Programming I

Variables, Types and Constants

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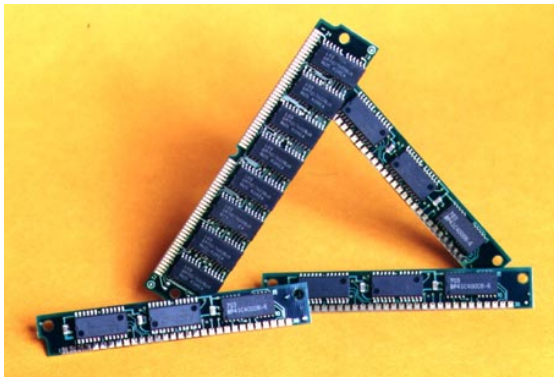
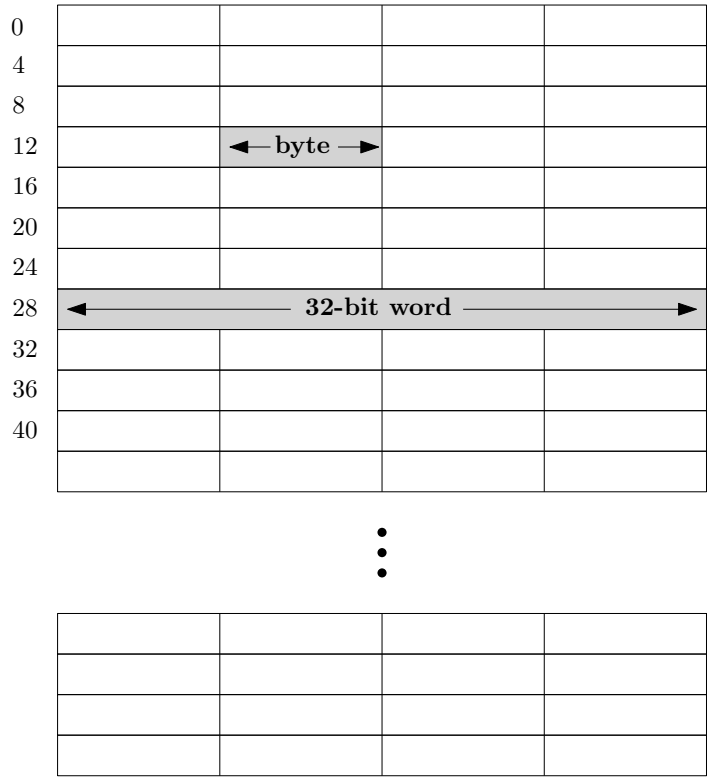
Memory





Memory behaves like an one dimensional array which we can address using an address which is either a 32-bit or 64-bit number depending on the architecture. The figure above presents the 32-bit version.

Variables in C

C language provides with an easy way to address the memory, without the need to memorize memory addresses.

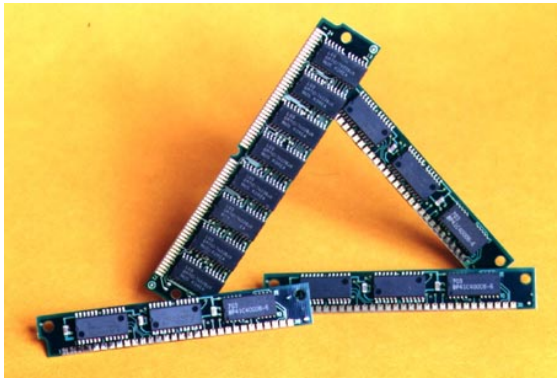
Variables in C

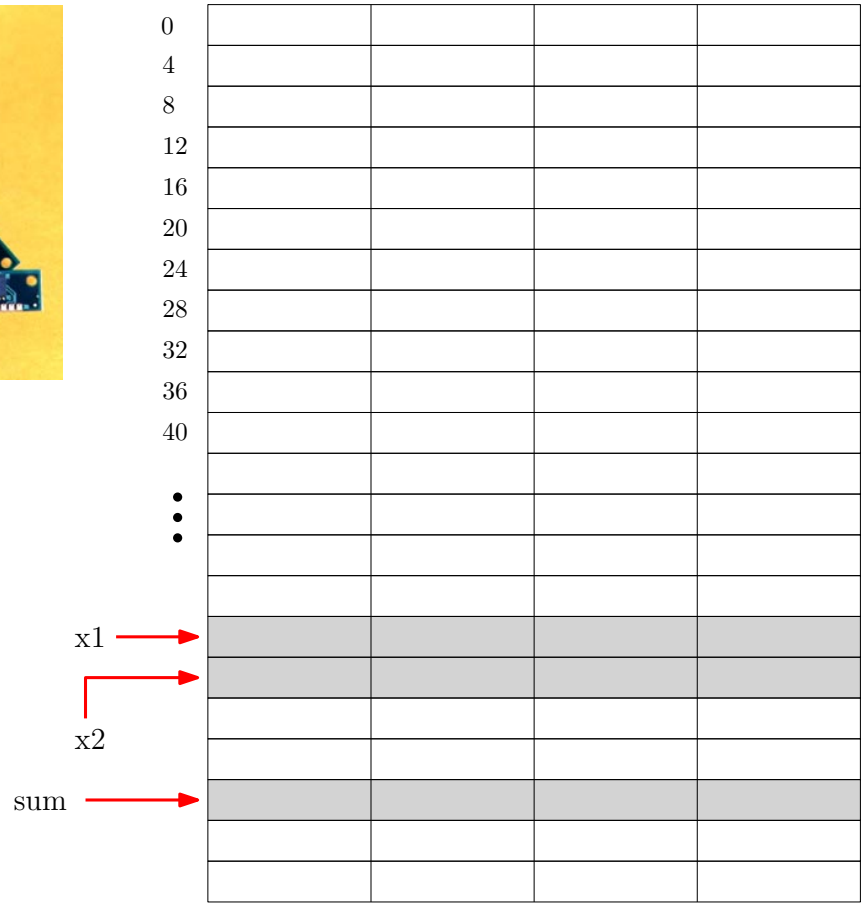
```
int main() {
    int x1, x2, sum;

    x1 = 1;
    x2 = 2;
    sum = x1 + x2;
}
```

In the program above we inform the compiler that we are going to require the use of three memory locations in order to store integer numbers. These 3 memory locations are going to be named `x1`, `x2`, and `sum` respectively.

The compiler remembers the mapping between names and addresses.

Memory





Variable names are shorthands for memory addresses.

Variables in C

```
int main() {
    int x1, x2, sum;

    x1 = 1;
    x2 = 2;
    sum = x1 + x2;
}
```

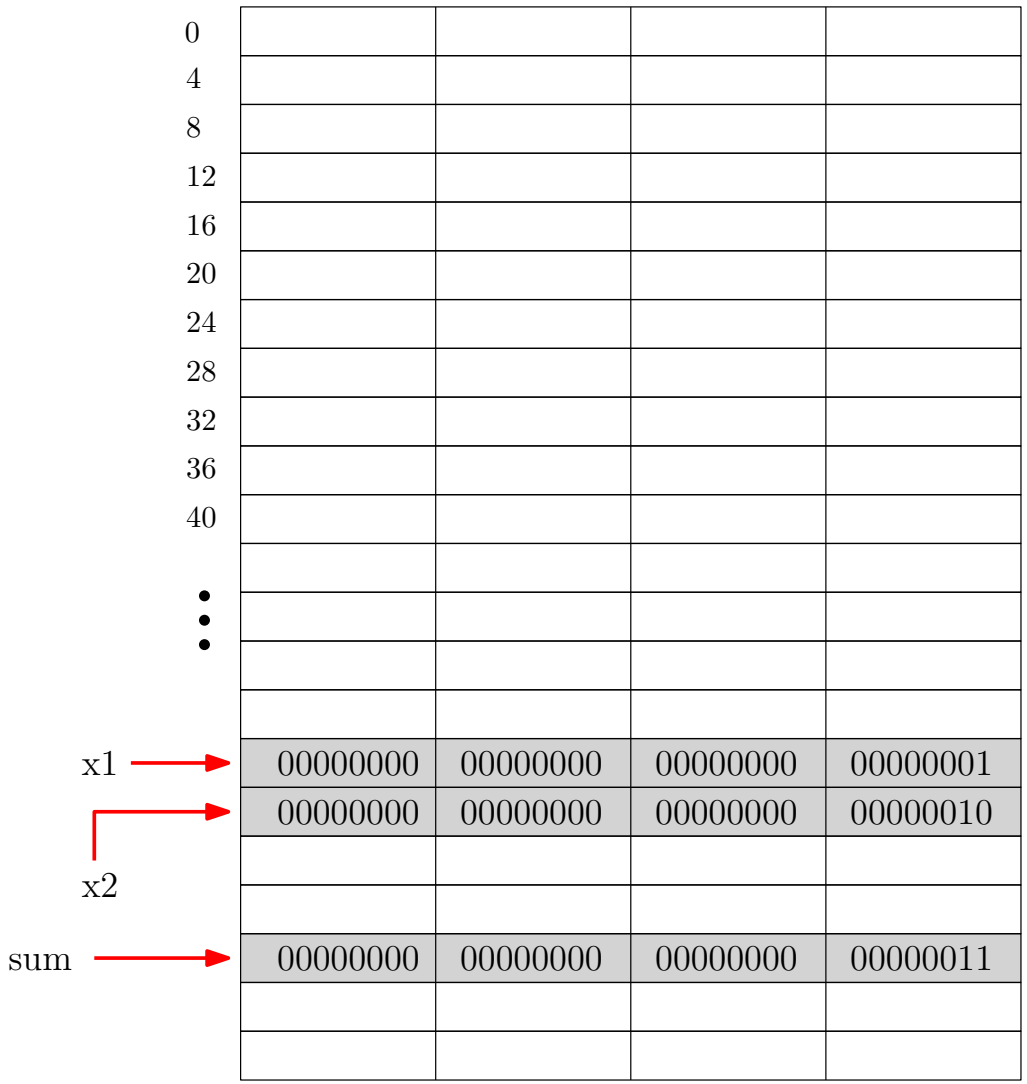
Memory locations of local variables are not initialized. It is the duty of the programmer to provide with initial values.

Variables in C

```c
#include <stdio.h>

int main() {
    int x1, x2, sum;

    x1 = 1;
    x2 = 2;
    sum = x1 + x2;
}
```

- Store value 1 at the memory location of variable $x1$ and 2 at the memory location of variable $x2$.
- Finally read these two values again, add them up and store the result at the memory location of variable *sum*.

Variables in C



Variables are shorthands for memory addresses.

Variables in C

Every variable has:

1. name
2. type
3. value

Variables in C

Name

A valid variable name in C must begin with a letter (not a digit), it should not contain any spaces and should be equal to certain reserved keywords such as `main`.

wrong variable names

```
int main;
int 3x;
int hello world;
```

correct variable names

```
int Main;
int x123456;
int hello_world;
```

Variables in C

Type

When we are declaring a variable, we explain to the compiler what kind of information we are going to store in that location.

Basic data types

1. integer: `int x;`
2. character: `char x;`
3. floating point (approximate representation for real numbers): `float x;`

There are more data types. We are going to see them in more detail after we learn a few things about number representation in a computer.

Variables in C

C language requires all variable sto be declared at the beginning of a block. For example:

```
int main() {
    int x, y, z; /* declare all variables */

    x = 1;
    y = 2;
    z = x + y;

    int i;       /* NO! */
}
```

Variables in C

From C99 and afterwards, we can also declare variable in other locations.

```
int main() {
    int x, y, z; /* declare some variables */

    x = 1;
    y = 2;
    z = x + y;

    int i;       /* YES! */

}
```

It is nowadays considered best practice to declare variables as close to their use as possible.

Type `int`

Type `int` stores integers and its size depends on the architecture of the computer that we are compiling our program.

- it must be able to take any value $\in [-32767, 32767]$
- in recent architectures, it can take any value $\in [-2147483648, 2147483647]$

This means that it needs 32-bits.

Type `char`

Type `char` is used to store characters.

```
int main() {
    char c;

    c = 'x';
}
```

In C characters are representation by numbers using the ASCII encoding.

Type `char`

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

The 95 printable characters from 32 to 126 (decimal). Characted from 0 to 31 are special characters for controlling the output devices, e.g. 8 is BACKSPACE, 13 is ENTER and 27 is ESC.

printf and characters

```c
#include <stdio.h>

int main() {
   char c = 'a';

   printf("character %c is number %d in ASCII encoding\n", c, c);
}
```

The above program prints:

character a is number 97 in ASCII encoding

Type `float`

`float` is a type for approximately representing real numbers.

```
#include <stdio.h>

int main() {
    float pi = 3.14159265;

    printf("pi is approximately %f\n", pi);
}
```

Maximum and Minimum Values for Integer Types

The table below is taked from the C specification.

type	minimum value	maximum value
`char`	≤ -127	$\geq +127$
`unsigned char`	≤ 0	$\geq +255$
`short int`	≤ -32767	$\geq +32767$
`unsigned short int`	≤ 0	$\geq +65535$
`int`	≤ -32767	$\geq +32767$
`unsigned int`	≤ 0	$\geq +65535$
`long`	≤ 2147483647	$\geq +2147483647$
`unsigned long`	≤ 0	$\geq +4294967295$

Recent compilers have larger bounds. For example type `int` usually has the bounds that are shown for `long` in the table above.

Types and Limits of Floating Point Numbers

type	minimum value	maximum value
`float`	$\leq -1E-37$	$\geq 1E+37$
`double`	$\leq -1E-37$	$\geq 1E+37$

Modern compilers have larger limits from the ones mentioned in the ANSI C specification. For example, **gcc** on my computer has:

$$-1.175494E-38 \leq x \leq 3.402823E+38$$

for type `float` and:

$$-2.225074E-308 \leq x \leq 1.797693E+308$$

for type `double`.

Function `printf`

The general form of `printf()` is:

```
int printf(const char * format, ...);
```

The parameter *format* contains the text to be printed along with special character sequences which help to print the expressions that follow. These special sequences have the general form:

`%[flags][width][.precision][length]specifier`

Except for the specifier everything else is optional.

Specifiers of `printf()`

Most specifiers are shown in the following table:

specifier	Output	Example
c	character	a
d i	decimal with sign	392
e	scientific notation using e	3.9265e+2
E	scientific notation using E	3.9265E+2
f	decimal floating point number	392.65
o	octal with sign	610
s	string	sample
u	decimal without sign	7235
x	hexadecimal without sign	7fa
X	hexadecimal without sign with capitals	7FA

Line

```
printf("%d, %o and %x\n", 27, 27, 27);
```

prints 27, 33 and 1b.

printf() and padding

The width is a number which tells `printf` how many spaces to add to the output in order for the result to have the specified characters.

```c
#include <stdio.h>
#include <stdlib.h>

int main() {
    int a = 100;
    int b = 1000;
    int c = 10000;

    printf("%7d\n", a);
    printf("%7d\n", b);
    printf("%7d\n", c);
    printf("%7d\n", 1000000);
}
```

prints

```
    100
   1000
  10000
1000000
```

`printf()` and precision

Precision has different meaning based on each type:

- for integers it denotes the least amount of digits to be printed (possible by including additional zeros a the beginning)
- for floats is represents the number of digits after the decimal
- for strings it denotes the maximum number of characters to be printed

`int` and precision

Denotes the least amount of digits to be printed (possible by including additional zeros a the beginning)

```
#include <stdio.h>
#include <stdlib.h>

int main() {
    int a = 100;
    int b = 10000;
    int c = 1000000;

    printf( "%10.7d\n", a );
    printf( "%.7d\n", b );
    printf( "%.7d\n", c );

    return 0;
}
```

prints

```
   0000100
0010000
1000000
```

float and precision

Denotes the number of digits after the decimal.

```c
#include <stdio.h>
#include <stdlib.h>

int main() {
    float pi = 3.14159265;

    printf( "%.3f\n", pi );
    printf( "%.10f\n", pi );

    return 0;
}
```

prints

```
3.142
3.1415927410
```

printf() and Special Characters

The special characters in C can be found in the following table:

character	ASCII code	special character in C
newline	10	'\n'
tab	9	'\t'
carriage return	13	'\r'
backspace	8	'\b'
form feed	12	'\f'
backslash	92	'\\'
single quotation mark	39	'\''
double quotation mark	34	'\"'
null character	0	'\0'

for example the following code

```
printf("Very\tSimple\nExample");
```

prints

```
Very        Simple
Example
```

Constants

There are several different kind of constants:

- literals
- symbolic constants
- declared constants using `const`

Constants

There are several different kind of constants:

- literals: types directly in the code

```
int count;

count = 3;
```

- symbolic constants
- declared constants using `const`

Constants

There are several different kind of constants:

- literals
- symbolic constants: the pre-processor allows us to define symbols which during the pre-processing phase are replaced with corresponding values.

```
#include <stdio.h>

#define MAX 100

int main() {
    int x = MAX;
    printf( "%d\n", x );

    return 0;
}
```

- declared constants using `const`

Constants

There are several different kind of constants:

- literals
- symbolic constants
- declared constants using `const`:

  used in variable declarations and informs the compiler that a variable is not supposed to change value.

```
int main() {
    const int x = 3;

    x = 5; /* Compilation error! */
}
```

  If anyone tries to change the value, the compiler reports an error.