

Test-Driven Development (TDD) with JUnit



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Motivating Example: Two Types of Errors (2)



Approach 1 – Specify: Indicate in the method signature that a specific exception might be thrown.

Example 1: Method that throws the exception

```
class C1 {
    void m1(int x) throws ValueTooSmallException {
        if(x < 0) {
            throw new ValueTooSmallException("val " + x);
        }
    }
}
```

Example 2: Method that calls another which throws the exception

```
class C2 {
    C1 c1;
    void m2(int x) throws ValueTooSmallException {
        c1.m1(x);
    }
}
```

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Motivating Example: Two Types of Errors (1)



Consider two kinds of exceptions for a counter:

```
public class ValueTooLargeException extends Exception {
    ValueTooLargeException(String s) { super(s); }
}
public class ValueTooSmallException extends Exception {
    ValueTooSmallException(String s) { super(s); }
}
```

Any thrown object instantiated from these two classes must be handled (**catch-specify requirement**):

- Either **specify** throws ... in the method signature (i.e., propagating it to other caller)
- Or **handle** it in a try-catch block

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Motivating Example: Two Types of Errors (3)



Approach 2 – Catch: Handle the thrown exception(s) in a try-catch block.

```
class C3 {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        int x = input.nextInt();
        C2 c2 = new C2();
        try {
            c2.m2(x);
        }
        catch(ValueTooSmallException e) { ... }
    }
}
```

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A Simple Counter (1)

Consider a class for keeping track of an integer counter value:

```
public class Counter {
    public final static int MAX_VALUE = 3;
    public final static int MIN_VALUE = 0;
    private int value;
    public Counter() {
        this.value = Counter.MIN_VALUE;
    }
    public int getValue() {
        return value;
    }
    ... /* more later! */
}
```

- Access **private** attribute `value` using **public** accessor `getValue`.
- Two class-wide (i.e., `static`) constants (i.e., `final`) for lower and upper bounds of the counter value.
- Initialize the counter value to its lower bound.
- **Requirement** :

The counter value must be between its lower and upper bounds.

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A Simple Counter (2)

```
/* class Counter */
public void increment() throws ValueTooLargeException {
    if (value == Counter.MAX_VALUE) {
        throw new ValueTooLargeException("value is " + value);
    }
    else { value++; }
}

public void decrement() throws ValueTooSmallException {
    if (value == Counter.MIN_VALUE) {
        throw new ValueTooSmallException("value is " + value);
    }
    else { value--; }
}
}
```

- Change the counter value via two mutator methods.
- Changes on the counter value may **trigger an exception**:
 - Attempt to **increment** when counter already reaches its **maximum**.
 - Attempt to **decrement** when counter already reaches its **minimum**.

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Exceptional Scenarios

Consider the two possible exceptional scenarios:

- An attempt to increment **above** the counter's upper bound.
- An attempt to decrement **below** the counter's lower bound.

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Components of a Test

- Manipulate the relevant object(s).
 - e.g., **Initialize a counter object `c`, then call `c.increment()`.**
 - e.g., **Initialize a counter object `c`, then call `c.decrement()`.**
- What do you **expect to happen**?
 - e.g., **value of counter is such that `Counter.MIN_VALUE + 1`**
 - e.g., **`ValueTooSmallException` is thrown**
- What does your program **actually produce**?
 - e.g., **call `c.getValue()` to find out.**
 - e.g., **Use a `try-catch` block to find out** (to discuss!).
- A test:
 - **Passes** if expected outcome occurs.
 - **Fails** if expected outcome does *not* occur.
- So far, you ran tests via a tester class with the `main` method.

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Testing Counter via Console V1 (1.1)



```
1 public class CounterTester1 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Init val: " + c.getValue());
5         try {
6             c.decrement();
7             println("Error: ValueTooSmallException NOT thrown.");
8         }
9         catch (ValueTooSmallException e) {
10            println("Success: ValueTooSmallException thrown.");
11        }
12    } /* end of main method */
13 } /* end of class CounterTester1 */
```

- o L3 sets c.value to 0.
- o At L6, if method decrement was implemented:
 - **Correctly** ⇒ we expect a ValueTooSmallException.
⇒ Execution jumps to L9, L10 – L12, then the program terminates.
 - **Incorrectly** ⇒ expected ValueTooSmallException *wouldn't* occur.
⇒ Execution continues to L7, L8, L12, then the program terminates.

See the equivalent, automated JUnit test testDecFromMinValue.

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Testing Counter via Console V1 (1.3.1)



- The real value of a **test** is:
 - o Not only to confirm when your implementation is **correct**,
 - o But also to reveal errors when your implementation is **incorrect**.
- Say now method decrement was implemented **incorrectly**:

```
class Counter {
...
public void decrement() throws ValueTooSmallException {
    if(value < Counter.MIN_VALUE) {
        throw new ValueTooSmallException("value is " + value);
    }
    else { value --; }
}
}
```

- Is the same console tester able to **reveal** this **incorrect** implementation?

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Testing Counter via Console V1 (1.2)



```
1 public class CounterTester1 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Init val: " + c.getValue());
5         try {
6             c.decrement();
7             println("Error: ValueTooSmallException NOT thrown.");
8         }
9         catch (ValueTooSmallException e) {
10            println("Success: ValueTooSmallException thrown.");
11        }
12    } /* end of main method */
13 } /* end of class CounterTester1 */
```

- Say method decrement is implemented **correctly**.
- Lines 3 – 6, 9 – 11, 12 executed, giving the Console Output:

```
Init val: 0
Success: ValueTooSmallException thrown.
```

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Testing Counter via Console V1 (1.3.2)



```
1 public class CounterTester1 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Init val: " + c.getValue());
5         try {
6             c.decrement();
7             println("Error: ValueTooSmallException NOT thrown.");
8         }
9         catch (ValueTooSmallException e) {
10            println("Success: ValueTooSmallException thrown.");
11        }
12    } /* end of main method */
13 } /* end of class CounterTester1 */
```

- Say method decrement is implemented **incorrectly**.
- Lines 3 – 6, 7 – 8, 12 executed, giving the Console Output:

```
Init val: 0
Error: ValueTooSmallException NOT thrown.
```

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Testing Counter via Console V1 (2.1)



```
1 public class CounterTester2 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Current val: " + c.getValue());
5         try {
6             c.increment(); c.increment(); c.increment();
7             println("Current val: " + c.getValue());
8             try {
9                 c.increment();
10                println("Error: ValueTooLargeException NOT thrown.");
11            } /* end of inner try */
12            catch (ValueTooLargeException e) {
13                println("Success: ValueTooLargeException thrown.");
14            } /* end of inner catch */
15        } /* end of outer try */
16        catch (ValueTooLargeException e) {
17            println("Error: ValueTooLargeException thrown unexpectedly.");
18        } /* end of outer catch */
19    } /* end of main method */
20 } /* end of CounterTester2 class */
```

See the equivalent, automated JUnit test testIncFromMaxValue.

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Testing Counter via Console V1 (2.3.1)



```
1 public class CounterTester2 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Current val: " + c.getValue());
5         try {
6             c.increment(); c.increment(); c.increment();
7             println("Current val: " + c.getValue());
8             try {
9                 c.increment();
10                println("Error: ValueTooLargeException NOT thrown.");
11            } /* end of inner try */
12            catch (ValueTooLargeException e) {
13                println("Success: ValueTooLargeException thrown.");
14            } /* end of inner catch */
15        } /* end of outer try */
16        catch (ValueTooLargeException e) {
17            println("Error: ValueTooLargeException thrown unexpectedly.");
18        } /* end of outer catch */
19    } /* end of main method */
20 } /* end of CounterTester2 class */
```

- o Exercise: Give an **incorrect** method increment, so that
- o Lines 3 – 6, 16 – 18, 19 executed, with Console Output:

```
Current val: 0
Error: ValueTooLargeException was thrown unexpectedly.
```

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Testing Counter via Console V1 (2.2)



```
1 public class CounterTester2 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Current val: " + c.getValue());
5         try {
6             c.increment(); c.increment(); c.increment();
7             println("Current val: " + c.getValue());
8             try {
9                 c.increment();
10                println("Error: ValueTooLargeException NOT thrown.");
11            } /* end of inner try */
12            catch (ValueTooLargeException e) {
13                println("Success: ValueTooLargeException thrown.");
14            } /* end of inner catch */
15        } /* end of outer try */
16        catch (ValueTooLargeException e) {
17            println("Error: ValueTooLargeException thrown unexpectedly.");
18        } /* end of outer catch */
19    } /* end of main method */
20 } /* end of CounterTester2 class */
```

- o Say method increment is implemented **correctly**.
- o Lines 3 – 9, 12 – 15, 19 executed, with Console Output:

```
Current val: 0
Current val: 3
Success: ValueTooLargeException thrown.
```

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Testing Counter via Console V1 (2.3.2)



```
1 public class CounterTester2 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Current val: " + c.getValue());
5         try {
6             c.increment(); c.increment(); c.increment();
7             println("Current val: " + c.getValue());
8             try {
9                 c.increment();
10                println("Error: ValueTooLargeException NOT thrown.");
11            } /* end of inner try */
12            catch (ValueTooLargeException e) {
13                println("Success: ValueTooLargeException thrown.");
14            } /* end of inner catch */
15        } /* end of outer try */
16        catch (ValueTooLargeException e) {
17            println("Error: ValueTooLargeException thrown unexpectedly.");
18        } /* end of outer catch */
19    } /* end of main method */
20 } /* end of CounterTester2 class */
```

- o Exercise: Give an **incorrect** method increment, so that
- o Lines 3 – 11, 15, 19 executed, with Console Output:

```
Current val: 0
Current val: 3
Error: ValueTooLargeException was NOT thrown.
```

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Testing Counter via Console V1 (2.3.3)



Question. Can this alternative to ConsoleTester2 work (without nested try-catch)?

```
1 public class CounterTester2 {
2     public static void main(String[] args) {
3         Counter c = new Counter();
4         println("Current val: " + c.getValue());
5         try {
6             c.increment(); c.increment(); c.increment();
7             println("Current val: " + c.getValue());
8         }
9         catch (ValueTooLargeException e) {
10            println("Error: ValueTooLargeException thrown unexpectedly.");
11        }
12        try {
13            c.increment();
14            println("Error: ValueTooLargeException NOT thrown.");
15        } /* end of inner try */
16        catch (ValueTooLargeException e) {
17            println("Success: ValueTooLargeException thrown.");
18        } /* end of inner catch */
19    } /* end of main method */
20 } /* end of CounterTester2 class */
```

- Say one of the first 3 `c.increment()` *mistakenly* throws VTLE.
- After L10 is executed, flow of execution *still continues* to L12.
- This allows the 4th `c.increment()` to be executed!

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Testing Counter via Console (V2): Test 1



Test Case 1: Decrement when the counter value is too small.

```
Enter "inc", "dec", or "val":
val
0
Enter "inc", "dec", or "val":
dec
Value too small!
Enter "inc", "dec", or "val":
exit
Bye!
```

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Testing Counter via Console (V2)



```
import java.util.Scanner;
public class CounterTester3 {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        String cmd = null; Counter c = new Counter();
        boolean userWantsToContinue = true;
        while (userWantsToContinue) {
            println("Enter \"inc\", \"dec\", or \"val\":");
            cmd = input.nextLine();
            try {
                if (cmd.equals("inc")) { c.increment(); }
                else if (cmd.equals("dec")) { c.decrement(); }
                else if (cmd.equals("val")) { println(c.getValue()); }
                else { userWantsToContinue = false; println("Bye!"); }
            } /* end of try */
            catch (ValueTooLargeException e) { println("Value too big!"); }
            catch (ValueTooSmallException e) { println("Value too small!"); }
        } /* end of while */
    } /* end of main method */
} /* end of class CounterTester3 */
```

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Testing Counter via Console (V2): Test 2



Test Case 2: Increment when the counter value is too big.

```
Enter "inc", "dec", or "val":
inc
Enter "inc", "dec", or "val":
inc
Enter "inc", "dec", or "val":
inc
Enter "inc", "dec", or "val":
val
3
Enter "inc", "dec", or "val":
inc
Value too big!
Enter "inc", "dec", or "val":
exit
Bye!
```

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Limitations of Testing from the Console

- Do **Test Cases 1 & 2** suffice to test Counter's *correctness*?
 - Is it plausible to claim that the implementation of Counter is *correct* because it passes the two test cases?
- What other test cases can you think of?

c.getValue ()	c.increment ()	c.decrement ()
0	1	ValueTooSmall
1	2	0
2	3	1
3	ValueTooLarge	2

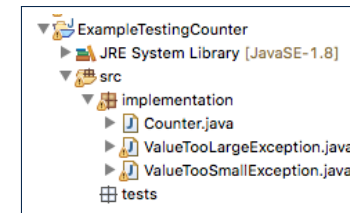
- So in total we need 8 test cases. \Rightarrow 6 more separate
 - CounterTester classes to create (like CounterTester1)!
 - Console interactions with CounterTester3!
 - Problems? It is inconvenient to:
 - Run each TC by executing main of a CounterTester and comparing console outputs *with your eyes*.
 - Re-run manually** all TCs whenever Counter is changed.
- Regression Testing**: Any **change** introduced to your software *must not compromise* its established **correctness**.

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How to Use JUnit: Packages

Step 1:

- In Eclipse, create a Java project ExampleTestingCounter
- Separation of concerns**:
 - Group classes for *implementation* (i.e., Counter) into package implementation.
 - Group classes for *testing* (to be created) into package tests.



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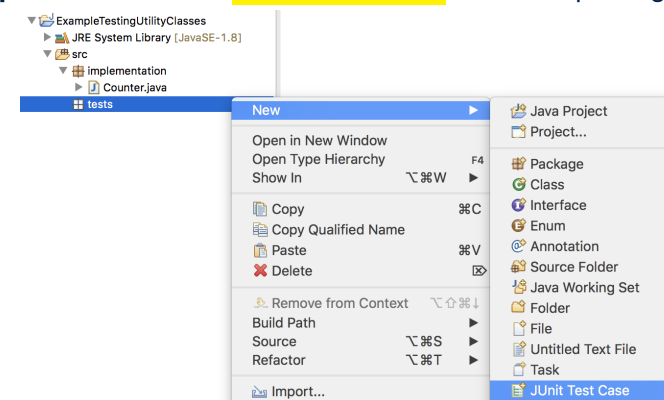
Why JUnit?

- Automate** the *testing of correctness* of your Java classes.
- Once you derive the list of tests, translate it into a JUnit test case, which is just a Java class that you can execute upon.
- JUnit tests are **helpful callers/clients** of your classes, where each test may:
 - Either attempt to use a method in a *legal* way (i.e., *satisfying* its precondition), and report:
 - Success** if the result is as expected
 - Failure** if the result is *not* as expected
 - Or attempt to use a method in an *illegal* way (i.e., *not satisfying* its precondition), and report:
 - Success** if the expected exception (e.g., ValueTooSmallException) occurs.
 - Failure** if the expected exception does *not* occur.

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How to Use JUnit: New JUnit Test Case (1)

Step 2: Create a new **JUnit Test Case** in tests package.

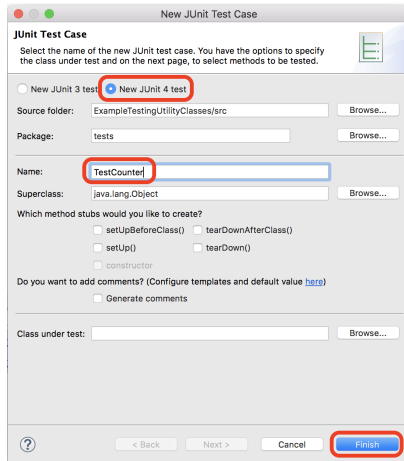


- Create one JUnit Test Case to test one Java class only.
- \Rightarrow If you have *n Java classes to test*, create *n JUnit test cases*.

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How to Use JUnit: New JUnit Test Case (2)

Step 3: Select the version of JUnit (JUnit 4); Enter the name of test case (`TestCounter`); Finish creating the new test case.



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How to Use JUnit: Generated Test Case

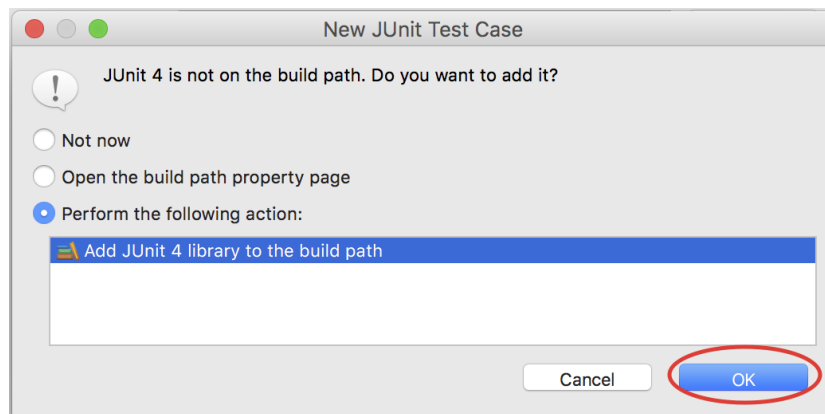
```
TestCounter.java
1 package tests;
2 import static org.junit.Assert.*;
3 import org.junit.Test;
4 public class TestCounter {
5     @Test
6     public void test() {
7         fail("Not yet implemented");
8     }
9 }
```

- Lines 6 – 8: test is just an *ordinary mutator method* that has a one-line implementation body.
- Line 5 is critical: Prepend the tag `@Test` verbatim, requiring that *the method is to be treated as a JUnit test*.
⇒ When `TestCounter` is run as a JUnit Test Case, only *those methods prepended by the `@Test` tags* will be run and reported.
- Line 7: By default, we deliberately fail the test with a message “Not yet implemented”.

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How to Use JUnit: Adding JUnit Library

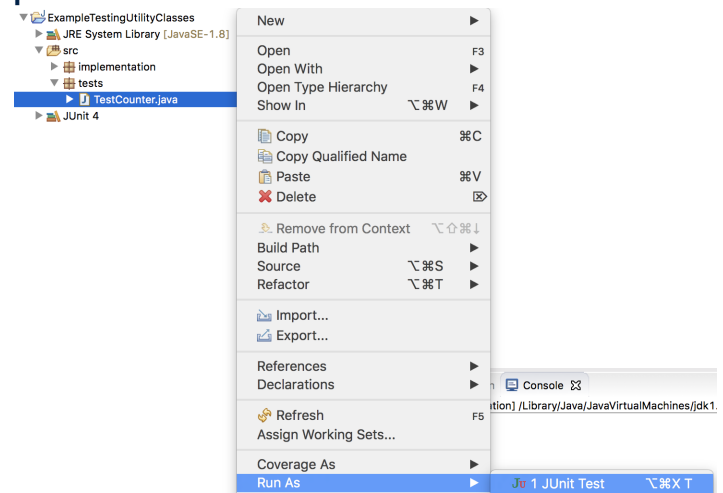
Upon creating the very first test case, you will be prompted to add the JUnit library to your project’s build path.



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How to Use JUnit: Running Test Case

Step 4: Run the `TestCounter` class as a JUnit Test.

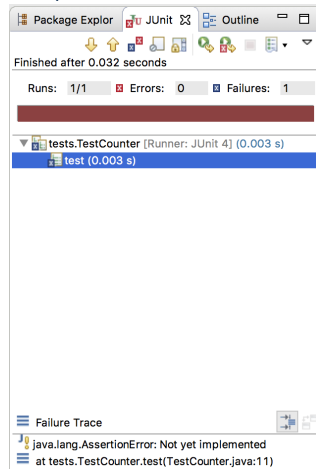


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How to Use JUnit: Generating Test Report



A **report** is generated after running all tests (i.e., methods prepended with **@Test**) in TestCounter.



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How to Use JUnit: Revising Test Case



```
TestCounter.java x
1 package tests;
2 import static org.junit.Assert.*;
3 import org.junit.Test;
4 public class TestCounter {
5     @Test
6     public void test() {
7         // fail("Not yet implemented");
8     }
9 }
```

Now, the body of `test` simply does nothing.

⇒ Neither assertion failures nor exceptions will occur.

⇒ The execution of `test` will be considered as a **success**.

∴ There is currently only one test in `TestCounter`.

∴ We will receive a **green** bar!

Caution: test which passes at the moment is **not useful** at all!

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How to Use JUnit: Interpreting Test Report



- A **test** is a method prepended with the **@Test** tag.
- The result of running a test is considered:
 - **Failure** if either
 - an assertion failure (e.g., caused by `fail`, `assertTrue`, `assertEquals`) occurs; or
 - an **unexpected** exception (e.g., `NullPointerException`, `ArrayIndexOutOfBoundsException`) is thrown.
 - **Success** if neither assertion failures nor **unexpected** exceptions occur.
- After running all tests:
 - A **green** bar means that **all** tests succeed.
⇒ Keep challenging yourself if **more tests** may be added.
 - A **red** bar means that **at least one** test fails.
⇒ Keep fixing the class under test and re-running all tests, until you receive a **green** bar.
- **Question:** What is the easiest way to making `test` a **success**?
Answer: Delete the call `fail("Not yet implemented")`.

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How to Use JUnit: Re-Running Test Case



A new report is generated after re-running all tests (i.e., methods prepended with **@Test**) in TestCounter.



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How to Use JUnit: Adding More Tests (1)

- Recall the complete list of cases for testing Counter:

c.getValue()	c.increment()	c.decrement()
0	1	ValueTooSmall
1	2	0
2	3	1
3	ValueTooLarge	2

- Let's turn the two cases in the 1st row into two JUnit tests:
 - Test for the *green* cell *succeeds* if:
 - No failures and exceptions occur; and
 - The new counter value is 1.
 - Tests for *red* cells *succeed* if the **expected exceptions** occur (ValueTooSmallException & ValueTooLargeException).
 - Common JUnit assertion methods:
 - `void assertNull(Object o)`
 - `void assertEquals(int expected, int actual)`
 - `void assertEquals(double exp, double act, double epsilon)`
 - `void assertEqualsArray(expected, actuals)`
 - `void assertTrue(boolean condition)`
 - `void fail(String message)`

JUnit Assertions: Examples (2)

- Consider the following class:

```
class Circle {
    double radius;
    Circle(double radius) { this.radius = radius; }
    int getArea() { return 3.14 * radius * radius; }
}
```

- How do we test `c.getArea()`?
 - Mathematically: $3.4 \times 3.4 \times 3.14 = 36.2984$
 - However, base-10 numbers **cannot** be represented perfectly in the binary format.
 - When comparing fractional numbers, allow some **tolerance**:

$$36.2984 - 0.01 \leq c.getArea() \leq 36.2984 + 0.01$$

- Then consider these assertions. Do they *pass* or *fail*?

```
Circle c = new Circle(3.4);
assertTrue(36.2984, c.getArea(), 0.01); ✓
```

JUnit Assertions: Examples (1)

Consider the following class:

```
class Point {
    int x; int y;
    Point(int x, int y) { this.x = x; this.y = y; }
    int getX() { return this.x; }
    int getY() { return this.y; }
}
```

Then consider these assertions. Do they *pass* or *fail*?

```
Point p;
assertNull(p); ✓
assertTrue(p == null); ✓
assertFalse(p != null); ✓
assertEquals(3, p.getX()); ✗ /* NullPointerException */
p = new Point(3, 4);
assertNull(p); ✗
assertTrue(p == null); ✗
assertFalse(p != null); ✗
assertEquals(3, p.getX()); ✓
assertTrue(p.getX() == 3 && p.getY() == 4); ✓
```

How to Use JUnit: Assertion Methods

method name / parameters	description
<code>assertTrue(test)</code> <code>assertTrue("message", test)</code>	Causes this test method to fail if the given boolean test is not true.
<code>assertFalse(test)</code> <code>assertFalse("message", test)</code>	Causes this test method to fail if the given boolean test is not false.
<code>assertEquals(expectedValue, value)</code> <code>assertEquals("message", expectedValue, value)</code>	Causes this test method to fail if the given two values are not equal to each other. (For objects, it uses the equals method to compare them.) The first of the two values is considered to be the result that you expect; the second is the actual result produced by the class under test.
<code>assertNotEquals(value1, value2)</code> <code>assertNotEquals("message", value1, value2)</code>	Causes this test method to fail if the given two values are equal to each other. (For objects, it uses the equals method to compare them.)
<code>assertNotNull(value)</code> <code>assertNotNull("message", value)</code>	Causes this test method to fail if the given value is not null.
<code>assertNotNull(value)</code> <code>assertNotNull("message", value)</code>	Causes this test method to fail if the given value is null.
<code>assertSame(expectedValue, value)</code> <code>assertSame("message", expectedValue, value)</code> <code>assertNotSame(value1, value2)</code> <code>assertNotSame("message", value1, value2)</code>	Identical to <code>assertEquals</code> and <code>assertNotEquals</code> respectively, except that for objects, it uses the <code>==</code> operator rather than the <code>equals</code> method to compare them. (The difference is that two objects that have the same state might be equals to each other, but not <code>==</code> to each other. An object is only <code>==</code> to itself.)
<code>fail()</code> <code>fail("message")</code>	Causes this test method to fail.

How to Use JUnit: Adding More Tests (2.1)



```
1 @Test
2 public void testIncAfterCreation() {
3     Counter c = new Counter();
4     assertEquals(Counter.MIN_VALUE, c.getValue());
5     try {
6         c.increment();
7         assertEquals(1, c.getValue());
8     }
9     catch(ValueTooBigException e) {
10        /* Exception is not expected to be thrown. */
11        fail("ValueTooBigException is not expected.");
12    }
13 }
```

- Line 6 requires a try-catch block ∴ potential *ValueTooBigException*
- Lines 4, 7 11 are all assertions:
 - Lines 4 & 7 assert that *c.getValue()* returns the expected values.
 - Line 11: an assertion failure ∴ unexpected *ValueTooBigException*
- Line 7 can be rewritten as `assertTrue(1 == c.getValue())`.

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How to Use JUnit: Adding More Tests (3.1)



```
1 @Test
2 public void testDecFromMinValue() {
3     Counter c = new Counter();
4     assertEquals(Counter.MIN_VALUE, c.getValue());
5     try {
6         c.decrement();
7         fail("ValueTooSmallException is expected.");
8     }
9     catch(ValueTooSmallException e) {
10        /* Exception is expected to be thrown. */
11    }
12 }
```

- Line 6 requires a try-catch block ∴ potential *ValueTooBigException*
- Lines 4 & 7 are both assertions:
 - Lines 4 asserts that *c.getValue()* returns the expected value (i.e., *Counter.MIN_VALUE*).
 - Line 7: an assertion failure ∴ expected *ValueTooSmallException* not thrown

See the equivalent, manual `ConsoleTester1`.

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How to Use JUnit: Adding More Tests (2.2)



- Don't lose the big picture!
- JUnit test in previous slide automates this console interaction:

```
Enter "inc", "dec", or "val":
val
0
Enter "inc", "dec", or "val":
inc
1
Enter "inc", "dec", or "val":
val
1
Enter "inc", "dec", or "val":
exit
Bye!
```

- **Automation** is exactly rationale behind using JUnit!

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How to Use JUnit: Adding More Tests (3.2)



- Again, don't lose the big picture!
- JUnit test in previous slide automates `CounterTester1` and the following console interaction for `CounterTester3`:

```
Enter "inc", "dec", or "val":
val
0
Enter "inc", "dec", or "val":
dec
Value too small!
Enter "inc", "dec", or "val":
exit
Bye!
```

- Again, **automation** is exactly rationale behind using JUnit!

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How to Use JUnit: Adding More Tests (4.1)



```
1 @Test
2 public void testIncFromMaxValue() {
3     Counter c = new Counter();
4     try {
5         c.increment(); c.increment(); c.increment();
6     }
7     catch (ValueTooLargeException e) {
8         fail("ValueTooLargeException was thrown unexpectedly.");
9     }
10    assertEquals(Counter.MAX_VALUE, c.getValue());
11    try {
12        c.increment();
13        fail("ValueTooLargeException was NOT thrown as expected.");
14    }
15    catch (ValueTooLargeException e) {
16        /* Do nothing: ValueTooLargeException thrown as expected. */
17    }
18 }
```

- o L4 – L9: a VTLE *is not* expected; L11 – 17: a VTLE *is* expected.

See the equivalent, manual ConsoleTester2.

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How to Use JUnit: Adding More Tests (4.3)



Q: Can we rewrite testIncFromMaxValue to:

```
1 @Test
2 public void testIncFromMaxValue() {
3     Counter c = new Counter();
4     try {
5         c.increment();
6         c.increment();
7         c.increment();
8         assertEquals(Counter.MAX_VALUE, c.getValue());
9         c.increment();
10        fail("ValueTooLargeException was NOT thrown as expected.");
11    }
12    catch (ValueTooLargeException e) { }
13 }
```

No!

At Line 12, we would not know which line throws the VTLE:

- o If it was any of the calls in L5 – L7, then it's *not right*.
- o If it was L9, then it's *right*.

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How to Use JUnit: Adding More Tests (4.2)



- o JUnit test in previous slide **automates** CounterTester2 and the following console interaction for CounterTester3:

```
Enter "inc", "dec", or "val":
inc
Enter "inc", "dec", or "val":
inc
Enter "inc", "dec", or "val":
inc
Enter "inc", "dec", or "val":
val
3
Enter "inc", "dec", or "val":
inc
Value too big!
Enter "inc", "dec", or "val":
exit
Bye!
```

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How to Use JUnit: Adding More Tests (5)



Loops can make it effective on generating test cases:

```
1 @Test
2 public void testIncDecFromMiddleValues() {
3     Counter c = new Counter();
4     try {
5         for(int i = Counter.MIN_VALUE; i < Counter.MAX_VALUE; i++) {
6             int currentValue = c.getValue();
7             c.increment();
8             assertEquals(currentValue + 1, c.getValue());
9         }
10        for(int i = Counter.MAX_VALUE; i > Counter.MIN_VALUE; i--) {
11            int currentValue = c.getValue();
12            c.decrement();
13            assertEquals(currentValue - 1, c.getValue());
14        }
15    }
16    catch (ValueTooLargeException e) {
17        fail("ValueTooLargeException is thrown unexpectedly");
18    }
19    catch (ValueTooSmallException e) {
20        fail("ValueTooSmallException is thrown unexpectedly");
21    }
22 }
```

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Exercises



1. Run all 8 tests and make sure you receive a *green* bar.
2. Now, introduction an error to the implementation: Change the line `value ++` in `Counter.increment` to `--`.
 - Re-run all 8 tests and you should receive a *red* bar. [Why?]
 - Undo the error injection, and re-run all 8 tests. [What happens?]

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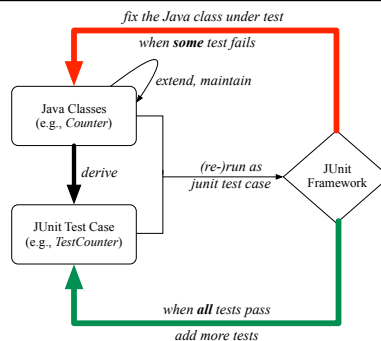
Resources



- Official Site of JUnit 4:
<http://junit.org/junit4/>
- API of JUnit assertions:
<http://junit.sourceforge.net/javadoc/org/junit/Assert.html>
- Another JUnit Tutorial example:
<https://courses.cs.washington.edu/courses/cse143/11wi/eclipse-tutorial/junit.shtml>

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Test-Driven Development (TDD)



Maintain a collection of tests which define the *correctness* of your Java class under development (CUD):

- Derive and run tests as soon as your CUD is *testable*.
i.e., A Java class is testable when defined with method signatures.
- *Red* bar reported: Fix the class under test (CUT) until *green* bar.
- *Green* bar reported: Add more tests and Fix CUT when necessary.

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Exercises

Test-Driven Development (TDD)

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