



# ivyscript reference

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- Ivyscript is a programming language wrapper around the ivy engine control C++ API.
  - See "programming the ivy engine"
- Ivyscript – for scripting test workflow
  - The somewhat easier way for a human to operate ivy.
  - Similar to a subset of C/C++, with some minor differences.
  - Extensible - parser auto-generated from language grammar. (flex+bison)
- ivy engine REST API
  - Easier for programmers to integrate ivy into a wider framework.

- Statements in the programming language end with a semi-colon, like C / C++ / Java.
- C style comments are supported
  - The part from `/*` to `*/` is ignored
- C++ style comments are supported
  - From `//` to the end of the line is ignored.
- `#` style comments are supported
  - From `#` to the end of the line is ignored.

# Make .ivyscript programs executable

- So-called "sha-bang" lines work.
- A sha-bang line is when you start a script with a line that specifies a path to the program used to interpret the script.
- For example, as the first line of an .ivyscript program:

```
#!/path_to_ivy_executables/ivy
```

(followed by remainder of ivyscript program)

- Then you can invoke the .ivyscript file as a program itself.

- Anywhere you can put a statement, you can put a nested block, which starts with "{" and ends with "}".
- Any variable or function declarations made inside a nested block are not "visible" to code outside the nested block.
- Nested blocks are typically used in `if` statements, looping constructs, etc.

- There are 3 types: `int`, `double`, and `string`.

- Examples of constants, also called literals:

<code>int:</code>	<code>0</code>	<code>-5</code>	<code>12345</code>			
<code>double:</code>	<code>5.</code>	<code>.5</code>	<code>5.5</code>	<code>5E-2</code>	<code>5%</code>	<code>5.5%</code>
<code>string:</code>	<code>"house"</code>	<code>" "</code>				

- There is also a hex form of `int` literal (constant)
  - `0x0` to `0x7FFFFFFF`
  - The hex form of `int` literal only supports non-negative values
- `5%` means the same thing as `0.05`.

- To include a double quote character in a string constant, escape it with a backslash:
  - `"the word \"house\" is double-quoted"`
- Other escaped characters: `\r`, `\n`, `\t`
- An escaped octal character value has 3 digits, e.g. `\001`
- An escaped hex character value has one or two digits, e.g. `\xf` or `\x0f`
- Raw strings start with `<<` and end with `>>`. Use this for JSON and you won't need to escape the double-quote characters.

```
<< { "port" : "1A", "LDEV" : "00:FF" } >>
```

- "identifiers" are eligible to serve as the name of a variable or function.
- An identifier begins with an alphabetic character (a letter) or a Japanese hiragana, katakana, or Kanji character, and continues with letters, Japanese hiragana, katakana, or Kanji characters, digits, and underscore \_ characters.



- `<type> <list of identifiers <with optional = initializer expression>;`
- Examples:
- ```
int i, j;  
int k = -1;  
double c;  
double d = 1.5;  
string s;  
string name = "bert";
```

- A constant (a literal of one of the types) is an expression
  - e.g. `"constant"`
- A variable reference is an expression
  - e.g. `x`
- Expressions may be combined together with operators, which operate the same as in C/C++:
  - `+, -, *, /, %, >, <, >=, <=, ==, !=, =, |, &, ^, &&, ||`
- Expressions have a type, `int`, `double`, or `string`

# Converting an expression to a different type

- `int( <expression> )`  
`double( <expression> )`  
`string( <expression> )`
- Some times called a "cast".
- The expression is evaluated and the result is converted to the target type.
- Can result in a run time error
  - E.g. evaluating `int( "cow" )` would cause a run-time error.

- + plus – for numbers, adds, for strings, concatenates
- minus
- \* multiply
- / divide
- % remainder from integer division

- - > greater than
  - < less than
  - >= greater than or equal to
  - <= less than or equal to
  - == equal to
  - != not equal to
- There is no true/false type. Logical operators evaluate to an integer value just like the old C language before there was a `bool` type.
  - An `int` or a `double` value used as a logical expression means "false" if the numeric value is zero, and means "true" for any non-zero value.
  - Use of `int` logical values is transparent – it works the way you expect it to.

- The bitwise operators operate on the individual bits in an `int` value, exactly like in C/C++.
- |      bitwise or
- &     bitwise and
- ^     bitwise exclusive or

- These operate on logical expressions, which evaluate to an `int` interpreted to mean "false" if the `int` value is zero, "true" otherwise.
  - Like in C/C++ the second expression after the operator is not evaluated if the result is known from evaluating the first expression before the operator.
- `||`      logical or
  - Evaluates the first expression, and if true, returns true. Otherwise, it evaluates the second expression and returns its true/false value.
- `&&`      logical and
  - Evaluates the first expression, and if false, returns false. Otherwise it evaluates the second expression and returns its true/false value.
- `!`      not
  - Evaluates a logical expression and returns the opposite.

- `<identifier> = <expression>`
- The identifier is looked up in the symbol table at compile time, and if it's valid, at execution the expression is evaluated and the variable is set to that value.
- If the expression is not of the same type as the variable, the value may be coerced / converted, or in some cases a compile time error occurs.



- `<identifier> ( <comma separated list of zero or more expressions> )`
  - E.g. `sin(.5)`
- Identifier and parameter list signature are looked up at compile time to and if valid, a function call is built.
- At run time, the expressions are evaluated and the resulting parameter values are passed to the function, the function is executed, and the result is returned.

- Same as C/C++

- `if ( 3*4+5*6 == fred || ! Person == Nancy = 4)`

- Means

- `if ( ( ( (3*4) + (5*6) ) == fred) || ( ! (Person == (Nancy=4) ) ) )`

- If you are not sure, group with parentheses ().

- E.g.

```
- int add_three( int i )  
  {  
    return i+3;  
  };
```

Semicolon needed for function definitions, unlike in C / C++

- Functions have a type, which is the type of the object they return to the caller.
- Functions can be "declared" without being defined yet:  

```
int add_three(int i);
```

- As in most programming languages you can "include" or "import" a copy of some ivyscript code from a library.
- In ivyscript, you say:

```
include port_scalability_test.ivyscript
```

- Just be advised that the initial implementation of this feature allows infinite loops.
  - Need to consider use cases – in some cases it could be valid to be importing multiple copies, but from different and separate places.
  - Maybe default to #pragma once behaviour, requiring specific override.

- It's OK to have different functions with the same name as long as the sequence of types of the parameters is different so the compiler can tell them apart.
- ```
int      addtwo(int i)      { return i+2;}  
string  addtwo(string s) { return s + "two";}
```

# `ivy_engine_get("thing")` `ivy_engine_set("thing", "value")`

- `"thing"` must be an identifier starting with a letter and continuing with letters, digits, and underscores
  - `"thing"` names are normalized before examination by removing underscores and translating to lower case, that is, `"outputFolderRoot"`, `"output_Folder_Root"`, and `"output_folder_root"` are equivalent.
- `ivy_engine_get("summary_csv")` gets the `"all=all"` summary csv filename
- `ivy_engine_get("outputFolderRoot")` from `[OutputFolderRoot]` statement – default `"."`
- `ivy_engine_get("testName")` root part of ivyscript file without `.ivyscript` suffix
- `ivy_engine_get("masterlogfile")` gets the filename
- `ivy_engine_set("masterlogfile", "message")` writes a timestamp and `"message"` to the log
- `ivy_engine_get("testFolder")` root folder for output from this run
- `ivy_engine_get("stepNNNN")` from most recent `[Go!]`, e.g. `step0002`
- `ivy_engine_get("stepName")` from most recent `[Go]`
- `ivy_engine_get("stepFolder")` subfolder for most recent `[Go]` within `testFolder()`
- `ivy_engine_get("last_result")` for most recent `[Go]`, returns `"success"` or `"failure"`
- `ivy_engine_get("rollup_structure")` gets type / instance / workload thread hierarchy.

- `ivy_engine_get("achieved_IOPS_tolerance")`  
`ivy_engine_set("achieved_IOPS_tolerance", "0.25%")`
- When running at a specific IOPS numeric value (that is, not running `IOPS=max`), the measurement will be marked "invalid" if the achieved IOPS is more than `achieved_IOPS_tolerance` different from the (rollup instance's) `Total_IOPS` setting.
- This is also the criterion that determines when to stop a `DFC=IOPS_staircase` run to saturation that doesn't specify an `ending_IOPS` or equivalent. The staircase will stop after a step that fails to achieve its IOPS setting.
- The default `achieved_IOPS_tolerance` is 0.25%. This is good for the vast majority of cases.

# Deprecated ivyscript ivy engine accessor builtins

- The following ivyscript builtin functions still work, but users are encouraged to switch over to using the equivalent calls to `ivy_engine_get("thing")` and `ivy_engine_set("thing", "value")`
- `string outputFolderRoot();` from [OutputFolderRoot] statement – default "."
- `string testName();` root part of ivyscript file without .ivyscript suffix
- `string masterlogfile();` ivy master log filename
- `string testFolder();` root folder for output from this run
- `string stepNNNN();` from most recent [Go!], e.g. step0002
- `string stepName();` from most recent [Go]
- `string stepFolder();` subfolder for most recent [go] within testFolder()
- `string last_result();` for most recent [Go], returns "success" or "failure"
- `string show_rollup_structure();` shows type / instance / workload thread hierarchy.



# Math builtin functions – same as C/C++

- `double sin(double), double cos(double), double tan(double)`
- `double sinh(double), double cosh(double), double tanh(double)`
- `double asin(double), double acos(double),  
double atan(double), double atan2(double, double)`
- `double log(double), log10(double),  
double exp(double), double pow(double, double)`
- `double sqrt(double)`
- `int abs(int)` - **absolute value**
- `double pi(), double e()`

# String builtin functions

- `string substring(string s, int begin_index_from_zero, int number_of_chars);`
- `string left(string s, int n);`     like in BASIC, gives you leftmost / rightmost characters  
`string right(string s, int n);`
- `string trim(string s);`     removes leading / trailing whitespace
- `string to_lower(string s);`  
`string to_upper(string s);`
- `int stringCaseInsensitiveEquality(string s1, string s2);`
- `string int_to_ldev(int n);`     `int_to_ldev(0xFF)` **returns** "00:FF"
- `string to_string_with_decimal_places(double x, int n);`  
`to_string_decimal_places(3.1415,2)` **returns** "3.14"

- ivy uses the default flavour of C++ `std::regex`, which I think uses the ECMAScript dialect
- `int regex_match(std::string s, string regex);`  
E.g. `if ( regex_match("horse","(horse)|(cow)") ) then print("animal\n");`
- `int regex_sub_match_count(string s, string regex);`
- `string regex_sub_match(string s, string regex, int n);`  
n must be less than `regex_sub_match_count(s, regex)`
- `int matches_digits(string s);`  
`int matches_float_number(string s);`  
`int matches_float_number_optional_trailing_percent(string s);`  
some ivy parameters can be set to these  
`int matches_identifier(string s);`  
alphabetic, continued with alphanumeric and underscores  
`int matches_IPv4_dotted_quad(string s);`

# Accessing csv files – row and column

	A	B	C	Q	R	S	AW	AX			
Header row is row -1											
	Test Name	Step Number	Step Name	iogenerator type	blocksize	maxTags	Overall IOPS	Overall Decimal MB/s	Overall Average Blocksize (KiB)	Overall Little's Law Avg Q	Overall Average Service Time (ms)
1											
2	demo9	step0000	iops_max	random_independent	4 KiB	32	2597.16	10.638	4	64.0024	24.6432
3	demo9	step0001	baseline_service_time	random_independent	4 KiB	32	25.81	0.105718	4	0.164588	6.37691
4	demo9	step0002	1.125_x_baseline	random_independent	4 KiB	32	555.849	2.27676	4	4.08014	7.34037
5	demo9	step0003	1.25_x_baseline	random_independent	4 KiB	32	1097.86	4.49682	4	8.74646	7.96686
6	demo9	step0004	1.5_x_baseline	random_independent	4 KiB	32	1486.01	6.08671	4	14.2187	9.56836
7	demo9	step0005	1.75_x_baseline	random_independent	4 KiB	32	1722.35	7.05476	4	19.2298	11.1649
8	demo9	step0006	2_x_baseline	random_independent	4 KiB	32	1898.07	7.77448	4	24.2199	12.7603
9	demo9	step0007	3_x_baseline	random_independent	4 KiB	32	2353.68	9.64067	4	45.0346	19.1337
10	demo9	step0008	4_x_baseline	random_independent	4 KiB	32	2602.77	10.6609	4	63.9994	24.589
11	demo9	step0009	5_x_baseline	random_independent	4 KiB	32	2601.7	10.6566	4	63.9962	24.5978

Test step csv files (not shown) have one line per subinterval (both host & subsystem data)

Summary csv files like this one have one line per test step.

Use column number from 0, or say "Overall IOPS"

Row 0 is test step 0 or subinterval 0

- These csv functions are the same as the standalone ivy companion csv file command line utilities
- `int csv_rows(string filename);`
  - Number of rows following the header row.
  - Returns -1 if invalid file or file empty. Returns 0 if there was only a header row.
- `int csv_columns_in_row(string filename, int row);`
- `int csv_header_columns(string filename);`
  - Same as `csv_columns_in_row(filename, -1)`

# Csv file builtin functions 2/3 – individual cells

- `string csv_cell_value(string filename, int row, int column);`  
`string csv_cell_value(string filename, int row, string column_header_text);`
  - You can refer to a column using an int, the column index from zero.
  - You can refer to a column using a string, the column header text.
  
- `string csv_raw_cell_value(string filename, int row, int column);`  
`string csv_raw_cell_value(string filename, int row, string column_header_text);`
  - ivy "wraps" text fields as a formula with a string constant, e.g. `"horse"`
    - This stops Excel from interpreting 1-1 as January 1<sup>st</sup>, and 00:00 from interpreting as a time.
  - The csv file functions normally "unwrap" csv column values, removing this kind of wrapper or removing simple double quotes surrounding a value, to treat `"horse"`, `"horse"` and `horse` the same
  - Retrieving the raw value give you exactly what was between the commas in the csv file.

# Csv file builtin functions 3/3 – headers & slices

- `int csv_lookup_column(string filename, string column_header);`
  - Gives you the column number for a column title string.
- `string csv_column_header(string filename, int col);`
  - Give you the text of the column header for a column number from zero.
- `string csv_column(string filename, int col);`  
`string csv_column(string filename, string column_header);`
  - Gives you a "column slice" of the spreadsheet showing "raw" values.
  - E.g. "IOPS,55,66,55,44"
  - Demo number 8 shows iterating through the column slices to write out the transpose of a csv file.
- `string csvfile_row(string filename, int row);`
  - Gives you a "row slice" of the spreadsheet showing the "raw" values.
  - E.g. "random\_independent",="4 KiB",32,2601.7

- `string print(string), double print(double), int print(int)`
  - Prints the specified value to stdout and then returns that value.
- `int fileappend(string filename, string s)`
  - One way to write output. Does not append a newline to `s`.
- `int log(string s)`
  - Writes to the ivy master log file, adding a timestamp prefix before the string, and adds terminating newline if the last line in `s` doesn't already have one.
- `trace_evaluate(int)`
  - Turns execution tracing on/off. Zero means off, otherwise on.



- `string shell_command(string)`  
or equivalently `string system(string)`
  - Executes the shell command and returns its output.
    - **Runs as `root`. You have been warned.**
    - Ivy runs as `root` in our lab because ivy uses ssh to fire up ivydriver and `ivy_cmddev` on test hosts, and "`root`" has been set up to not require a password to ssh. Ivy may also need to run as `root` to do I/O to raw LUNs – not sure.
    - The only ivy component that definitely requires to run as `root` is the SCSI Inquiry tool, which has the executable that issues "SCSI Inquiry" marked `setuid` as `root`, and thus works for any user.
  - Use `shell_command()` to do almost anything
    - `grep` in an ivy output folder to find a csv file name
    - Get a time or date stamp

- As in

```
– if ( last_result() != "success" )  
  {  
    print "timed out without making a valid measurement.\n";  
    exit();  
  }
```

# Statements: expression statement

- `<expression> ;`
- Executes the expression and discards the result.

- `if ( <logical expression> ) <statement>`
- `if ( <logical expression> ) <statement> else <statement>`
- `<statement>` can be a single statement, or it can be a nested block starting with `{` and ending with `}`.

- `int x = 1;`

```
if ( x >= 0 ) print( "x is greater than or equal to zero.\n");  
else          print( "x is less than zero.\n");
```

```
if ( x >= 0 ) { print( "x is greater than or equal to zero.\n"); x = x + 1; }  
else        { print( "x is less than zero.\n");                x = x - 1; }
```

# Statements – traditional C style for loop

- `for ( <initializer expression> ; <logical expression>; <epilogue expression> )`  
    <loop body statement>
- The initializer expression is run.
- Then the logical expression is evaluated, if false, execution of the statement is complete.
- Otherwise, the loop body statement is run, then the epilogue expression is run, then we loop back to where we will evaluate the logical expression.

# Example of traditional for loop

- ```
int i;  
for ( i=0; i<10; i=i+1 )  
{  
    print( "i = " + string(i) + "\n");  
}
```
- Note that it's not `for (int i=0; i<10; i++)`
  1. The initializer is an expression, not a statement, so can't declare `i` to be an `int`.
  2. There is no increment operator `++` as in C++.

# Statement – list-style for loop

- For <identifier> = { <list of expressions> } statement
- E.g.

```
int i;  
for i = { 0, 1, 2 }  
    print("i = " + string(i) + "\n");
```

```
string s;  
for s = { "cat", "dog", "mouse" }  
{  
    print ( "A " + s + " has four legs.\n");  
}
```

# Statement – while loop

- `while ( <logical expression> ) <loop body statement>`
- The logical expression is evaluated, and if false, execution of the statement is complete.
- Otherwise, the loop body statement is executed and then we loop back to evaluating the logical expression again.



# Statement – do - while loop

- `do <loop body statement> while ( <logical expression> ) ;`
- The loop body statement is executed, and then the logical expression is evaluated, and if the result was "false", execution of the statement is complete.
- Otherwise, and then we loop back to running the loop body statement again.



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