

# Control Structures: Conditionals

Wolfgang Schreiner

Research Institute for Symbolic Computation (RISC)

Johannes Kepler University, Linz, Austria

[Wolfgang.Schreiner@risc.jku.at](mailto:Wolfgang.Schreiner@risc.jku.at)

<http://www.risc.jku.at>

## Control Structures

- **Control flow**: order in which statements are executed.
  - Default: from first statement of a method to the last; control flow forms a single path.
  - **Control structures**: statements that modify control flow.
- **Conditional** statements:
  - Selection of a statement from a set of candidates.
  - Control flow is split into multiple alternative paths.
  - `if`, `if-else`, `switch`.
- **Iteration** statements:
  - Repetition of a statement until the **termination condition** holds.
  - Control flow forms a **loop** that may be traversed multiple times.
  - `while`, `do`, `for`.
- **Other** statements: `{ }`, `break`, `continue`.

## Assertions

```
assert boolean_expression ;  
assert boolean_expression : message ;
```

- Statement that indicates knowledge about program.

- We are convinced that the boolean expression evaluates to true.
- If not, the assertion has **failed** and the program is aborted.
- Examples:

```
x = 1;    assert x == 1;  
x = a+b; assert x == a+b;  
x = x+1; // x == x+1 does not hold!
```

- Assertions are only checked, if the Java option `-ea` is used:

```
java -ea Main
```

**Most valuable technique for debugging programs.**

## Block Statement

Grouping of multiple statements into one.

```
{  
  statement ;  
  statement ;  
  ...  
}
```

Block statement can appear wherever a single statement can appear.

## Declarations in Block Statements

Variable/constant declarations are **local** to a block.

- Correct:

```
{
  int i = 1;
  System.out.println(i);
}
{
  int i = 2;
  System.out.println(i);
}
```

- Wrong:

```
{
  int i = 1;
}
System.out.println(i);
```

Main.java:9: cannot resolve symbol  
symbol : variable i  
location: class Main  
System.out.println(i);

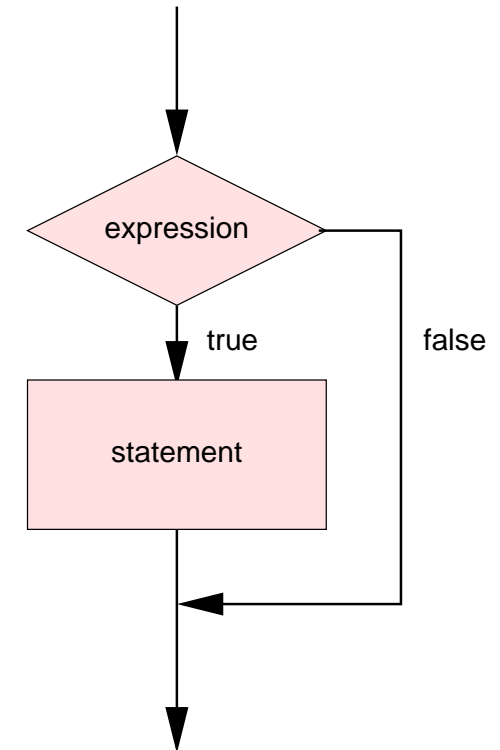
## The if Statement

```
if (boolean expression)  
    statement;
```

- One-branch conditional

- Boolean expression is evaluated.
- If result is true, statement is executed.
- If result is false, statement is not executed.
- Execution continues with the statement after the conditional.

Conditional execution of a statement.



## Examples

- If statement with a single statement.

```
if (count < max)
    count = count+1;
```

- If statement with a block:

```
if (count < max)
{
    count = count+1;
    sum = sum+count;
}
```

If branch may be single statement or a block.

## Assertions

- At the beginning of an if branch, the condition holds:

```
if (expression)
{
    assert expression;
    ...
}
```

- Assertion holds after assignment for the **old** variable values.

```
if (count < max)
{
    assert count < max;    // if branch
    count = count+1;
    assert count-1 < max; // count-1 = old count
    sum = sum+count;
}
```



## Assertions

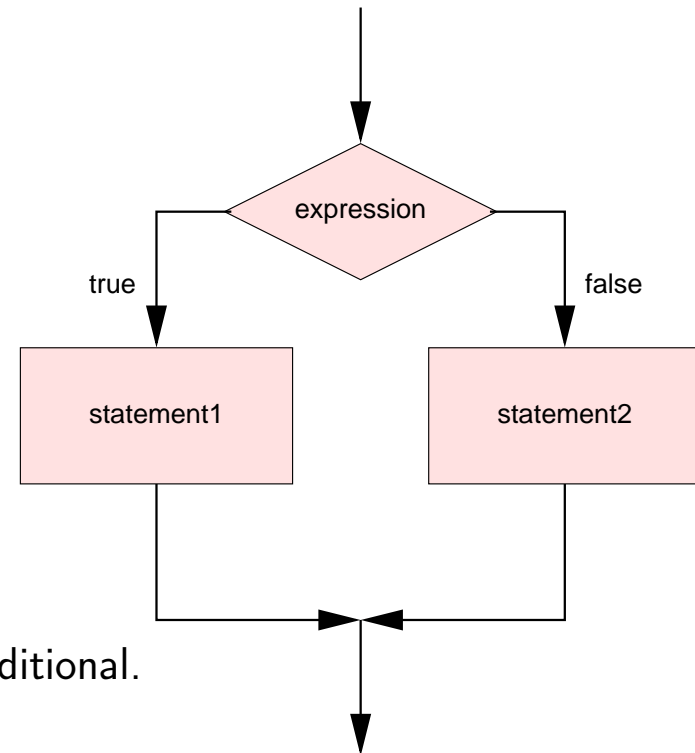
- If assertion holds before if statement, it holds at start of branch.
  - May concatenate assertions with the `&&` operator.

```
if (sum < max)
{
    assert sum < max;                // first if branch
    if (count < max)
    {
        assert sum < max && count < max;    // second branch with
                                           // previous condition
        count = count+1;
        assert sum < max && count-1 < max;    // count-1 == old count
        sum = sum+count;
        assert sum-count<max && count-1<max;    // sum-count == old sum
    }
}
```

## The if-else Statement

```
if (boolean expression)  
    statement1;  
else  
    statement2;
```

- Two-branch conditional.
  - Boolean expression is evaluated.
  - If result is true, first statement is executed.
  - If result is false, second statement is executed
  - Execution continues with the statement after the conditional.



Selection of a statement from two candidates.

## If Statements with Blocks

```
if (boolean expression)
{
    statement;
    statement;
    ...
}
else
{
    statement;
    statement;
    ...
}
```

```
if (value % 2 == 0)
    value = value/2;
else
{
    value = value-1;
    count = count+1;
}
```

## Dangling Else Problem

- Program:

```
if (a > b)
  if (a > 0) max = a;
else
  max = b;
```

- Compiler reads:

```
if (a > b)
  if (a > 0)
    max = a;
else
  max = b;
```

- Solution:

```
if (a > b)
{
  if (a > 0) max = a;
}
else
  max = b;
```

## Assertions

```
if (expression)
{
    assert expression;
    statement;
    ...
}
else
{
    assert !expression;
    statement;
    ...
}
```

At start of the second branch the boolean expression does not hold.

## Minimum of Three Numbers

Variable *min* shall hold minimum of three variables *a*, *b*, and *c*.

```
if (a < b)
  if (a < c)
    min = a;
  else
    min = c;
else
  if (b < c)
    min = b;
  else
    min = c;
```

Are we sure that the program is correct?

## Assertions

```
if (a < b)
{
    assert a < b;
    if (a < c)
    {
        assert a < b && a < c;
        min = a;
    }
    else
    {
        assert a < b && c <= a;
        min = c;
    }
}
...
```

## Assertions

```
...
else
{
    assert b <= a;
    if (b < c)
    {
        assert b <= a && b < c;
        min = b;
    }
    else
    {
        assert b <= a && c <= b;
        min = c;
    }
}
```



## Multi-Branch Conditionals

The `else` branch may be an `if-else` statement.

```
if (expression1)
    statement1;
else if (expression2)
    statement2;
else if (expression3)
    statement3;
...
else
    statementN;
```

- Multi-Branch conditional:

- One boolean expression after the other is evaluated.
- First branch is executed, for which evaluation returns true.
- If no expression yields true, final `else` branch is executed (if any).

## Example: Input Check

```
int i = Input.readInt();
if (Input.isOkay())
{
    handle input i
}
else if (Input.hasEnded())
{
    handle case that input stream has ended
}
else
{
    String error = Input.getError();
    handle error case
    Input.clearError();
}
```

## Assertions

```
if (exp1)
{
    assert exp1;
    ...
}
else if (exp2)
{
    assert !exp1 && exp2;
    ...
}
...
else
{
    assert !exp1 && !exp2 && !exp3 && ... && !expN-1;
    ...
}
```

## Example

```
if (value < 5)
    count = count+1;    // value < 5
else if (value < 10)
    count = count+2;    // 5 <= value < 10
else if (value < 20)
    count = count+3;    // 10 <= value < 20
else
    count = count+4;    // 20 <= value
```

Decomposition of variable range into four parts.

## Multiple Case Tests

Frequently control flow is determined by value of a single expression:

```
if (expression == const1)
    stat1;
else if (expression == const2)
    stat2;
else if (expression == const3)
    stat3;
...
else
    statN;
```

Inefficient and cumbersome.

## The switch Statement

```
switch (expression)
{
  case const1:
    stat1;
    break;
  case const2:
    stat2;
    break;
  case const3:
    stat3;
    break;
  ...
  default:
    statN;
}
```

## The `switch` Statement

- **Syntax:**

- Expression must be of integer or string type.
- Case tags must be literals/constants of this type.
- Same case tag must not appear in different branches.
- Default statement is optional.

- **Execution:**

- Expression is evaluated.
- Statement whose tag matches value is executed.
- If no tag matches, `default` statement (if any) is executed.

- **Implementation:**

- Compiler constructs a table of jump addresses for each case constant.
- At runtime, table lookup determines address of statement to execute.

## Example

Multiple tags may prefix a branch.

```
switch (i%5) // value is in 0..4
{
    case 0:
        System.out.println("divided by 5");
        break;
    case 1: case 3:
        System.out.println("odd remainder");
        break;
    default:
        System.out.println("even remainder");
}
```

Value range is decomposed into three cases.