Unit Testing

Anti-Patterns:
- Only system testing
- Testing only “happy paths”
- Forgetting to test “missing” code

Unit testing
- Test a single subroutine/procedure/method
  - Use low level interface (“unit” = “code module”)
- Test both based on structure and on functionality
  - White box structural testing + Black box functional testing
- This is the best way to catch corner-case bugs
  - If you can’t exercise them here, you won’t see them in system testing

Test cases:
\[
a = 0; b = 0; \\
a = -1; b = +1;
\]
...

\[
uint16_t proc(uint16_t a, uint16_t b) \\
{ .... \\
return(result); 
}
\]

Expected Test Results:
\[
a = 0; b = 0; \quad ==> 0 \\
a = -1; b = +2; \quad ==> 1 
\]
...
Tests designed based on behavior
- But without knowledge of implementation
- “Functional” or behavioral testing

Idea is to test what software does, but not how function is implemented
- Example: cruise control black box test
  - Test operation at various speeds
  - Test operation at various underspeed/overspeed amounts
  - BUT, no knowledge of whether lookup table or control equation is used

- Advantage: can be written only based on requirements
- Disadvantage: difficult to exercise all code paths
White Box Testing

- Tests designed with knowledge of software design
  - Often called “structural” testing
  - Sometimes: “glass box” or “clear box”

- Idea is to exercise software, knowing how it is designed
  - Example: cruise control white box test
    - Exercise every line of code
      - Tests that exercise both paths of every conditional branch statement
    - Test operation at every point in control loop lookup table

- Advantage: helps getting high structural code coverage
- Disadvantage: doesn’t prompt coverage of “missing” code
Unit Testing Strategies

- **Boundary tests:**
  - At borders of behavioral changes
  - At borders of min & max values, counter rollover
  - Time crossings: hours, days, years, …

- **Exceptional values:**
  - NULL, NaN, Inf, null string, …
  - Undefined inputs, invalid inputs
  - Unusual events: leap year, DST change, …

- **Justify your level of coverage**
  - Trace to unit design
  - Get high code coverage
  - Define strategy for boundary & exception coverage
**MCDC Coverage as White Box Example**

**Modified Condition/Decision Coverage (MC/DC)**

- Used by DO-178 for critical aviation software testing
- Exercise all ways to reach all the code
  - Each entry and exit point is invoked
  - Each decision tries every possible outcome
  - Each condition in a decision takes on every possible outcome
  - Each condition in a decision is shown to independently affect the outcome of the decision

- For example: “if (A == 3 || B == 4)” => you need to test at least
  - A == 3 ; B != 4 (A causes branch, not masked by B)
  - A !=3 ; B == 4 (B causes branch, not masked by A)
  - A !=3 ; B != 4 (Fall-through case AND verifies A==3 and B==4 are in fact responsible for taking the branch)

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https://www.youtube.com/watch?v=DivaWCNohdw
WHAT’S MODIFIED CONDITION / DECISION COVERAGE TESTING?

Heres an analogy

IMAGINE A LIGHT CONTROLLED BY THREE SWITCHES...

IN MC/DC TESTING, WE NEED TO SHOW THAT EACH LIGHT SWITCH CAN INDEPENDENTLY TURN THE LIGHT ON OR OFF...

THE LIGHT CORRESPONDS TO THE DECISION AND THE SWITCHES CORRESPOND TO CONDITIONS

HOW DOES THAT APPLY TO SOFTWARE?

www.rapitasystems.com
Example MCDC

http://www.verifysoft.com/en_example_mcdc.html

- Each clause is tested with both true and false ("_" is don’t care)
- Each clause’s value (true/false), if inverted, would change value of output

A full Test Coverage would consist into building the following truth table and testing each combination:

| Test case n° | A: (u == 0) | B: (x>5) | C: (y<6) | D: (z == 0) | (A || B) && (C || D) |
|--------------|-------------|-----------|-----------|-------------|----------------------|
| 1            | F           | F         | F         | F           | F                    |
| 2            | F           | F         | F         | T           | F                    |
| 3            | F           | F         | T         | _           | F                    |
| 4            | F           | T         | F         | F           | F                    |
| 5            | F           | T         | F         | T           | T                    |
| 6            | F           | T         | T         | _           | T                    |
| 7            | T           | _         | F         | F           | F                    |
| 8            | T           | _         | F         | T           | T                    |
| 9            | T           | _         | T         | _           | T                    |

On the other hand, to ensure Modified condition/decision coverage, we should test (for instance) only the 5 combinations here-before underlined in yellow.
Unit Testing Frameworks

Cunit as an example framework
- **Test Suite**: set of related test cases
- **Test Case**: A procedure that runs one or more executions of a module for purpose of testing
- **Assertion**: A statement that determines if a test has passed or failed

Test case example: ([http://cunit.sourceforge.net/doc/writing_tests.html#tests](http://cunit.sourceforge.net/doc/writing_tests.html#tests))

```c
int maxi(int i1, int i2)
{ return (i1 > i2) ? i1 : i2; }
```

```c
void test_maxi(void)
{ CU_ASSERT(maxi(0, 2) == 2); // this is both a test case + assertion
  CU_ASSERT(maxi(0, -2) == 0);
  CU_ASSERT(maxi(2, 2) == 2); }
```
Best Practices For Unit Testing

- **Unit Test every module**
  - Use a unit testing framework
    - Don’t let test case complexity get too high
  - Use combination of white box & black box
    - Get good coverage, ideally 100% coverage
  - Get good coverage of data values
    - Especially, validate all lookup table entries

- **Unit Testing Pitfalls**
  - Creating test cases is a development effort
    - Code quality for test cases matters; test cases can have bugs!
  - Difficult to test code can lead to dysfunctional “unit test” strategies
    - Breakpoint debugging is not an effective unit test strategy
    - Using Cunit to accomplish subsystem testing is not really unit testing
  - Pure white box testing doesn’t test “missing” code

[Best Practices For Unit Testing](https://goo.gl/SjzaBm)