to recurse %s", "human", "divine")
WARNING:root:To iterate is human, to recurse divine
```

It looks a little weird, right? This seems to defy the conventions of how percent-style string formatting works, but it's a more efficient function call because the format string gets formatted **lazily** rather than **greedily**. Here's what that means.

The method signature for `Logger.warning()` looks like this:

Python

```
def warning(self, msg, *args, **kwargs)
```

The same applies to the other methods, such as `.debug()`. When you call `warning("To iterate is %s, to recurse %s", "human", "divine")`, both `"human"` and `"divine"` get caught as `*args` and, within the scope of the method's body, `args` is equal to `("human", "divine")`.

Contrast this to the first call above:

Python

```
logging.warning("To iterate is %s, to recurse %s" % ("human", "divine"))
```

In this form, everything in the parentheses gets immediately merged together into `"To iterate is human, to recurse divine"` and passed as `msg`, while `args` is an empty tuple.

Why does this matter? Repeated logging calls can degrade runtime performance slightly, but the `logging` package does its very best to control that and keep it in check. By not merging the format string with its arguments right away, `logging` is delaying the string formatting until the `LogRecord` is requested by a `Handler`.

This happens in [`LogRecord.getMessage()`](#), so only after `logging` deems that the `LogRecord` will actually be passed to a handler does it become its fully merged self.

All that is to say that the `logging` package makes some very fine-tuned performance optimizations in the right places. This may seem like minutia, but if you're making the same `logging.debug()` call a million times inside a loop, and the `args` are function calls, then the lazy nature of how `logging` does string formatting can make a difference.

Before doing any merging of `msg` and `args`, a `Logger` instance will check its `.isEnabledFor()` to see if that merging should be done in the first place.

Functions vs Methods

Towards the bottom of `logging/__init__.py` sit the module-level functions that are advertised up front in the public API of `logging`. You already saw the `Logger` methods such as `.debug()`, `.info()`, and `.warning()`. The top-level functions are wrappers around the corresponding methods of the same name, but they have two important features:

1. They always call their corresponding method from the root logger, `root`.
2. Before calling the root logger methods, they call `logging.basicConfig()` with no arguments if `root` doesn't have any handlers. As you saw earlier, it is this call that sets a `sys.stdout` handler for the root logger.

For illustration, here's `logging.error()`:

Python

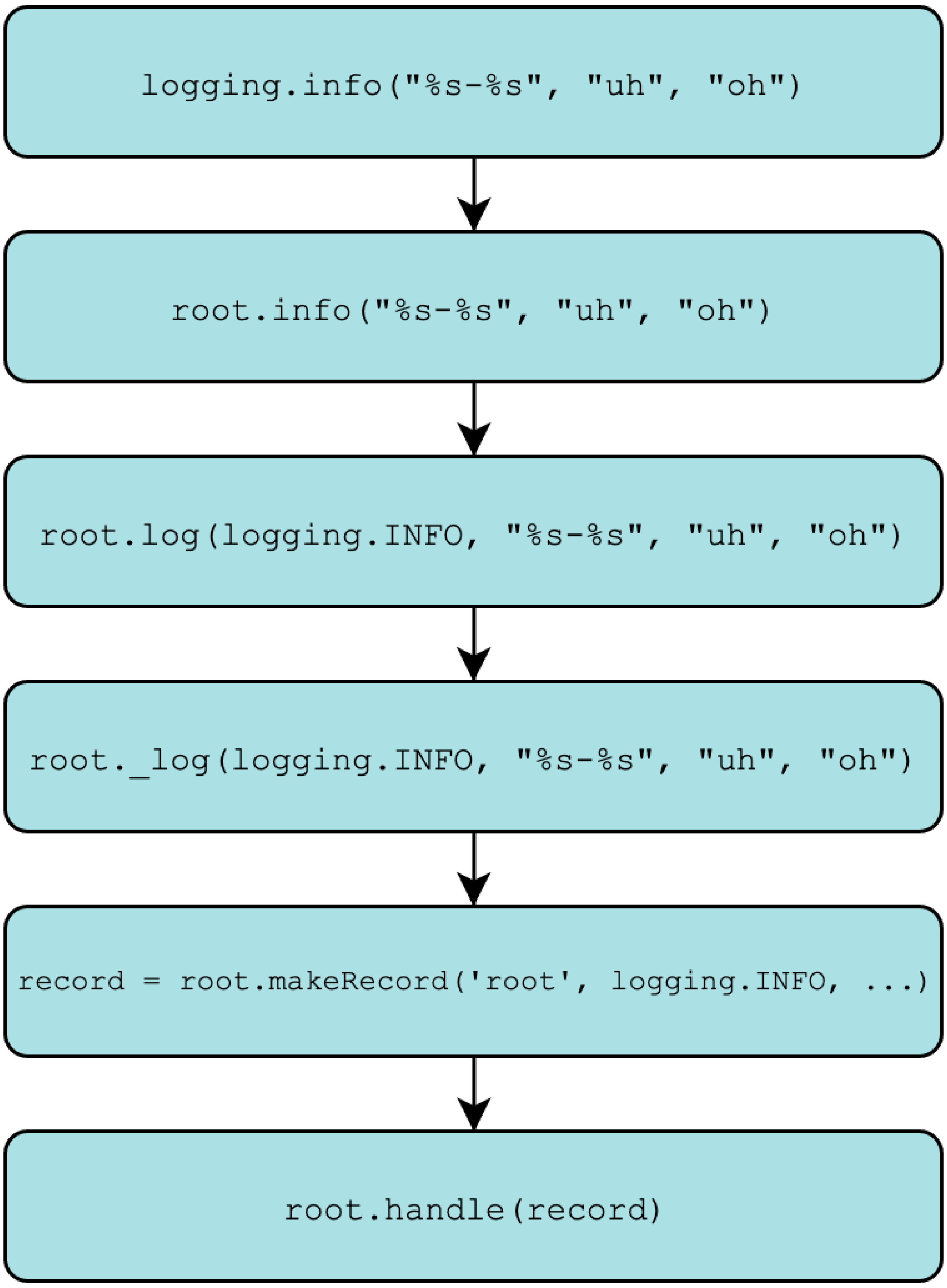
```
def error(msg, *args, **kwargs):
    if len(root.handlers) == 0:
        basicConfig()
    root.error(msg, *args, **kwargs)
```

You'll find the same pattern for `logging.debug()`, `logging.info()`, and the others as well. Tracing the chain of commands is interesting. Eventually, you'll end up at the same place, which is where the internal `Logger._log()` is called.

The calls to `debug()`, `info()`, `warning()`, and the other level-based functions all route to here. `_log()` primarily has two purposes:

1. **Call `self.makeRecord()`:** Make a `LogRecord` instance from the `msg` and other arguments you pass to it.
2. **Call `self.handle()`:** This determines what actually gets done with the record. Where does it get sent? Does it make it there or get filtered out?

Here's that entire process in one diagram:



Internals of a logging call (Image: Real Python)

You can also trace the call stack with `pdb`.

Tracing the Call to logging.warning() Show/Hide

What Does `getLogger()` Really Do?

Also hiding in this section of the source code is the top-level `getLogger()`, which wraps `Logger.manager.getLogger()`:

Python

```
def getLogger(name=None):
    if name:
        return Logger.manager.getLogger(name)
    else:
        return root
```

This is the entry point for enforcing the singleton logger design:

- If you specify a `name`, then the underlying `.getLogger()` does a `dict` lookup on the string `name`. What this comes down to is a lookup in the `loggerDict` of `logging.Manager`. This is a dictionary of all registered loggers, including the intermediate `PlaceHolder` instances that are generated when you reference a logger far down in the hierarchy before referencing its parents.
- Otherwise, `root` is returned. There is only one `root`—the instance of `RootLogger` discussed above.

This feature is what lies behind a trick that can let you peek into all of the registered loggers:

Python

```
>>> import logging
>>> logging.Logger.manager.loggerDict
{}

>>> from pprint import pprint
>>> import asyncio
>>> pprint(logging.Logger.manager.loggerDict)
{'asyncio': <Logger asyncio (WARNING)>,
 'concurrent': <logging.PlaceHolder object at 0x10d153710>,
 'concurrent.futures': <Logger concurrent.futures (WARNING)>}
```

Whoa, hold on a minute. What's happening here? It looks like something changed internally to the `logging` package as a result of an import of another library, and that's exactly what happened.

Firstly, recall that `Logger.manager` is a class attribute, where an instance of `Manager` is tacked onto the `Logger` class. The `manager` is designed to track and manage all of the singleton instances of `Logger`. These are housed in `.loggerDict`.

Now, when you initially import `logging`, this dictionary is empty. But after you import `asyncio`, the same dictionary gets populated with three loggers. This is an example of one module setting the attributes of another module in-place. Sure enough, inside of `asyncio/log.py`, you'll find the following:

Python

```
import logging

logger = logging.getLogger(__package__)  # "asyncio"
```

The key-value pair is set in `Logger.getLogger()` so that the `manager` can oversee the entire namespace of loggers. This means that the object `asyncio.log.logger` gets registered in the logger dictionary that belongs to the `logging` package. Something similar happens in the `concurrent.futures` package as well, which is imported by `asyncio`.

You can see the power of the singleton design in an equivalence test:

Python

```
>>> obj1 = logging.getLogger("asyncio")
>>> obj2 = logging.Logger.manager.loggerDict["asyncio"]
>>> obj1 is obj2
True
```

This comparison illustrates (glossing over a few details) what `getLogger()` ultimately does.

Library vs Application Logging: What Is `NullHandler`?

That brings us to the final hundred or so lines in the `logging/__init__.py` source, where `NullHandler` is defined. Here's the definition in all its glory:

Python

```python
class NullHandler(Handler):
    def handle(self, record):
        pass

    def emit(self, record):
        pass

    def createLock(self):
        self.lock = None
```

The `NullHandler` is all about the distinctions between logging in a library versus an application. Let's see what that means.

A **library** is an extensible, generalizable Python package that is intended for other users to install and set up. It is built by a developer with the express purpose of being distributed to users. Examples include popular open-source projects like NumPy, `dateutil`, and `cryptography`.

An **application** (or app, or program) is designed for a more specific purpose and a much smaller set of users (possibly just one user). It's a program or set of programs highly tailored by the user to do a limited set of things. An example of an application is a Django app that sits behind a web page. Applications commonly use (`import`) libraries and the tools they contain.

When it comes to logging, there are different best practices in a library versus an app.

That's where `NullHandler` fits in. It's basically a do-nothing stub class.

If you're writing a Python library, you really need to do this one minimalist piece of setup in your package's `__init__.py`:

Python

```python
# Place this in your library's uppermost `__init__.py`
# Nothing else!

import logging

logging.getLogger(__name__).addHandler(NullHandler())
```

This serves two critical purposes.

Firstly, a library logger that is declared with `logger = logging.getLogger(__name__)` (without any further configuration) will log to `sys.stderr` by default, even if that's not what the end user wants. This could be described as an opt-out approach, where the end user of the library has to go in and disable logging to their console if they don't want it.

Common wisdom says to use an opt-in approach instead: don't emit any log messages by default, and let the end users of the library determine if they want to further configure the library's loggers and add handlers to them. Here's that philosophy worded more bluntly by the author of the `logging` package, Vinay Sajip:

> A third party library which uses `logging` should not spew logging output by default which may not be wanted by a developer/user of an application which uses it. (Source)

This leaves it up to the library user, not library developer, to incrementally call methods such as `logger.addHandler()` or `logger.setLevel()`.

The second reason that `NullHandler` exists is more archaic. In Python 2.7 and earlier, trying to log a `LogRecord` from a logger that has no handler set would raise a warning. Adding the no-op class `NullHandler` will avert this.

Here's what specifically happens in the line `logging.getLogger(__name__).addHandler(NullHandler())` from above:

1. Python gets (creates) the `Logger` instance with the same name as your package. If you're designing the `calculus` package, within `__init__.py`, then `__name__` will be equal to `'calculus'`.
2. A `NullHandler` instance gets attached to this logger. That means that Python will not default to using the `lastResort` handler.

Keep in mind that any logger created in any of the other `.py` modules of the package will be children of this logger in the logger hierarchy and that, because this handler also belongs to them, they won't need to use the `lastResort` handler and won't default to logging to standard error (`stderr`).

As a quick example, let's say your library has the following structure:

```
calculus/
│
├── __init__.py
└── integration.py
```

In `integration.py`, as the library developer you are free to do the following:

Python

```python
# calculus/integration.py
import logging

logger = logging.getLogger(__name__)

def func(x):
    logger.warning("Look!")
    # Do stuff
    return None
```

Now, a user comes along and installs your library from PyPI via `pip install calculus`. They use `from calculus.integration import func` in some application code. This user is free to manipulate and configure the `logger` object from the library like any other Python object, to their heart's content.

What Logging Does With Exceptions

One thing that you may be wary of is the danger of exceptions that stem from your calls to `logging`. If you have a `logging.error()` call that is designed to give you some more verbose debugging information, but that call itself for some reason raises an exception, that would be the height of irony, right?

Cleverly, if the `logging` package encounters an exception that has to do with logging itself, then it will print the traceback but not raise the exception itself.

Here's an example that deals with a common typo: passing two arguments to a format string that is only expecting one argument. The important distinction is that what you see below is *not* an exception being raised, but rather a prettified printed traceback of the internal exception, which itself was suppressed:

Python

```
>>> logging.critical("This %s has too many arguments", "msg", "other")
--- Logging error ---
Traceback (most recent call last):
  File "lib/python3.7/logging/__init__.py", line 1034, in emit
    msg = self.format(record)
  File "lib/python3.7/logging/__init__.py", line 880, in format
    return fmt.format(record)
  File "lib/python3.7/logging/__init__.py", line 619, in format
    record.message = record.getMessage()
  File "lib/python3.7/logging/__init__.py", line 380, in getMessage
    msg = msg % self.args
TypeError: not all arguments converted during string formatting
Call stack:
  File "<stdin>", line 1, in <module>
Message: 'This %s has too many arguments'
Arguments: ('msg', 'other')
```

This lets your program gracefully carry on with its actual program flow. The rationale is that you wouldn't want an uncaught exception to come from a `logging` call itself and stop a program dead in its tracks.

Tracebacks can be messy, but this one is informative and relatively straightforward. What enables the suppression of exceptions related to `logging` is `Handler.handleError()`. When the handler calls `.emit()`, which is the method where it attempts to log the record, it falls back to `.handleError()` if something goes awry. Here's the implementation of `.emit()` for the `StreamHandler` class:

Python

```
def emit(self, record):
    try:
        msg = self.format(record)
        stream = self.stream
        stream.write(msg + self.terminator)
        self.flush()
    except Exception:
        self.handleError(record)
```

Any exception related to the formatting and writing gets caught rather than being raised, and `handleError` gracefully writes the traceback to `sys.stderr`.

Logging Python Tracebacks

Speaking of exceptions and their tracebacks, what about cases where your program encounters them but should log the exception and keep chugging along in its execution?

Let's walk through a couple of ways to do this.

Here's a contrived example of a lottery simulator using code that isn't Pythonic on purpose. You're developing an online lottery game where users can wager on their lucky number:

Python

```
import random

class Lottery(object):
    def __init__(self, n):
        self.n = n

    def make_tickets(self):
        for i in range(self.n):
            yield i

    def draw(self):
        pool = self.make_tickets()
        random.shuffle(pool)
        return next(pool)
```

Behind the frontend application sits the critical code below. You want to make sure that you keep track of any errors caused by the site that may make a user lose their money. The first (suboptimal) way is to use `logging.error()` and log the `str` form of the exception instance itself:

Python

```
try:
    lucky_number = int(input("Enter your ticket number: "))
    drawn = Lottery(n=20).draw()
    if lucky_number == drawn:
        print("Winner chicken dinner!")
except Exception as e:
    # NOTE: See below for a better way to do this.
    logging.error("Could not draw ticket: %s", e)
```

This will only get you the actual exception message, rather than the traceback. You check the logs on your website's server and find this cryptic message:

Text

```
ERROR:root:Could not draw ticket: object of type 'generator' has no len()
```

Hmm. As the application developer, you've got a serious problem, and a user got ripped off as a result. But maybe this exception message itself isn't very informative. Wouldn't it be nice to see the lineage of the traceback that led to this exception?

The proper solution is to use `logging.exception()`, which logs a message with level `ERROR` and also displays the exception traceback. Replace the two final lines above with these:

Python

```
except Exception:
    logging.exception("Could not draw ticket")
```

Now you get a better indication of what's going on:

Python

```
ERROR:root:Could not draw ticket
Traceback (most recent call last):
  File "<stdin>", line 3, in <module>
  File "<stdin>", line 9, in draw
  File "lib/python3.7/random.py", line 275, in shuffle
    for i in reversed(range(1, len(x))):
TypeError: object of type 'generator' has no len()
```

Using `exception()` saves you from having to reference the exception yourself because `logging` pulls it in with `sys.exc_info()`.

This makes things clearer that the problem stems from `random.shuffle()`, which needs to know the length of the object it is shuffling. Because our `Lottery` class passes a generator to `shuffle()`, it gets held up and raises before the pool can be shuffled, much less generate a winning ticket.

In large, full-blown applications, you'll find `logging.exception()` to be even more useful when deep, multi-library tracebacks are involved, and you can't step into them with a live debugger like `pdb`.

The code for `logging.Logger.exception()`, and hence `logging.exception()`, is just a single line:

Python

```
def exception(self, msg, *args, exc_info=True, **kwargs):
    self.error(msg, *args, exc_info=exc_info, **kwargs)
```

That is, `logging.exception()` just calls `logging.error()` with `exc_info=True`, which is otherwise `False` by default. If you want to log an exception traceback but at a level different than `logging.ERROR`, just call that function or method with `exc_info=True`.

Keep in mind that `exception()` should only be called in the context of an exception handler, inside of an `except` block:

Python

```python
for i in data:
    try:
        result = my_longwinded_nested_function(i)
    except ValueError:
        # We are in the context of exception handler now.
        # If it's unclear exactly *why* we couldn't process
        # `i`, then log the traceback and move on rather than
        # ditching completely.
        logger.exception("Could not process %s", i)
        continue
```

Use this pattern sparingly rather than as a means to suppress any exception. It can be most helpful when you're debugging a long function call stack where you're otherwise seeing an ambiguous, unclear, and hard-to-track error.

Conclusion

Pat yourself on the back, because you've just walked through almost 2,000 lines of dense source code. You're now better equipped to deal with the `logging` package!

Keep in mind that this tutorial has been far from exhaustive in covering all of the classes found in the `logging` package. There's even more machinery that glues everything together. If you'd like to learn more, then you can look into the `Formatter` classes and the separate modules `logging/config.py` and `logging/handlers.py`.

Mark as Completed

About **Brad Solomon**