Back to the Future: Strategies for Dealing with Date and Time in Test and Production Code

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CTO at SPARKBYTE SOLUTIONS

Hands-on architect and team lead at MINTRA

Agenda:

- Date and time in production code
- Date and time in test code
- Testing complex scenarios (Sagas)
- Ensuring rules in the codebase
- Q/A

Who has experienced issues with date and time in production and / or test code?

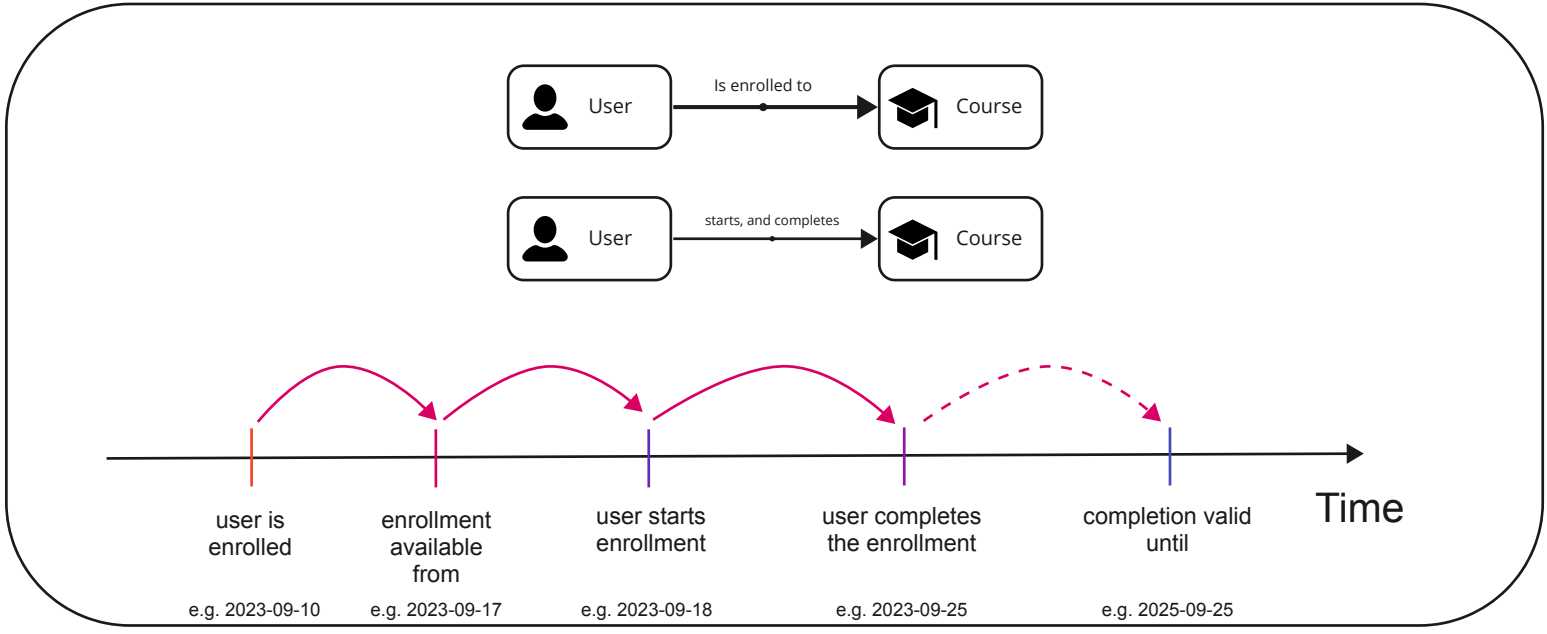
How do we create dates in our code? Which one do you use?

```
1. new Date()

2. LocalDateTime.now()

3. new Timestamp(System.currentTimeMillis())

4. Instant.now()
```

Or maybe those?

```
1. LocalDateTime.now(ZoneId.of("UTC"))

2. new Timestamp(System.currentTimeMillis())

3. Instant.now(Clock.systemUTC())

4. Clock clock = Clock.systemDefaultZone();
   clock.instant()

5. Clock clock = Clock.system(ZoneId.of("UTC"));
   clock.instant();
```

Example: Course Progress / Enrollment Sub-domain



What is the difference between runs of the code on the left and right side?

```
var student = new User();
var enroller = new User();
Enrollment enrollment =
    Enrollment.builder()
        .enroller(enroller)
        .student(student)
        .course(someCourse())
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        .build();
enrollment.start();
```

VS

```
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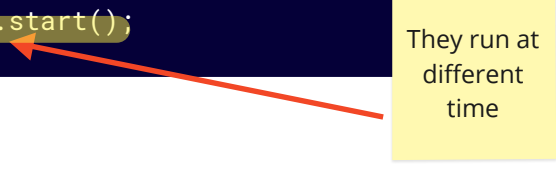

enrollment.start()

```
public class Enrollment ... {
    // ...
    public void start() {
        var now = Instant.now();
        if (now.isBefore(this.availableFrom)) {
            throw new IllegalStateException(
                    "Cannot start the enrollment. Current date %s
                        is before available date %s."
                            .formatted(now, this.availableFrom)
            );
        }
        this.startedAt = now;
    }
}
```

enrollment.start()

Looks innocent

```
public class Enrollment ... {
    // ...
    public void start() {
        var now = Instant.now();
        if (now.isBefore(this.availableFrom)) {
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            );
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But it's not

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        }
        this.startedAt = now;
    }
}
```

enrollment.start()

Pandora box opens here

Looks innocent

But it's not

```
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        }
        this.startedAt = now;
    }
}
```

They run at different times!

```
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        .build();
enrollment.start();
```

Because run on 2023-09-20

Throws error

They run at different time

Works

Because run on 2023-09-26

Consequences

Problem: Dependency on system clock

How can we reliably test scenarios in the past and future if we can't control time?

Problem: Dependency on system clock

"Solution" 1:

Let's hack our domain objects!

```
DomainObjectUtil.forceSetValue(enrollment, Enrollment.FieldName.enrollmentDate, fiveYearsAgo());
//when & then
assertThat(specification.isSatisfiedBy(user)).isTrue();
```

Problem: Dependency on system clock

"Solution" 2:

Let's add some sleeps.

```
private void forgiveMeForThisHack() {
    try {
        Thread.sleep( time: 1000);
    } catch (InterruptedException e) {
    }
}
```

Problem: Dependency on system clock

"Solution" 2:

Let's add some sleeps.

```
TimeUnit.NANOSECONDS.sleep( timeout: 1);
```

```
private void forgiveMeForThisHack() {
    try {
        Thread.sleep( time: 1000);
    } catch (InterruptedException e) {
    }
}
```

Problem: Dependency on system clock

"Solution" 3: Let's Mock!

- PowerMock
- Mockito from version 3.4.0

Problem: Dependency on system clock

Some "solutions":

- Delete this flickering test

Problem: Dependency on system clock

Some "solutions":

- Delete this flickering test
- Hack the domain object, bypass the domain rules

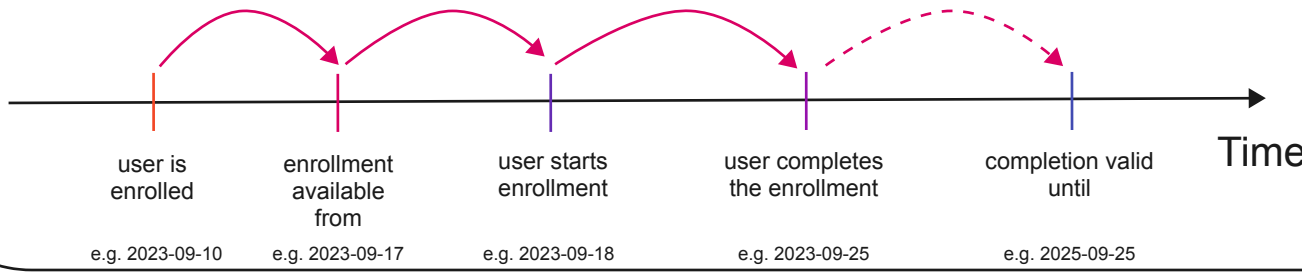
Problem: Dependency on system clock

Some "solutions":

- Delete this flickering test
- Hack the domain object, bypass the domain rules
- Test manually by changing the system clock

Some other problems

How will you test / simulate this whole process taking hours / weeks without hacking domain, and without sleeping in the code?



Hard to test scenarios

- Online exam must take no longer than 2 hours, each question should take **minimum** 12 seconds => **100 questions exam takes minimum 1200 seconds** (20 minutes)

- Notification about expiring completion is sent 2 weeks before it's become invalid (2 years - 2 weeks)?

- This list just goes on ...

... and more problems

- You have no idea on what to expect from the code
    - Violated The Principle of Least Surprise
- If you have to write tests for code that create dates 5 levels of code invocations below, that is no fun at all :)

... and more problems

On the outside:

```
///...
enrollment.start();
///.
```

... and more problems

On the outside:

```
///...
enrollment.start();
///.
```

On the inside:

```
///...
enrollment.start() calls
enrollment.doStart(...) that calls
availabilityDomainService that calls
corporateTrainingAvailPolicy that calls
some private methods
and eventually
trainingAvailabilitySpecification calls
Instant.now() /// !!!!
///...
```

... and more problems

On the outside:

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Instant.now() /// !!!!
///...
```

Have fun with testing and refactoring this code

TIME is a dependency in our code!

Application-wide control of TIME

- You should have control over TIME application wide.
- Meaning, there should be only one place in that service / module / project that really creates dates.

The Clock

```
package java.time;

//...
public abstract class Clock implements
    InstantSource {
    // ...
    public abstract Instant instant();
    // ...
}
```

Creating instants with Clock

```
// We can create them as we want
1. Clock clock = Clock.systemUTC();
   clock.instant();

2. Clock clock = Clock.system(ZoneId.of("UTC"));
   clock.instant();

3. Clock fixedClock = Clock.fixed(Instant.parse("2023
    -10-25T14:30:00.00Z");
   clock.instant();
```

Make the time explicit in the code!

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```
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        .course(someCourse())
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        .build();
enrollment.startAt(clock);
```

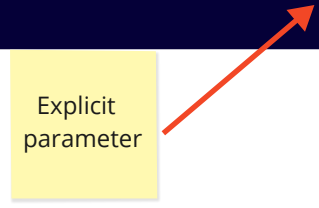

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Clock clock = ...
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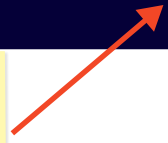
enrollment.startAt(clock);
```

I know, I know ... It's a big ugly

Explicit parameter



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enrollment.startAt(clock);
```
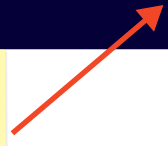

I know, I know ... It's a big ugly

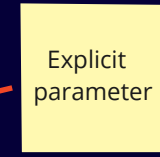
But it is explicit and gives us control!

Explicit parameter



Better enrollment.startAt(clock)

```
public class Enrollment {
    // ...
    public void startAt(Clock clock) {
        var now = Instant.now(clock);
        if (now.isBefore(this.availableFrom)) {
            throw new IllegalArgumentException(
                    "Cannot start the enrollment. Current date %s
                        is before available date %s.".formatted(now
                        , this.availableFrom)
            );
        }
        this.startedAt = now;
    }
}
```



Ok, so how to configure it in Spring?

```
/**
 * Configuration for having a real Clock in the
 * production code.
 */
@Profile("!test")
@Configuration
public class ClockConfig {
    @Bean
    Clock clock() {
        return Clock.systemUTC();
    }
}
```

Ok, so how to configure it in Spring?

1. Only for production code

2. Singleton

```
/**
 * Configuration for having a real Clock in the
 * production code.
 */
@Profile("!test")
@Configuration
public class ClockConfig {
    @Bean
    Clock clock() {
        return Clock.systemUTC();
    }
}
```

How to use it?

```
@Service
@Transactional
public class StartEnrollmentHandler {
    private final EnrollmentRepository repository;
    private final Clock clock;

    public StartEnrollmentHandler(EnrollmentRepository repository, Clock clock) {
        this.repository = repository;
        this.clock = clock;
    }

    public void startEnrollment(@NonNull UUID enrollmentId) {
        Enrollment enrollment = repository.findById(enrollmentId)
                .orElseThrow(() -> new IllegalArgumentException("Enrollment id=%s
                    not found".formatted(enrollmentId)));
        enrollment.startAt(clock);
        repository.save(enrollment);
    }
}
```

1. Inject Clock

2. Pass it to your domain object

How to use it?

```
public class Enrollment {
    // ...
    public void startAt(Clock clock) {
        var now = Instant.now(clock);
        if (now.isBefore(this.availableFrom)) {
            throw new IllegalArgumentException(
                    "Cannot start the enrollment. Current date %s
                        is before available date %s.".formatted(now
                        , this.availableFrom)
            );
        }
        this.startedAt = now;
    }
}
```

3. Use the Clock to get the current date

That's it!

Look at the official docs

Best practice for applications is to pass a `Clock` into any method that requires the current instant. A dependency injection framework is one way to achieve this:

```
public class MyBean {
  private Clock clock;  // dependency inject
  ...
  public void process(LocalDate eventDate) {
    if (eventDate.isBefore(LocalDate.now(clock)) {
      ...
    }
  }
}
```

This approach allows an alternate clock, such as `fixed` or `offset` to be used during testing.

Ref: https://docs.oracle.com/javase/8/docs/api/java/time/Clock.html

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Important notes about Production code

- Inject Clock only in Spring Beans.

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- Inject Clock only in Spring Beans.
- Domain objects should be given the Clock instance from the outside.

Two types of tests

- Fast tests - no IO ops (some call them Unit tests)
- Slow tests - with IO ops (flavours of Integration tests)

Date and time in Fast tests

- You can use Clock.fixed(instant, zone)
- If you use Spock - you can use MutableClock
- If you use JUnit - you can implement it on your own (it's quite simple), see code of OurMutableClock

Ref: https://spockframework.org/spock/javadoc/2.0/spock/util/time/MutableClock.html

In Spock: you can use Trait

```
trait UnitClockSupport {
    final MutableClock clock = new MutableClock()
    /**
     * Example: adjustClock { it + ofHours(30) }, adjustClock { it - ofDays(10) }
     */
    MutableClock adjustClock(Closure<MutableClock> adjuster) {
        adjuster(clock)
    }
    MutableClock setClockTo(Instant instant) {
        clock.setInstant(instant)
        clock
    }
    LocalDateTime localDateTime() { LocalDateTime.now(clock) }
    LocalDate localDate() { LocalDate.now(clock) }
    Instant instant() { Instant.now(clock) }
}
```

Ref: https://spockframework.org/spock/javadoc/2.0/spock/util/time/MutableClock.html

Example of a fast test in Spock

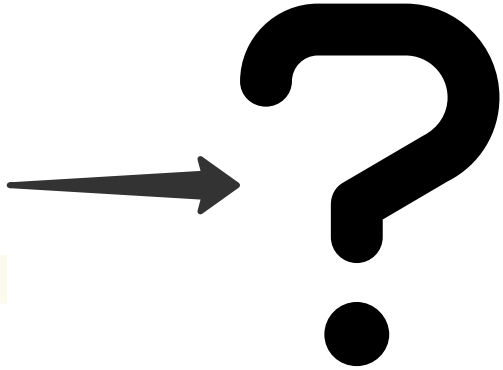
```
def "Enrollment can be started"() {
    given:
    def enrolledAt = Instant.now(clock)
    def availableFrom = enrolledAt
    Enrollment enrollment = Enrollment.initialEnrollment
        (student, student, course, enrolledAt, availableFrom)

    when:
    adjustClock { it + ofDays(1) }
    enrollment.startAt(clock)

    then:
    enrollment.isStarted()
}
```

Another example of a fast test in Spock

```
def "Enrollment can be created, started and then completed during a longer period"() {
    given:
    def enrolledAt = Instant.now(clock)
    def availableFrom = enrolledAt + ofDays(14)
    def enrollment = Enrollment.initialEnrollment(student, student, course, enrolledAt, availableFrom)

    when: 'time passes'
    adjustClock { it + ofDays(30) }

    and: 'enrollment is started'
    enrollment.startAt(clock)

    and: 'some more time time passes'
    adjustClock { it + ofDays(7) }

    and: 'enrollment is completed'
    enrollment.completeAt(clock)

    then:
    enrollment.startedAt == enrolledAt + ofDays(30)
    enrollment.completedAt == enrolledAt + ofDays(30 + 7)
    // other verifications
}
```

Verification on millis/nanos

```
def "Millis verification fail"() {
    when:
    def now :Instant = Instant.now()
    def now2 :Instant = Instant.now()
    then:
    now == now2
}
```



Verification on millis/nanos

```groovy
def "Millis verification fail"() {
    when:
    def now : Instant = Instant.now()
    def now2 : Instant = Instant.now()
    then:
    now == now2
}
```

```
Condition not satisfied:

now == now2
|   |  |
|   |  2023-10-21T20:31:05.202178940Z
|   false
2023-10-21T20:31:05.201920666Z
```

MutableClock is awesome

It is fixed unless you adjust / change it.

```
def "Millis verification works"() {
    when:
    def now :Instant = Instant.now(clock)
    def now2 :Instant = Instant.now(clock)
    then:
    now == now2
}
```

Test passed

Back to the future

```
def "Back to the Future"() {
    when:
    setClockTo(midnightOf(LocalDate.of(1985, 10, 26)))
    log.info("Base Time: " + localDate())
    log.info("Marty travels to 1955\n")

    setClockTo(midnightOf(LocalDate.of(1955, 11, 5)))
    log.info("Time Travel: " + localDate())
    log.info("Marty meets young Doc\n") // Explanation

    setClockTo(midnightOf(LocalDate.of(1955, 11, 12)))
    log.info("Enchantment Under the Sea Dance: " + localDate())
    log.info("Marty saves his parents\n") // Explanation

    setClockTo(midnightOf(LocalDate.of(2015, 10, 21)))
    log.info("Future: " + localDate())
    log.info("Marty and Doc arrive\n")

    setClockTo(midnightOf(LocalDate.of(1885, 1, 1)))
    log.info("Wild West: " + localDate())
    log.info("Marty rescues Doc\n")
    //...
}
```

Back to the future

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    setClockTo(midnightOf(LocalDate.of(2015, 10, 21)))
    log.info("Future: " + localDate())
    log.info("Marty and Doc arrive\n")

    setClockTo(midnightOf(LocalDate.of(1885, 1, 1)))
    log.info("Wild West: " + localDate())
    log.info("Marty rescues Doc\n")
    //...
}
```

Output

```
BackToTheFutureSpec        : Base Time: 1985-10-26
BackToTheFutureSpec        : Marty travels to 1955

BackToTheFutureSpec        : Time Travel: 1955-11-05
BackToTheFutureSpec        : Marty meets young Doc

BackToTheFutureSpec        : Enchantment Under the Sea Dance: 1955-11-12
BackToTheFutureSpec        : Marty saves his parents

BackToTheFutureSpec        : Future: 2015-10-21
BackToTheFutureSpec        : Marty and Doc arrive

BackToTheFutureSpec        : Wild West: 1885-01-01
BackToTheFutureSpec        : Marty rescues Doc
```

Date and time in Slow tests

- You can use Clock.fixed(instant, zone)
- If you use Spock - you can use MutableClock
- If you use JUnit - you can implement it on your own (it's quite simple), see code of OurMutableClock
- Keep in mind that you may need to take care of your clock between tests

Ref: https://spockframework.org/spock/javadoc/2.0/spock/util/time/MutableClock.html

Clock configuration for tests

```
@Configuration
public class TestClockConfig {

    @Bean
    MutableClock clock() {
        return new MutableClock(ZoneId.of("UTC"));
    }
}
```

Ref: https://spockframework.org/spock/javadoc/2.0/spock/util/time/MutableClock.html

Clock configuration for tests

Located in test code

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Clock configuration for tests

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Singleton

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}
```

Ref: https://spockframework.org/spock/javadoc/2.0/spock/util/time/MutableClock.html

Example of a slow test

```
@SpringBootTest
class StartEnrollmentHandlerTest {
    @Autowired StartEnrollmentHandler handler;
    @Autowired MutableClock clock;
    // ...
    @Test
    void shouldNotAllowToStartEnrollmentTooEarly() {
        // given
        var enrolledAt = date("2023-09-10");
        clock.setInstant(enrolledAt);
        var availableFrom = enrolledAt.plus(ofDays(1));
        var enrollment = initialEnrollment(student, student, course, enrolledAt, availableFrom);
        enrollmentRepository.save(enrollment);
        // when & then
        assertThatThrownBy(() -> handler.start(enrollment.getId()))
                .hasMessageContaining("Cannot start the enrollment");
    }
}
```

1. Normal injections

2. time manipulation

3. Method called on Spring bean

Example of a slow test

```
@SpringBootTest
class StartEnrollmentHandlerTest {
    @Autowired StartEnrollmentHandler handler;
    @Autowired MutableClock clock;
    // ...
    @Test
    void shouldCreateASimpleEnrollmentAndStartIt() {
        // given
        var enrolledAt = date("2023-09-11");
        clock.setInstant(enrolledAt);
        var availableFrom = enrolledAt.plus(ofDays(1));
        var enrollment = initialEnrollment(student, student, course, enrolledAt, availableFrom);
        enrollmentRepository.save(enrollment);
        // when
        moveToFutureBy(ofDays(2));
        handler.start(enrollment.getId());
        // then
        assertThat(enrollmentRepository.findById(enrollment.getId()))
                .hasValueSatisfying(e -> assertThat(e.isStarted()).isTrue());
    }
}
```

1. Normal injections

2. time manipulation

3. Method called on Spring bean

Trait for integration tests

```groovy
@TestExecutionListeners(mergeMode = TestExecutionListeners.MergeMode.MERGE_WITH_DEFAULTS,
                        listeners = MutableClockTestExecutionListener)
trait IntegrationClockSupport {
    @Autowired MutableClock clock

    // Example: adjustClock { it + ofHours(30) }
    MutableClock adjustClock(Closure<MutableClock> adjuster) {
        adjuster(clock)
    }
    MutableClock setClockTo(Instant instant) {
        clock.setInstant(instant)
        clock
    }
    LocalDateTime localDateTime() { LocalDateTime.now(clock) }
    LocalDate localDate() { LocalDate.now(clock) }
    Instant instant() { Instant.now(clock) }
}
```

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Back to the future Integration Test

```groovy
@SpringBootTest
class BackToTheFutureIntegrationSpec extends Specification
    implements IntegrationClockSupport {
    @Autowired BackToTheFutureBean bean

    def "Back to the Future"() {
        when:
        setClockTo(midnightOf(LocalDate.of(1985, 10, 26)))
        bean.log("Marty travels to 1955")
        setClockTo(midnightOf(LocalDate.of(1955, 11, 5)))
        bean.log("Marty meets young Doc") // Explanation
        setClockTo(midnightOf(LocalDate.of(1955, 11, 12)))
        bean.log("Marty saves his parents") // Explanation
        setClockTo(midnightOf(LocalDate.of(2015, 10, 21)))
        bean.log("Marty and Doc arrive")
        setClockTo(midnightOf(LocalDate.of(1885, 1, 1)))
        bean.log("Marty rescues Doc")
        then:
        // ...
    }
```

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        setClockTo(midnightOf(LocalDate.of(2015, 10, 21)))
        bean.log("Marty and Doc arrive")
        setClockTo(midnightOf(LocalDate.of(1885, 1, 1)))
        bean.log("Marty rescues Doc")
        then:
        // ...
    }
```

Output

```
..
(BackToTheFutureBean): Message: "Marty travels to 1955}" at (1985-10-26})

(BackToTheFutureBean): Message: "Marty meets young Doc}" at (1955-11-05})

(BackToTheFutureBean): Message: "Marty saves his parents}" at (1955-11-12})

(BackToTheFutureBean): Message: "Marty and Doc arrive}" at (2015-10-21})

(BackToTheFutureBean): Message: "Marty rescues Doc}" at (1885-01-01})
```

Slow tests: clean up before/after each test

Remember about **resetting*** your clock:

- You can use JUnit, @BeforeEach with resetting the clock
- You can create a simple @TestExecutionListener, see:
    - StartEnrollmentHandlerTest.java
    - MutableClockTestExecutionListener.java

But how will we ensure people use Clock in their code?

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But how will we ensure people use Clock in their code?

```
public class DateRulesArchTest {
    JavaClasses prodClasses = new ClassFileImporter().withImportOption(new DoNotIncludeTests
        ()).importPackages("com.trainitek");

    @Test
    void checkThatClockIsUsedToCreateDateInProdCode() {
        ArchRuleDefinition.noClasses()
                .should().callMethod(LocalDate.class, "now")
                .orShould().callMethod(LocalDate.class, "now", ZoneId.class)
                .orShould().callMethod(LocalDateTime.class, "now")
                .orShould().callMethod(LocalDateTime.class, "now", ZoneId.class)
                .orShould().callMethod(ZonedDateTime.class, "now")
                .orShould().callMethod(ZonedDateTime.class, "now", ZoneId.class)
                .orShould().callMethod(OffsetDateTime.class, "now")
                .orShould().callMethod(OffsetDateTime.class, "now", ZoneId.class)
                .orShould().callMethod(Instant.class, "now")
                .orShould().callConstructor(Date.class)
                .because("In prod code we use Clock to create dates (Our rules in HERE_LIK_TO_WIKI )")
                .check(prodClasses);
    }
}
```

Ref: https://www.archunit.org/

But how will we ensure people use Clock in their code?

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                .orShould().callMethod(ZonedDateTime.class, "now")
                .orShould().callMethod(ZonedDateTime.class, "now", ZoneId.class)
                .orShould().callMethod(OffsetDateTime.class, "now")
                .orShould().callMethod(OffsetDateTime.class, "now", ZoneId.class)
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                .because("In prod code we use Clock to create dates (Our rules in HERE_LIK_TO_WIKI )")
                .check(prodClasses);
    }
}
```

Ref: https://www.archunit.org/

Slow Tests: Tests against other services

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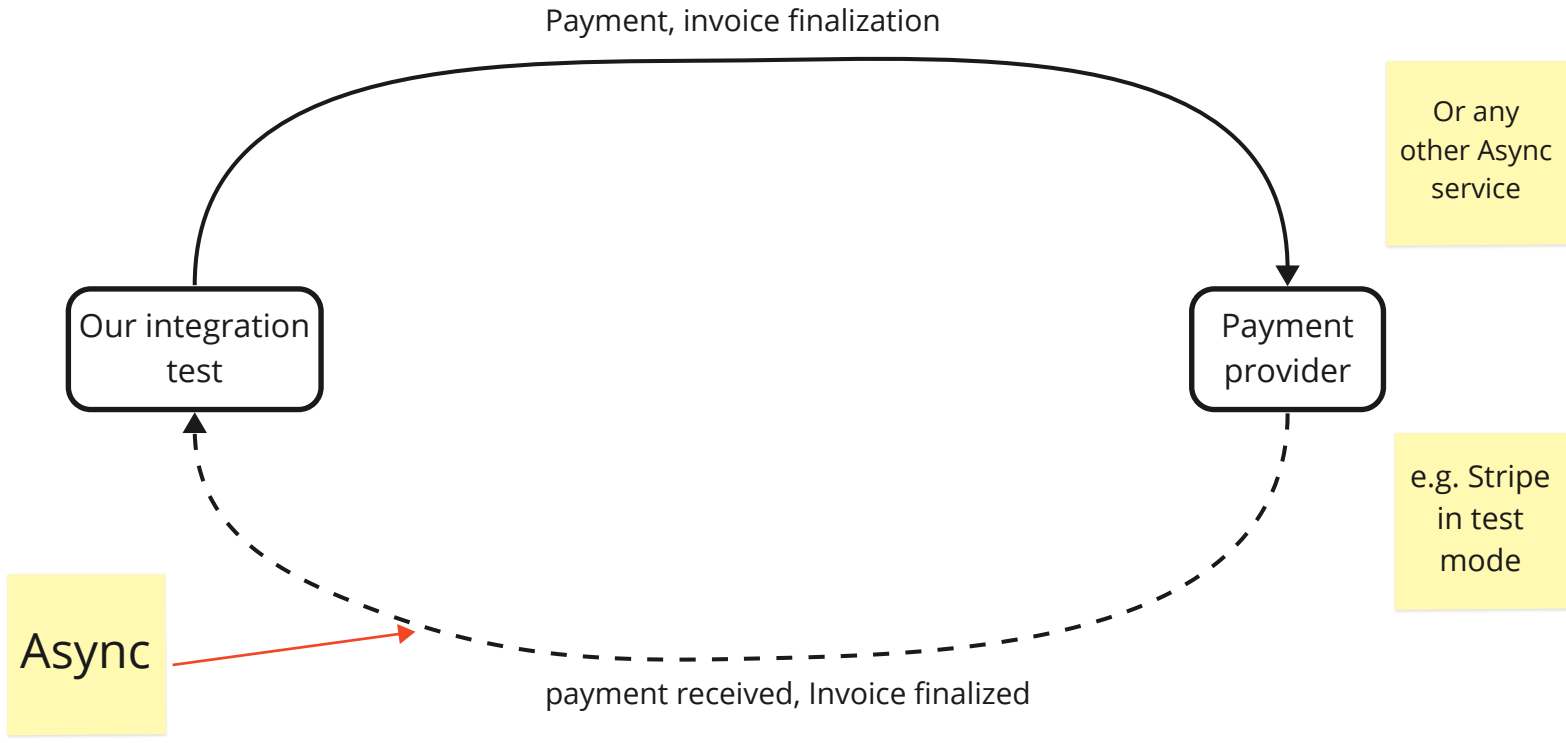


Slow Tests: Tests against other services

When you need to really wait until something asynchronous happens in tests use ...

Slow Tests: Tests against other services

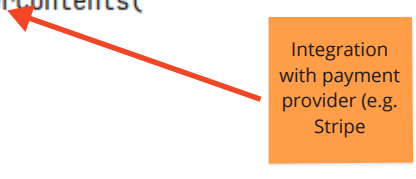
When you need to really wait until something asynchronous happens in tests use Awaitality

Ref: http://www.awaitility.org/ https://github.com/awaitility/awaitility

Slow Tests: Tests against other services

When you need to really wait until something asynchronous happens in tests use Awaitality

```
private void waitAndVerifyInvoiceCanBeDownloaded(PlacedOrderDetailsResource orderDetails) {
    Awaitility.await()
        .atMost(Duration.ofMinutes(1))
        .pollInterval(Duration.ofSeconds(1))
        .untilAsserted(() → verifyInvoiceCanBeDownloadedAndHasProperContents(
            orderDetails.getId(), orderDetails.getCustomerName()));
}
```



Ref: http://www.awaitility.org/ https://github.com/awaitility/awaitility

Slow Tests: Tests against other services

Use Awaitility when you have to wait for results of an async operation (that is outside our control), e.g. when integrating with:

- External services: payment providers, SMTP servers etc.
- Elasticsearch
- Messaging systems
- Anything asynchronous outside your control

Ref: http://www.awaitility.org/ https://github.com/awaitility/awaitility

TIME is a dependency!
Take good care of it!

https://www.linkedin.com/in/marekdominiak/

https://github.com/trainitek/backtothefuture

{i}DD

RATE MY LECTURE!

Go to **eventory app**

- *Find my lecture in the agenda*
- *Click on it and **rate the lecture***

Q / A

https://www.linkedin.com/in/marekdominiak/

https://github.com/trainitek/backtothefuture

Timezones are not easy

- Use timezone aware classes ONLY when you really need them.
- Timezones can be configured as user preferences (to display date and time according to their timezones)
- If you need to store only date, use LocalDate.
- Make the production app deployments more deterministic by using -Duser.timezone=UTC

More deterministic CI runs

- Ensure code on CI is parametrized with the same settings as locally: E.g. "-Duser.timezone=UTC" is used
- Use Clocks you can control
- Avoid midnight jumping (-/+ 1 day problem)
- Turn off unnecessary Async tasks / Cron jobs running during your tests

Storing dates

- Use data-types offered by your datastore to save timestamps and dates:
    - Don't save year, month, day as separate columns :)

- Use UTC (UTC+0) to store all timestamps in datastores, and map them to Instant in code

- Only when you need to consider timezone use types like ZonedDateTime, OffsetDateTime

Date formats

- Keep them as an application wide configuration
- Use specific ones as user's preferences

"Funny" issues with date and time:

- User birthdate off by +/- 1 day.
- Production code untestable due to the passage of time.
- Threads in production code hanging indefinitely.
- Challenges debugging code due to timezone inconsistencies.
- Tests failing because of verification at millisecond precision.
- Tests failing because the machine was set up in a different timezone.
- Tests failing when run at certain times (before/after midnight).
- Flickering tests because responses from integrated services arrive too late or too early.
- Scheduled tasks running either too late or too early.
- Tests being very slow.
- Inconsistent date formats across application.
- QAs / POs waiting 14 days to check if the feature worked.