Make false and true first-class language features
proposal for C23

Jens Gustedt
INRIA and ICube, Université de Strasbourg, France

In its London 2019 meeting, WG14 has found consensus to elevate \texttt{false} and \texttt{true} to proper keywords.

Changes in v2: WG14 was not sympathetic to force these keywords also to be macros, so we remove the text corresponding to this idea. WG14 also was not in favor of the parts that proposed to introduce recommended practice and to add future language directions, so these are also removed.

Changes in v3: It was then observed in a discussion on the reflector, that the possible use of these predefined constants in the preprocessor needs some more precautions.

Changes in v4: Now that the type change has been integrated into C23, it remains to integrate the new keywords properly into all translation phases.

Changes in v5:
— Make it clear that the constants count as integer constant expressions.
— Synchronize the handling in the preprocessor with C++.
— Explicitly mark the macro \texttt{__bool_true_false_are_defined} as obsolescent and keep it as last remaining content in \texttt{<stdbool.h>}.

Changes in v6:
— Simplify the approach that makes them integer constant expressions.
— Synchronize the possible definition as predefined macro with N2884.
— Use the change to the \texttt{bool} type that previously was an alternate form. WG14 chose that one.
— Move the special promotion rules for the constants where they belong, namely to the definition of integer promotion.
— Make an optional proposal for a change for integer promotions of type \texttt{bool}.

1. INTRODUCTION
The integration of Boolean constants \texttt{false} and \texttt{true} as proper language constructs, is meant to provide a better feedback to programmers for the use of these constants by the translator or from debuggers. In particular, diagnostics will hopefully be provided when they are used in arithmetic or used contrary to the intent, e.g as null pointer constants.

2. IMPACT
A possible impact of changing \texttt{false} and \texttt{true} to keywords could be the use of these constants in preprocessing conditional expressions. Currently preprocessing arithmetic sees the existing macros from \texttt{<stdbool.h>} as signed values, and thus the result of expressions is merely consistent between the preprocessor and the rest of the language. When changing to keywords we should ensure that \texttt{false} and \texttt{true} may still be used in the preprocessor with the same semantics as before. This is done by enforcing the following:

— Other than for other keywords, \texttt{false} and \texttt{true} are not rewritten to pp-token 0 in preprocessor arithmetic.
— This ensures that preprocessor arithmetic uses signed values for these constants, such that results of such arithmetic remain the same between C17 and C2x.

3. REFERENCE IMPLEMENTATION
To add minimal support for the proposed changes, an implementation that does not yet want to implement \texttt{false} and \texttt{true} as full-featured keywords would have to add definitions that are equivalent to the following lines to their startup code:

\begin{verbatim}
#define false ((bool)+0)
\end{verbatim}
Notice that these do not use the literals 0\text{U} or 1\text{U} because with that arithmetic with these constants in the preprocessor would be performed as unsigned integers. This would have the consequence that something like \texttt{-true} would result to \texttt{UINTMAX\_MAX} in the preprocessor and \texttt{-1} otherwise.

4. CHANGES

We assume that the non-optional part of N2884 has been integrated into C23, otherwise the present paper is obsolete. Predefined constants need a little bit more effort for the integration, than the other keywords in N2884, because up to now C did not have named constants on the level of the language.

4.1. Syntax

We propose to integrate these constants by means of a new syntax term predefined constant. The text itself is then integrated as a specific clause.

\begin{change}
Add \texttt{false} and \texttt{true} into the alphabetic order of 6.4.1.
\end{change}

\begin{change}
Add a new syntax item predefined-constants to the end of 6.4.4 p1, Constants.
\end{change}

\begin{change}
Add a new clause 6.4.4.5 as follows.
\end{change}

\begin{verbatim}
6.4.4.5 Predefined constants
Syntax
predefined-constant:

false
true

Description
Some keywords represent constants of a specific value and type.
The keywords \texttt{false} and \texttt{true} are constants of type \texttt{bool} with value 0 for \texttt{false}
and 1 for \texttt{true}.
FOOTNOTE[The constants \texttt{false} and \texttt{true} promote to type \texttt{int}, see 6.3.1.1. When used for arithmetic in translation phase 4, they are signed values and the result of such arithmetic is consistent with results of later translation phases.]
\end{verbatim}

Up to C17 \texttt{false} and \texttt{true} promoted to \texttt{int} values 0 and 1, respectively. Keep the status quo.

\begin{change}
In 6.3.1.1 p2 change the following sentence:
\begin{verbatim}
If an \texttt{int} can represent all values of the original type (as restricted by the width, for a bit-field) or if the operand is one of the constants \texttt{false} or \texttt{true}, the value is converted to an \texttt{int}; otherwise, it is converted to an unsigned \texttt{int}. These are called the integer promotions.
\end{verbatim}
\end{change}

Also, the predefined constants should be constants of the right kind.

\begin{change}
Add to 6.6 p6:
\end{change}
6 An integer constant expression\(^{127}\) shall have integer type and shall only have operands that are integer constants, enumeration constants, character constants, predefined constants, sizeof expressions whose results are integer constants, alignof expressions, and floating constants that are the immediate operands of casts. Cast operators in an integer constant expression shall only convert arithmetic types to integer types, except as part of an operand to the sizeof or alignof operator.

**Change 6. Add to 6.6 p8:**

8 An arithmetic constant expression shall have arithmetic type and shall only have operands that are integer constants, floating constants, enumeration constants, character constants, predefined constants, sizeof expressions whose results are integer constants, and alignof expressions. Cast operators in an arithmetic constant expression shall only convert arithmetic types to arithmetic types, except as part of an operand to a sizeof or alignof operator.

### 4.2. Interaction with legacy code

There is still some code in the field that redefines these keywords. When compiler versions for C23 come out, it would be important that there is no silent redefinition of types or values depending on which headers are included and in which order.

**Change 7. Add the following to 6.10.8 p2:**

None of these macro names, nor the identifiers defined or \_has\_c\_attribute, shall be the subject of a \#define or a \#undef preprocessing directive. Any other predefined macro names shall begin with a leading underscore followed by an uppercase letter or a second underscore or shall be any of the identifiers alignas, alignof, bool, false, or static\_assert, or true.

### 4.3. The bool type

Definitions of the bool type should now directly refer to the constants and make no fuzz about zero or non-zero values anymore.

**Change 8. In 6.2.5 (Types) make the following change to p2:**

An object declared as type bool is large enough to store the values \#false and \#true.

The current state of conversion to the type bool makes several implicit references back and forth between conversions and the equality operator.\(^1\) The changes proposed here, give an opportunity to improve that situation and WG14 has seen this favorably.

**Change 9. In 6.3.1.2 (Boolean type) make the following change to p1 and remove the corresponding footnote:**

\(^1\)The process of converting a long to bool is e.g as follows: 1L \(\Rightarrow (1L == 0) \Rightarrow (1L == 0L) \Rightarrow false.\)
When any scalar value is converted to bool, the result is false if the value compares equal to 0 is a zero (for arithmetic types) or null (for pointer types) (FNT) otherwise, the result is true.

4.4. Preprocessing

The tokens false and true need a specific exception during preprocessing, such that constructs such as the following do not have surprising results.

```
#if true
...
#endif
```

**Change 10.** In 6.10.1 p7, amend the following partial phrase:

... all remaining identifiers other than false or true (including those lexically identical to keywords) are replaced with the pp-number 0, ...

Because transitionally these new keywords might still have predefined macro definitions, we also add them to the list for which the spelling after preprocessing is unspecified.

**Change 11.** In 6.4.1 p2’ (as of N2884) make the following changes:

The spelling of these keywords and their alternate forms of false and true inside expressions that are subject to the # and ## preprocessing operators is unspecified.

4.5. Changes to library clauses

Clause 7.18 <stdbool.h>

This header now holds no reasonable contents and should be removed after a time of adjustment.

**Change 12.** Replace the content of clause 7.18 by

The obsolescent header <stdbool.h> provides the obsolescent macro __bool_true_false_are_defined which expands to the integer constant 1.

Also update the corresponding entry for future library directions:

**Change 13.** Replace the content of clause 7.31.12 by

The header <stdbool.h> and the macro __bool_true_false_are_defined are obsolescent features.

Clause 7.26 <threads.h>

This header has several functions or macros that return bool values.

**Change 14.** In 7.17.5.1, 7.17.7.4 and 7.17.8.1 change the specification of return values to the keywords false and true where appropriate.
4.6. Integer promotions

Since the beginning, there has been an inconsistency in C that on some special architectures
the bool type is promoted to unsigned int instead of int, whereas bool bit-fields of width 1
and the symbolic constants false and true are always promoted to int. This is the case
for architectures where the types bool, unsigned char and unsigned short not only have
the same size as int but also the same width. On these architectures the representation of
a bool object could be manipulated to represent a value as large as UINT_MAX.

As proposed up to now, this paper maintains this status quo. Nevertheless we find it interesting
to change this situation and to make a normative change for those rare architectures.

Change 15 (optional). In 6.3.1.1 p2 change the following sentence:

If an int can represent all values of the original type (as restricted by the width,
for a bit-field) or if the operand is one of the constants false or true, it is bool.
The value is converted to an int; otherwise, it is converted to an unsigned int.

These are called the integer promotions.62)

5. QUESTIONS FOR WG14

Question 1. Does WG14 want to integrate the changes 1 – 14 as proposed in N2885
into C23?

Question 2. Does WG14 want to integrate the optional change 15 as proposed in N2885
into C23?

Acknowledgement

We thank Joseph Myers, JeanHeyd Meneide and Aaron Ballmann as well as the C/C++
liaison study group for feedback and discussions.