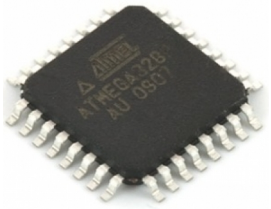
PROGRAM are instructions from Programmer(Human) to the micro-controller CPU, asking the CPU to do task.



The micro-controller CPU can only do task according to what it is capable of doing.

The manufacturer of the micro-controller will prepare a list of task that the CPU can perform, the list is known as the

"INSTRUCTION SET"

The "INSTRUCTION SET" is consist of many individual "INSTRUCTION" where each "INSTRUCTION" tell the CPU to perform a simple task

The ATMEGA328 micro-controller is using the AVR INSTRUCTION SET, The picture below (from ATMEGA328 datasheet) shows some of the "INSTRUCTION" from the "AVR INSTRUCTION SET", "ADD","ADC","ADIW",...

31. Instruction Set Summary

Mnemonics	Operands	Description	Operation	Flags	#Clocks
Arithmetic and Logic Instructions					
ADD	Rd, Rr	Add two registers	Rd ← Rd + Rr	Z,C,N,VH	1
ADC	Rd, Rr	Add with carry two registers	Rd ← Rd + Rr + C	Z,C,N,V,H	1
ADIW	Rdl, K	Add immediate to word	Rdh: Rdl ← Rdh: Rdl + K	Z,C,N,V,S	2
SUB	Rd, Rr	Subtract two registers	Rd ← Rd – Rr	Z,C,N,V,H	1
SUBI	Rd, K	Subtract constant from register	Rd ← Rd – K	Z,C,N,V,H	1
SBC	Rd, Rr	Subtract with carry two registers	Rd ← Rd – Rr – C	Z,C,N,V,H	1
SBCI	Rd, K	Subtract with carry constant from reg.	Rd ← Rd – K – C	Z,C,N,V,H	1
SBIW	Rdl, K	Subtract immediate from word	Rdh: Rdl ← Rdh: Rdl – K	Z,C,N,V,S	2

There are other types of "INSTRUCTION SET" used by different micro-controllers, some of the popular ones are, ARM, x86, RISC-V,...

Sending a single "INSTRUCTION" from the "INSTRUCTION SET" to the micro-controller CPU will not be able to do much for us

We will need to **combine many individual "INSTRUCTION" from the "INSTRUCTION SET"** before the CPU can **perform a meaningful task** for us

This combined multiple INSTRUCTIONS from the INSTRUCTION SET for the CPU to perform task is known as a **"PROGRAM"**

When we are using the Arduino Platform to write our Program for the ATMEGA328 micro-controller. We can make our PROGRAM in three different Programming Styles by using the Arduino IDE Software

1. AVR Assembly Language
2. C-Language with AVR Library
3. C-Language with Arduino Library

We will make two small PROGRAM to demonstrate all the three different Programming styles

1. A simple program to “Turn ON” the Arduino Uno Board test LED
2. A simple program to “Blink” the Arduino Uno Board test LED

Example 1:
A simple program to “Turn ON” the Arduino Uno Board test LED

AVR Assembly Language (program name: intro_asm)

```
#define __SFR_OFFSET 0
#include "avr/io.h"
.global main
main:
  SBI  DDRB,5   ; set Arduino Pin 13 Output Pin
  SBI  PORTB,5  ; set High to Arduino Pin 13
  CALL forever
  RET
forever:
  RJMP forever
```

The Assembly Language uses INSTRUCTION from the AVR INSTRUCTION SET in almost every lines of code, “SBI”,”CALL”,”RET”,”RJMP”. It also manipulates the CPU Memory DDRB and PORTB directly

Note:
to turn off LED, change “SBI PORTB,5” to “CBI PORTB,5”

C-Language with AVR Library (program name: intro_avr)

```
#include "avr/io.h"
int main() {
  DDRB  |= (1<<DDB5); // set Arduino Pin 13 Output Pin
  PORTB |= (1<<PB5);  // set High to Arduino Pin 13
  forever();
  return 0;
}

void forever() {
  while(1){};
}
```

We do not see INSTRUCTION SET codes here anymore. They are hidden from us by the C-Language. However, we are still manipulating the CPU Memory DDRB, PORTB directly

Note:
to turn off LED, change “PORTB |= (1<<PB5);” to “PORTB &= ~(1<<PB5);”

C-Language with Arduino Library (program name: intro_arduino)

```
void setup() {
  pinMode(13, OUTPUT);    // set Arduino Pin 13 Output Pin
  digitalWrite(13, HIGH); // set High to Arduino Pin 13
}

void loop() { }
```

We do not see the INSTRUCTION SET codes and the CPU Memory DDRB and PORTB anymore. They are all hidden and replaced by the functions from the Arduino Library. The Program has become so much easier now

Note:
to turn off LED, change “digitalWrite(13,HIGH);” to “digitalWrite(13,LOW);”

ATMEGA328/Arduino Uno - Introduction to Programming
https://github.com/teaksoon/lmaewapm

AVR Assembly Language (program name: intro_asm)

Pros:
We can access to the entire INSTRUCTION SET and CPU Memory directly, we are using the micro-controller to its maximum abilities. We also have the maximum flexibility as in Assembly Language, we code one INSTRUCTION at a time. Our program will also be very small as we only use what is required. This example program is only 144 bytes in size

Cons:
To code Assembly Language we need to know how the INSTRUCTION SET and micro-controller CPU Memory works. Since each line of Assembly code is one INSTRUCTION from the INSTRUCTION SET, our program will become very hard to manage as the program grows bigger

C-Language with AVR Library (program name: intro_avr)

Pros:
The INSTRUCTION SET are hidden from us, a single line of C-Language Codes can perform multiple INSTRUCTION from the INSTRUCTION SET for us behind the scene. While the INSTRUCTION SET is hidden from us, we can still access and manipulate CPU Memory directly. We still have a very high degree of flexbility. Our program can still be very small because C-Language can work directly with the CPU Memory. In this example, the Program size is even smaller than the Assembly Language, just 138 bytes in size

Cons:
We still have to deal with micro-controller CPU Memory, it can still be difficult because manipulating CPU Memory requires a deep understanding on how the CPU Memory works

C-Language with Arduino Library (program name: intro_arduino)

Pros:
The INSTRUCTION SET and CPU Memory are totally hidden from us. We do not need to know anything about the INSTRUCTION SET and the CPU Memory. Program are way easier to code and our Program can even work on non AVR based micro-controllers as are codes are not tied to a particular INSTRUCTION SET or a particular CPU Memory.

Cons:
Program size are now bloated. This example uses 712 bytes, which is about 5 times larger than the other 2 coding style. Program will also run way slower than the other 2 coding styles. Coding is also not flexible anymore as we have to follow some rules from the Arduino Library

Example 2:
A simple program to “Blink” the Arduino Uno Board test LED

These Codes for Example 2: are very much longer than the previous ones, they will not be posted here. You can download them and look at them on your own

https://github.com/teaksoon/lmaewapm/blob/main/2021_11_20_programming_intro_source.zip

Download and unzip the source .zip file into the following folders

intro_blink_asm – Coding in Assembly Language
intro_blink_avr – Coding in “C-Language with AVR Library”
intro_blink_arduino – Coding in “C-Language with Arduino Library”

1. Open the Program file from each folder with the Arduino IDE Software

2. Upload each of them and watch the LED on the Arduino Uno Board turning ON and OFF every 250ms.

If you look at the Assembly Language Source code (blink_asm), just to make a time delay of 250ms will take quite an effort. From that code alone, you will probably understand why we normally avoid Assembly Language and use the two C-Language Styles instead.

DO NOT WORRY IF YOU ARE LOST IN THIS TUTORIAL

Just keep in mind that we can make our Program in three different styles of Programming when using the Arduino IDE Software

Actually we have another Programming Style. That is to mix all the three Programming Styles together and get the best of everything or might get confused instead

So it is all up to us, we choose what is best for us and what is most suitable for our project