University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 120: Introduction to Computing

Expressions and Operators in C

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Expressions are Used to Perform Calculations

Let's talk in more detail starting with a fifth element of **C** syntax: expressions.

An **expression** is a calculation consisting of variables and operators.* For example,

A + 42

A / B

Deposits – Withdrawals

* And function calls, but that topic we leave for ECE220.

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Our Class Focuses on Four Types of Operator in C

The **C** language supports many operators.

In our class, we consider four types:
- **arithmetic** operators
- **bitwise** Boolean operators
- **relational** / **comparison** operators
- the **assignment** operator

We also introduce logical operators, but leave their full meaning for ECE220.

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Five Arithmetic Operators on Numeric Types

Arithmetic operators in **C** include
- addition: **+**
- subtraction: **–**
- multiplication: *****
- division: **/**
- modulus: **%** (integers only)

The **C** library includes many other functions, such as exponentiation, logarithms, square roots, and so forth. We leave these for ECE220.

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Arithmetic Mostly Does What You Expect

Declare: `int A = 120;  int B = 42;`
Then…

`A + B`	**evaluates to**	`162`
`A - B`	evaluates to	`78`
`A * B`	evaluates to	`5040`
`A % B`	evaluates to	`36`
`A / B`	evaluates to…	`2`

What's going on with division?

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A Few Pitfalls of C Arithmetic

No checks for overflow, so be careful.
- `unsigned int A = 0 - 1;`
- `A` is a large number!

Integer division
- Trying to **divide by 0** ends the program (floating-point produces **infinity** or **NaN**).
- Integer division **evaluates to an integer**, so `(100 / 8) * 8` **is not** `100`.

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C Behavior Sometimes Depends on the Processor

Integer division is rounded to an integer.
Rounding **depends on the processor**.
Most modern processors **round towards 0**, so…

`11 / 3`	evaluates to `3`
`-11 / 3`	evaluates to `-3`

Modulus `A % B` is defined such that
`(A / B) * B + (A % B)` is equal to `A`
So `(-11 % 3)` evaluates to `-2`.

Modulus is not always positive.

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Six Bitwise Operators on Integer Types

Bitwise operators in C include
- AND: `&`
- OR: `|`
- NOT: `~`
- XOR: `^`
- left shift: `<<`
- right shift: `>>`

In some languages, `^` means exponentation, but not in the **C** language.

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Bitwise Operators Treat Numbers as Bits

Declare: `int A = 120;  int B = 42;`
`/* A = 0x00000078, B = 0x0000002A`
`using C's notation for hexadecimal. */`

Then…

`A & B` evaluates to `40  0x00000028`

```
    0000 0000 0000 0000 0000 0000 0111 1000
AND 0000 0000 0000 0000 0000 0000 0010 1010
    0000 0000 0000 0000 0000 0000 0010 1000
```

Apply AND to pairs of bits.

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Bitwise Operators Treat Numbers as Bits

Declare: `int A = 120;  int B = 42;`
`/* A = 0x00000078, B = 0x0000002A`
`using C's notation for hexadecimal. */`

Then…

`A & B`	evaluates to	`40`	`0x00000028`
`A | B`	evaluates to	`122`	`0x0000007A`
`~A`	evaluates to	`-121`	`0xFFFFFF87`
`A ^ B`	evaluates to	`82`	`0x00000052`

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Left Shift by N Multiplies by 2^N

Shifting left by N bits adds **N** 0s on right.
- It's like **multiplying by 2^N**.
- **N** bits lost on left! (**Shifts can overflow.**)

Declare: `int A = 120;/* 0x00000078 */`
`unsigned int B = 0xFFFFFF00;`

Then…

`A << 2`	evaluates to	`480`	`0x000001E0`
`B << 4`	evaluates to	`(<B!)`	`0xFFFFF000`

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Right Shift by N Divides by 2^N

A question for you: **What bits appear on the left when shifting right?**

Declare: `int A = 120;/* 0x00000078 */`

`A >> 2` evaluates to `30  0x0000001E`

What about `0xFFFFFF00 >> 4`?

Is `0xFFFFFF00` equal to

`-256` (/16 = `-16`, so insert 1s)? or equal to

`4,294,967,040` (/16 = `268,435,440,` insert 0s)?

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Right Shifts Depend on the Data Type

A **C** compiler **uses the type of the variable** to decide which type of right shift to produce

For an **`int`**
- **2's complement** representation
- produces **arithmetic right shift**
- (copies the sign bit)

For an **`unsigned int`**
- **unsigned** representation
- produces **logical right shift**
- (inserts 0s on left)

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Right Shift by N Divides by 2^N

Declare:
```
int A = -120;/* 0xFFFFFF88 */
unsigned int B = 0xFFFFFF00;
```

Then…

`A >> 2`	evaluates to	**`-30`**	**`0xFFFFFFE2`**
`A >> 10`	evaluates to	**`-1`**	**`0xFFFFFFFF`**
`B >> 2`	evaluates to		**`0x3FFFFFC0`**
`B >> 10`	evaluates to		**`0x003FFFFF`**

Notice that **right shifts round down**.

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Six Relational Operators

Relational operators in **C** include
- less than: **<**
- less or equal to: **<=**
- equal: **==** (TWO equal signs)
- not equal: **!=**
- greater or equal to: **>=**
- greater than: **>**

C operators cannot include spaces, nor can they be reordered (so no "**< =**" nor "**=<**").

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Relational Operators Evaluate to 0 or 1

In C,
- **0 is false**, and
- **all other values are true**.

Relational operators always
- **evaluate to 0 when false**, and
- **evaluate to 1 when true**.

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Relational Operators Also Depend on Data Type

Declare:
```
int A = -120;/* 0xFFFFFF88 */
int B =  256;/* 0x00000100 */
```

Is `A < B`?
- Yes, -120 < 256.
- But if the same bit patterns were interpreted using the **unsigned** representation,

```
0xFFFFFF88 > 0x00000100
```

As with shifts, a **C** compiler **uses the data type to perform the correct comparison**.

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The Assignment Operator Can Change a Variable's Value

The **C** language uses **=** as the **assignment operator**. For example,

```
A = 42
```

changes the bits of variable **A** to represent the number **42**.

One can write **any expression on the right-hand side of assignment**. So

```
A = A + 1
```

increments the value of variable **A** by **1**.

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Only Assign Values to Variables

A **C** compiler can not solve equations.

For example,

```
A + B = 42
```

results in a compilation error (the compiler cannot produce instructions for you).

The left-hand side of an assignment must be a variable.*

* For ECE120. ECE220 teaches other ways to use the assignment operator.

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Pitfall of the Assignment Operator

Programmers sometimes
- write "`=`" (assignment)
- instead of "`==`" (comparison for equality).

For example, to compare variable **A** to **42**,
- one might want to write "`A == 42`"
- but instead write "`A = 42`" by accident.

A **C** compiler can **sometimes** warn you (in which case, fix the mistake!).

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Good Programming Habits Reduce Bugs

To avoid these mistakes, get in the habit of writing comparisons with the variable on the right.

For example, instead of "`A == 42`", write

```
42 == A
```

If you make a mistake and write "`42 = A`",
- the **compiler will always tell you**,
- and you can fix the mistake.

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Three Logical Operators

Logical operators in **C** include
- AND: **&&**
- OR: **||**
- NOT: **!**

Logical operators operate on truth values (again, **0 is false**, and **non-zero is true**).

Logical operators
- **evaluate to 0 (false)**, or
- **evaluate to 1 (true)**.

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Logical Operators Depend only on True/False in Operands

Declare: `int A = 120;  int B = 42;`

Then…

`(0 > A || 100 < A)`	evaluates to **1**
`(120 == A && 3 == B)`	evaluates to **0**
`!(A == B)`	evaluates to **1**
`!(0 < A && 0 < B)`	evaluates to **0**
`(B + 78 == A)`	evaluates to **1**

(So no bitwise calculations, just true/false.)

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Operator Precedence in C is Sometimes Obvious

A task for you:

Evaluate the C expression: `1 + 2 * 3`

Did you get 7?

Why not 9? (1 + 2) * 3

Multiplication comes before addition
- in elementary school
- and in **C**!

The order of operations is called operator **precedence**.

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Never Look Up Precedence Rules!

Another task for you:

Evaluate the C expression: `10 / 2 / 3`

Did you get 1.67?

Is it a friend's birthday?

Perhaps it causes a divide-by-0 error?

Or maybe it's … 1? (10 / 2) / 3, as `int`

If the order is not obvious,
- Do NOT look it up.
- **Add parentheses**!

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