



Mojo Compile-time

Reasoning and optimization: the facts you give the compiler, and what it does with them

Mojo language reference
v1.0.0

keyword type built-in "string" number operator @decorator True/False/None # comment

MOJO COMPILE-TIME

compile-time Mojo is just Mojo

One language. Compile time and runtime use the same Mojo.

The compiler acts on what it can prove, using constraints and conformance rules in code.

Proven facts enable or disable methods, constructors, and conformances.

Compile-time computation shifts expensive work out of runtime.

PARAMETERS: TYPES AND VALUES

[] compile-time parameters, () runtime arguments

```
def repeat[T: Copyable, n: Int](x: T) -> Array[T, n]:  
    ... # T is a type, n is a value  
struct Matrix[dtype: DType, rows: Int, cols: Int]: ...
```

Use parameterized declarations for functions and structs. The compiler creates a concrete implementation for each unique set of parameter values.

WHERE: PROVE, THEN GATE

on traits or parameter facts

```
def sort(mut self) where conforms_to(Self.T, Comparable): ...  
struct Box[T](Writable where conforms_to(T, Writable)): ...  
def chunk[w: Int]() where w.is_power_of_two(): ...
```

A precondition the compiler must prove, such as trait facts, numeric truths, or a DType's kind, before the call compiles.

CONFORMANCES PROVE CAPABILITIES

check and specialize

```
def largest[T: Comparable & Copyable](xs: List[T]) -> T:  
    ... # only operations T guarantees will compile
```

A trait conformance guarantees what capabilities the parameters support, so only valid code compiles.

CONDITIONAL AVAILABILITY

exists only when it can

```
struct Buffer[T: Copyable, n: Int](  
    Writable where conforms_to(T, Writable), # conforms only if T does  
):  
    def first(self) -> Self.T where Self.n > 0: ... # method only if n > 0
```

A type, method, conformance, or comptime declaration is available only when the compiler can prove its condition. The API is correct by construction: a missing capability or unmet constraint means calls with invalid parameters won't compile.

REFLECT A TYPE

read a type's shape

```
comptime name = reflect[T].name() # also .field_count(), .field_names(),  
    ...  
comptime t = type_of(x) # the type of an expression
```

reflect[T] reads a type's structure and **type_of** an expression's type, so parameterized code adapts to any shape.

RUN CODE AT COMPILE TIME

any function, no marker

```
def meters(ft: Float64) -> Float64:  
    return ft * 0.3048  
comptime track = meters(100.0) # runs while compiling, baked in
```

Every fact must be established at compile time.

COMPILE-TIME NUMERIC PRECISION

literals stay exact

```
comptime MAX = 2 ** 200 # arbitrary-precision integer  
comptime c = 0.1 + 0.2 # 0.3 exactly: a literal, kept exact  
var r = 0.1 + 0.2 # a Float64, subject to rounding
```

Literals stay exact. **Float64** rounds values like **0.1**, and repeated computations accumulate rounding error. Compute accuracy-sensitive constants at compile time.

FRONT-LOAD COMPUTE

move work to compile time

```
def slow_calc() -> Float64:  
    ... # an expensive calculation  
comptime FACTOR = slow_calc() # computed while compiling, baked in
```

Run expensive computation once while compiling; the result is baked in, free at runtime. For tables and other compile-time data, **global_constant** gives O(1) access without materializing them each time.

COMPTIME IF / FOR

branch and unroll early

```
comptime if is_nvidia_gpu(): # only the live branch compiles  
    use_nvidia()  
else:  
    use_fallback()  
comptime for i in range(4): # fully unrolled  
    process[i]()
```

comptime if compiles the live branch only; **comptime for** unrolls, removing loop overhead.

QUERY THE TARGET

size, alignment, SIMD width

```
comptime w = simd_width_of[DType.float32]() # lanes that fit a register  
size_of[T]() align_of[T]() # layout, at compile time
```

sys.info answers machine questions at compile time, so one source adapts to every target.

MATERIALIZATION

bring comptime values to runtime

```
comptime table: List[Int] = [3, 5, 7, 11, 13] # a comptime List (heap-backed)  
var t = materialize[table]() # -> a runtime List; you choose when it allocates  
ref g = global_constant[POWERS]() # POWERS: a fixed scalar table, read g[i], no copy
```

Scalars materialize automatically; heap-backed values (**List**, **Dict**) need **materialize**. **global_constant** keeps one static copy to index.

COMPTIME MEMBERS

comptime lives on types too

```
struct Stack[T: Copyable]:  
    comptime Element = Self.T # associated type  
    comptime capacity = 1024 # comptime value member  
    comptime Scalar[dt: DType] = SIMD[dt, 1] # parametric alias
```

A type carries its own compile-time members (values, associated types, and parametric aliases), reached through **Self**.

INLINING

force or forbid

```
@always_inline  
def lerp(a: Float64, b: Float64, t: Float64) -> Float64:  
    return a + (b - a) * t # expanded at every call site  
@no_inline  
def cold_path(): ... # kept as a real call
```

Inlining replaces a function call with the function body, reducing call overhead for small, frequently called functions. Add **@always_inline** to request inlining, **@no_inline** to exclude the option, or let the compiler decide.

THE COMPILE-TIME BOUNDARY

what can't happen early

Everything used in compile-time code must be known at compile time. A compile-time value, parameter, **if**, or **for** can't depend on runtime input.

At compile time, you can't perform file I/O, make foreign calls, or call functions that can raise.

Compile-time code runs on the CPU, like all compilation.