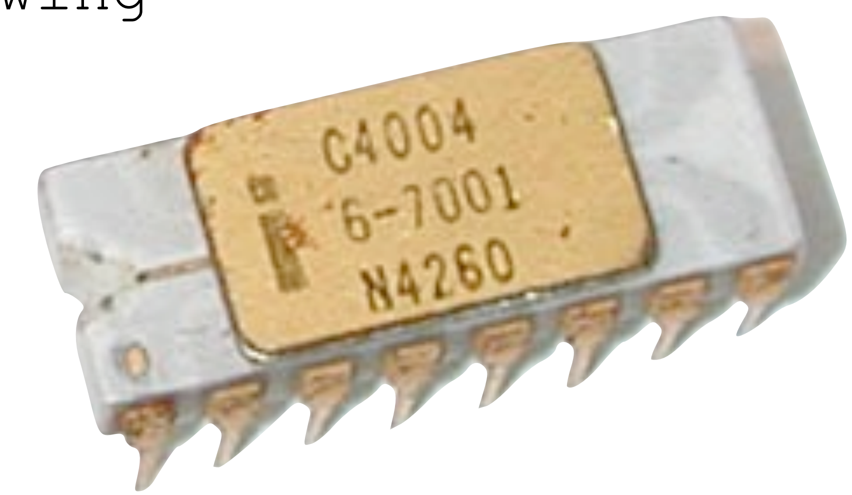
C

An introduction to programming

In the beginning...
all we had was **machine code**

```
mem[0]=0x23; // load register a with following
mem[1]=0x00;
mem[2]=0xa8; // output a to r0
mem[3]=0x17; // increment a
mem[4]=0xa9; // output a to r1
mem[5]=0x17; // increment a
mem[6]=0xaa; // output a to r2
mem[7]=0x17; // increment a
mem[8]=0xab; // output a to r3
mem[9]=0x17; // increment a
mem[10]=0xac; // output a to r4
mem[11]=0x17; // increment a
mem[12]=0xad; // output a to r5
mem[13]=0x17; // increment a
mem[14]=0xae; // output a to r6
mem[15]=0x17; // increment a
mem[16]=0xaf; // output a to r7
mem[17]=0x17; // increment a
mem[18]=0x04; // jump to first page with following
mem[19]=0x02;
```



Then along came abstraction, with an **assembly language** to provide symbolic references for the numeric machine codes

```
Main:
   clrf   PORTB                 ; initialize PORTB
   bsf    STATUS , RP0          ; Move to bank 1
   movlw  PORTB_DIR             ; value for TRISB
   movwf  TRISB                 ; set by defined variable
   bcf    STATUS , RP0          ; Move to bank 1
   movlw  MAX_BITS
   movwf  BIT_COUNT             ; sets the bit count to seven
   clrf   INPUT_BYTE

SSTestFall:
   btfsc  PORTB , SS_BIT        ; check slave bit, if clear, skip next
   goto   SSTestFall            ; loop to check again
   goto   ClockTestFall         ; move on
```

and now we have...

compiled languages

Basic

Cobol

C

C++

Forth

Fortran

Java

C#

Ada

Pascal

preprocessor directives

```c
#include “m_general.h”      // custom macros
```

constants

```c
#define PIN 4
```

subroutine prototypes

```c
void init(void);
```

global variables

```c
int x=100;
```

main function (local variables, directives)

```c
void main(void)
{
  int i;
  init();                   // initialize the system
  for(i=0; i<x; i++){       // do this 100 times
    toggle(PORTE,PIN);      // toggle PIN
  }
}
```

subroutine (local variables, directives)

```c
void init(void)
{
  set(DDRE,PIN)             // PIN as output
}
```

C is case-sensitive!

white space does not matter

don’t forget the semicolon;

don’t forget the { }

#define constants

declare variables before use

no magic numbers!

use subroutines

prototype your subroutines

compile and test as you go

comment your code!

please, comment your code...

translating common compiler errors

```
main.c: In function 'main':
main.c:17: error: 'i' undeclared (first use in this function)
main.c:17: error: (Each undeclared identifier is reported only once
main.c:17: error: for each function it appears in.)
make: *** [main.o] Error 1
```

(undeclared variable)

```
main.c: In function 'main':
main.c:43: error: expected declaration or statement at end of input
make: *** [main.o] Error 1
```

(missing "}")

```
main.c: In function 'main':
main.c:19: error: expected ';' before '}' token
make: *** [main.o] Error 1
```

(missing ";")

```
main.c: In function 'main':
main.c:25: warning: implicit declaration of function 'delay_ms'
main.o: In function `main':
main.c:(.text+0x88): undefined reference to `delay_ms'
make: *** [main.elf] Error 1
```

(missing subroutine)

preprocessor directives

directives processed before compilation

include other files (generally “header” files with other # defines, function prototypes, etc.)

```
#include <filename.h>        // file in the include path
#include “filename.h”        // file in the current directory
```

```
#include “m_general.h”
```

define constants (essentially a find & replace - no semicolon!)

```
#define CONSTANT value
```

```
#define ENC_LINES 1024
#define TRUE 1
```

functions and subroutines

functions must be prototyped - either with pre-processor directives, or in a separate header file (preferred for larger projects)

```
type function(type variable, type variable);
```

```
int multiply(int x, int y);
```

functions must return according to the specified type

```
type function(type variable, type variable)
{
  ...
  return variable;
}
```

```
int multiply(int x, int y){
  int i, answer=0;
  for(i=0;i<x;i++){
    answer += y;
  }
  return answer;
}
```

```
void init(void){
  set(DDRE,2);
}
```

variables

variables must be declared before they are used!

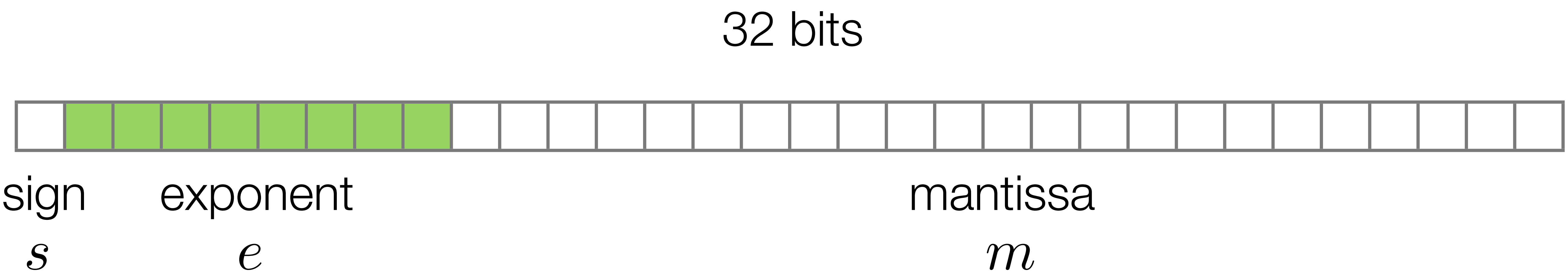
```
type variable=initial, variable=initial;
```

```
int x;
short y, z;
long foo = 456;
unsigned int a=5, b=6;
char c = ‘b’;
```

type	bits	min	max
char	8	-128	127
unsigned char	8	0	255
int	16	-32768	32767
unsigned int	16	0	65535
long	32	-2147483648	2147483647
unsigned long	32	0	4294967295
float / double	IEEE32	1.175494E-38	3.402823E+38

ultimately, everything is binary to the CPU

float storage



$$x = (-1)^s * 2^{(e-127)} * 1.m$$

floating-point math is
SSSSSLLLLLOOOOOWWWWW

basic operators

Arithmetic	
+	add
-	subtract
*	multiply
/	divide
%	modulus (remainder)

Bitwise	
&	and
|	or
^	exclusive or
<<	shift left
>>	shift right
~	one’s complement

all arithmetic and bitwise operators can be used in assignments

Conditional	
==	equal
!=	not equal
<	less than
<=	less than or equal
>	greater than
>=	greater than or equal

Unary	
++	increment
--	decrement
!	not

Logical	
&&	and
||	or
!	not

operator precedence

higher operators will be applied first

- parenthesis `() []`
- structure access `. ->`
- unary `! ~ ++ -- - * &`
- multiply, divide, modulus `* / %`
- add, subtract `+ -`
- bit shifts `>> <<`
- inequality `< <= >= >`
- equal, not equal `== !=`
- bitwise AND `&`
- bitwise exclusive OR `^`
- bitwise OR `|`
- logical AND `&&`
- logical OR `||`
- ternary conditional `? :`
- assignment `= *= /= %= += -= <<= >>= &= |= ^=`
- comma `,`

(when in doubt, add parentheses!)

iteration

WHILE: as long as the expression equals any non-zero value, the directives will be executed repeatedly

```
while(expression){
  directives;
}
```

```
while(!flag){
  directives;
}
```

```
int i=0;
while(i<10){
  directives;
  i++;
}
```

FOR: as long as the initialized variable is less than the termination value, the directives will be executed repeatedly

```
for(initialization; continuation; increment){
  directives;
}
```

```
int i;
for(i=0; i<10; i++){
  directives;
}
```

conditionals

IF: if the expression equals any non-zero value, directives will be executed

```
if(expression){
  directives;
} else {
  other directives;
}
```

```
expression ? directives : other directives;
```

expressions can be formed using:

Conditional	
==	equal
!=	not equal
<	less than
<=	less than or equal
>	greater than
>=	greater than or equal

Logical	
&&	and
||	or
!	not

examples

```
if(a==b)

if(a!=b)

if(a<b)

if(a&&b)

if((a==5)&&(b!=4))

if(!c)

(a==5)?___ : ___ ;
```

advanced conditionals

SWITCH: as long as the expression equals any non-zero value, the directives will be executed repeatedly

```
switch(variable){
  case condition:
    directives;
    break;
  case condition:
    directives;
    break;
  default:
    directives;
    break;
}
```

```
int state=0;
while(1){
  switch(state){
    case 0:
      set(PORTD,4);
      state=2;
      break;
    case 1:
      clear(PORTD,4);
      state=0;
      break;
    default:
      state=1;
      break;
  }
}
```

type casting

implied (and often wrong)

```
int a;
float b = 2.345;
a = b + 1;                    // a = 3
```

("=" converts the result to the specified datatype AFTER the operation)

explicit

```
int a = 2;
float b;
b = a/4;                     // b = 0
b = (float)a/4 ;             // b = 0.5
b = a/4.0;                   // b = 0.5


unsigned int a = 61000;
unsigned int b = 10000;
long c;
c = a + b;                   // c = 5465
c = (long)a + b;             // c = 71000
```

variable type modifiers

to preserve the value of a variable between successive subroutine calls

`static`

```
ISR(TIMER3_COMPA_vect)
{
  static long L_encoder_last=0, R_encoder_last=0;
  int L_velocity_raw, R_velocity_raw;

  // calcuate velocity in 10 * ticks (current - previous) per 0.01 sec

  L_velocity_raw = -EGAIN*(L_encoder - L_encoder_last);
  L_encoder_last = L_encoder;
  L_velocity = (float)L_velocity*V_FILTER + (1-V_FILTER)*(float)L_velocity_raw;

  R_velocity_raw = -EGAIN*(R_encoder - R_encoder_last);
  R_encoder_last = R_encoder;
  R_velocity = (float)R_velocity*V_FILTER + (1-V_FILTER)*(float)R_velocity_raw;
}
```

variable type modifiers

to alert the compiler that a variable may change outside the routine

`volatile`

```
volatile int flag = 0;
char message[3] = {0, 0, 0};

int main(void){
  while(1){
    if(flag){
      toggle(PORTE,6); // toggle the green LED
      flag = 0;
    }
  }
}

ISR(PCINT0_vect)
{
  if(!check(PINB,5))
  {
     flag = 1;
     RFreceive(message);
  }
}
```