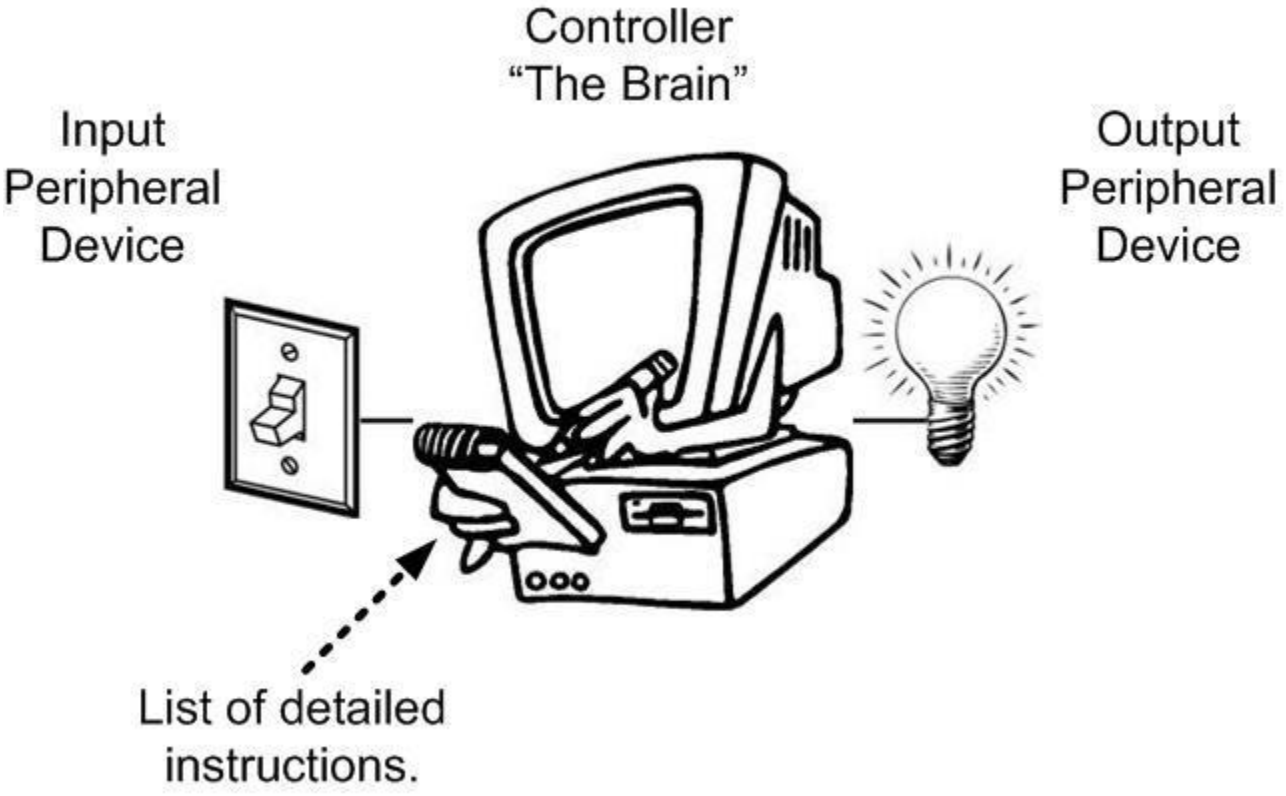
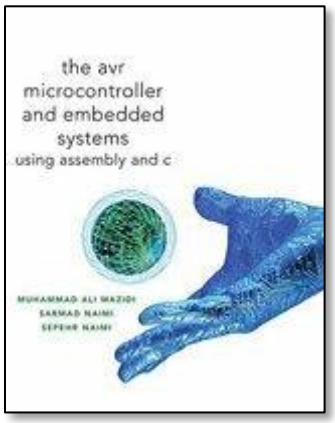
Software Programing in C++



C++ Introduction

READING



The AVR Microcontroller and Embedded Systems using Assembly and C)
by Muhammad Ali Mazidi, Sarmad Naimi, and Sepehr Naimi

Chapter 7: AVR Programming in C

- Section 7.1: Data Types and Time Delays in C (excluding Time Delays in C)
- Section 7.3: Logic Operations in in C
- Section 7.4: Data Conversion Programs in C
- Section 7.6: Memory Allocation in C

Here is a fun tool to translate your C++ code into Assembly[1]
https://godbolt.org/

[1] Source: email from Jan Borcher entitled "College textbook / resource recommendations" dated Sept 2, 2017

Table of Contents

DATA TYPES

Reading: Section 7.1: Data Types and Time Delays in C

Explicit Data Types

source: Wikipedia stdint.h

- **T**he C standard library introduced in the C99 standard library (stdint.h) allows programmers to write more portable code by allowing them to specify exact-width integer types, together with the defined minimum and maximum allowable values for each type.
- This new library is particularly useful for embedded programming which often involves considerable manipulation of hardware specific I/O registers requiring integer data of fixed widths, specific locations and exact alignments.
- The naming convention for exact-width integer types is **`intN_t`** for signed integers and **`uintN_t`** for unsigned integers. For example

```
uint16_t revsteps; // # steps per revolution
uint8_t steppernum;
uint32_t usperstep, steppingcounter;
```

Data Types – Continued

Implicit and Architecture Dependent Data Types

Data Type	Size in Bits	Data Range / Usage
void		
boolean		
char	8	-128 to +127
unsigned char	8	0 to 255
byte	8	0 to 255
int	16	-32,768 to +32,767
unsigned int	16	0 to 65,535
word	16	0 to 65,535 (Arduino)
long	32	-2,147,483,648 to +2,147,483,648
unsigned long		
float	32	+/-1.175e-38 to +/-3.402e38
double	32	+/-1.175e-38 to +/-3.402e38
string - char array		
String - object		
array		

Utilities

Conversion

- char()
- byte()
- int()
- word()
- long()
- float()

sizeof()

The sizeof operator returns the number of bytes in a variable type, or the number of bytes occupied by an array.

VARIABLE SCOPE & QUALIFIERS

Variable Scope

- Variables in the C programming language, which Arduino uses, have a property called *scope*.
- A **Global** variable is one that you can **access** anywhere in a program. Local variables are only visible to the function in which they are declared. In the Arduino environment, any variable declared outside of a function.
- **Local** variables insure that only one function has **access** to its own variables. This prevents programs from inadvertently modifying variables used by another function.
- A variable declared **inside a *for* loop** can only be accessed within the for-loop block (i.e., inside the brackets).

Example

Source: Arduino – Variable Scope

```
int gPWMval;  // any function will see this variable

void setup()
{
  // ...
}

void loop()
{
  int i;    // "i" is only "visible" inside of "loop"
  float f;  // "f" is only "visible" inside of "loop"
  // ...

  for (int j = 0; j <100; j++){
  // variable j can only be accessed inside the
  // for-loop brackets
  }

}
```

Variable Scope & Qualifiers

static

- The static keyword is used to create variables that are visible to only one function. However unlike local variables that get created and destroyed every time a function is called, static variables persist beyond the function call, preserving their data between function calls.

- Variables declared as static will only be created and initialized the first time a function is called.

Example

```
int randomWalk(int moveSize){
  static int  place; // variable to store value in random walk,
                     // declared static so that it stores
                     // values in between function calls, but
                     // no other functions can change its value

  place = place + (random(-moveSize, moveSize + 1));
  // check lower and upper limits
  if (place < randomWalkLowRange){
    place = randomWalkLowRange;
  } else if(place > randomWalkHighRange){
    place = randomWalkHighRange;
  }
  return place;
}
```

Variable Scope & Qualifiers

volatile

- The volatile qualifier directs the compiler to load the variable from RAM and not from a general purpose register (R0 – R31),
- A variable should be declared volatile when used within an Interrupt Service Routine (ISR).
- For more on Interrupts visit Gammon Software Solutions forum

Example

```
// toggles LED when interrupt pin changes state

int pin = 13;
volatile int state = LOW;

void setup()
{
  pinMode(pin, OUTPUT);
  attachInterrupt(0, blink, CHANGE);
}

void loop()
{
  digitalWrite(pin, state);
}

void blink()
{
  state = !state;
}
```

Variable Scope & Qualifiers

const

Reference: The C++ 'const' Declaration: Why & How

- The `const` qualifier declares a variable as a constant.

  Example

  ```
  // create integer constant myConst with value 33
  const int myConst=33;
  ```

- Such constants are useful for parameters which are used in the program but do not need to be changed after the program is **compiled**.
- It has an advantage over the C **preprocessor** '`#define`' command in that is understood & used by the compiler itself.
  - Used in the definition of a pointer to an array,
  - Error messages are much more helpful
  - Constant obey the rules of *variable scoping* that govern other variables.

  Example

  ```
  // The compiler will replace any mention of
  // ledPin with the value 3 at compile time.
  #define ledPin 3
  ```

- Constants are saved in SRAM not in Flash Program Memory (C was originally designed for Princeton based Machines). Click here to learn how to save data to Flash Program Memory.

WORKING WITH BITS IN C++

Resources

1. **Arduino**
2. **AVR-libc**

Set/Clear a Bit

Assembly

GPIO Port (first 32 I/O addresses)

`sbi PORTB, PB3`	`cbi PORTB, PB3`

IO Address Space

`in  r16, PORTB`
`sbr r16, 0b00001000`
`out PORTB, r16`
	`in  r16, PORTB`
	`cbr r16, 0b00001000`
	`out PORTB, r16`

Arduino

`// Set a Bit`	`// Clear a Bit`
`digitalWrite(MOTORLATCH, HIGH);`	`digitalWrite(MOTORLATCH, LOW);`

AVR-libc

`// Set a Bit`	`// Clear a Bit`

`PORTB |=  _BV(PB3);`
or
`sbi(PORTB, PB3); // deprecated`
	`PORTB &= ~_BV(PB3);`
	or
	`cbi(PORTB, PB3); // deprecated`

```
The AVR C library includes the following definition

#include <avr/io.h>

// _BV Converts a bit number into a Byte Value (BV).

#define _BV(bit) (1 << (bit)) // <avr/sfr defs.h>: Special function registers
```

C/C++

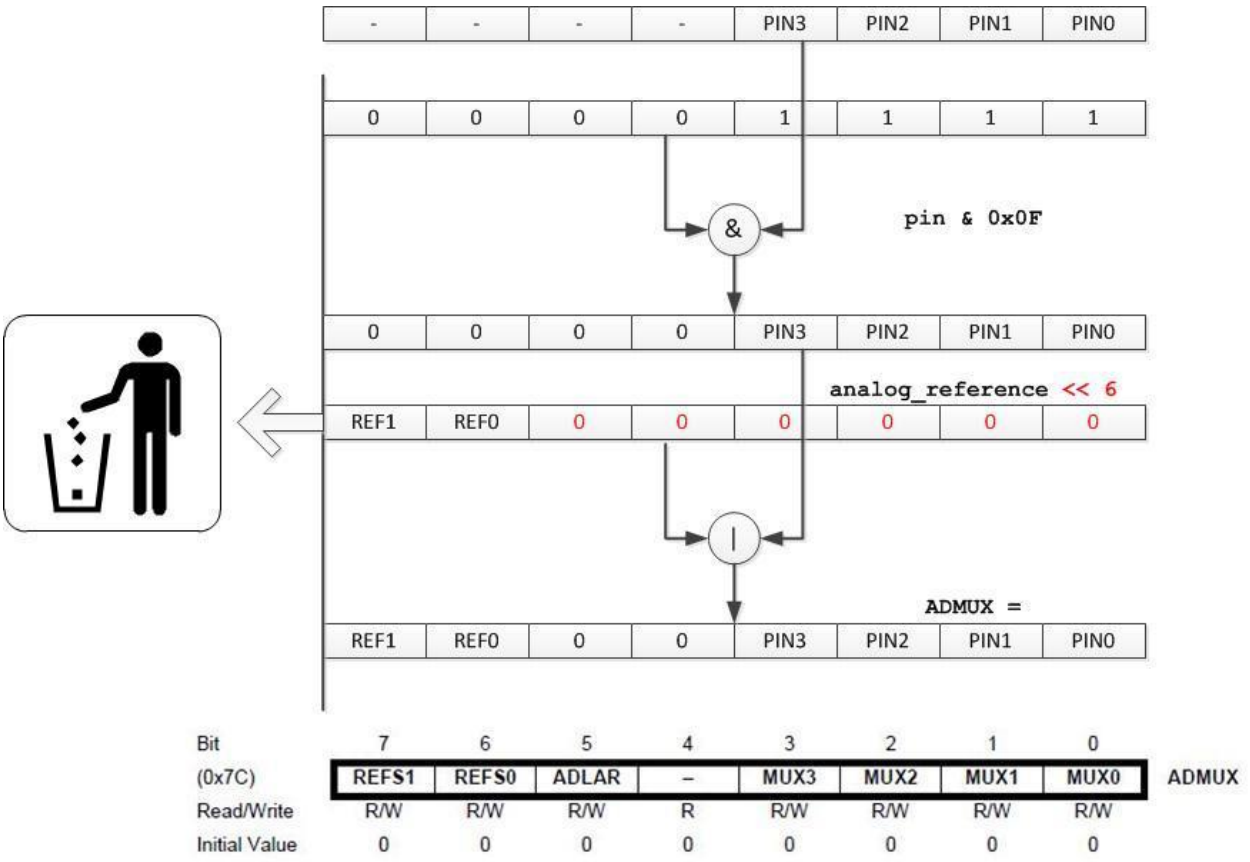
`// Set a Bit`	`// Clear a Bit`
`PORTB |=  (1 << (PB3));`	`PORTB &= ~(1 << (PB3));`

Set a Bit Pattern

ADC Subsystem ADMUX Register Example

In this example we set/clear 2 fields within a byte. **Undefined bits are cleared**.

```
ADMUX = (analog_reference << 6) | (pin & 0x0f);     // analogRead
```



Test Your Knowledge 1: Assume a function of type `uint16_t`. What would be returned if high = A and low = 3?

```
return (high << 8) | low;
```

Test Your Knowledge 2: How could you modify the ADMUX example to allow the programmer to set or clear the ADC Left Adjust Result ADLAR bit?

Program Example

Here is my Arduino Test Script ported to AVR Studio so I could use the simulator:
[ArduinoToAVRStudio-Blink]

In our first example “ADC Subsystem ADMUX Register” we assumed where each field was located within the register. In the next example we do not presuppose the location of the fields. This allows our program to adapt to different microcontroller register definitions. The downside is that, while in the first example the fields could be defined on the fly by the user (for example as arguments to a function), in this next example they must be predefined.

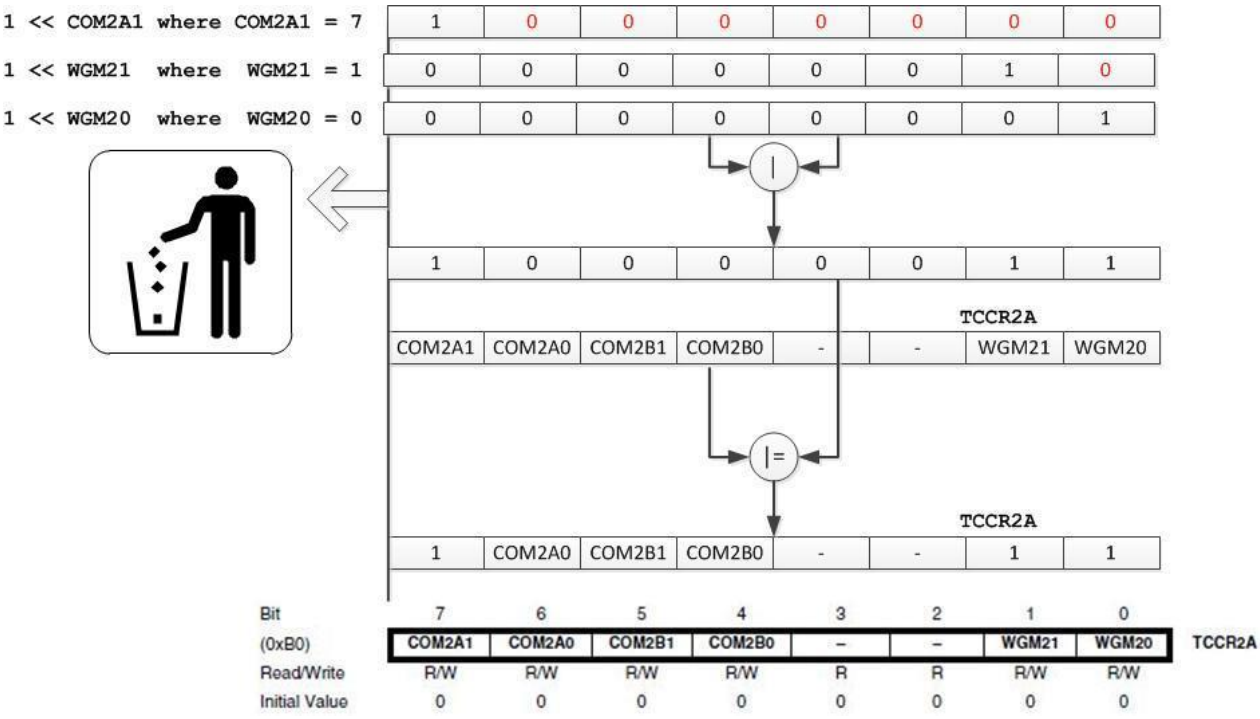
Timer/Counter 2 Control Register A Example 1

In this example,

- The wave generation mode of Timer/Counter 2 (WGM21:WGM20) is set to Fast PWM (0b11),
- the compare match output A mode (COM2A1:COM2A0) is configured to set on compare match (0b10),
- while the configuration bits for output compare register B are **not modified** (COM2B1:COM2B0).

```
#define _BV(bit) (1 << (bit))

TCCR2A |= _BV(COM2A1)|_BV(WGM21)|_BV(WGM20); // fast PWM, turn on oc0
```



Test Your Knowledge 3: At reset TCCR2A is cleared so our C++ example would result in COM2A1:COM2A0 = 0b10. What if another piece of software had set COM2A0 to 1 before this initialization routine was called. In this case our C++ code would not configure the register as expected. How could you solve this problem? Tip: *Because of operator precedence (see Compound Operators earlier in this document) you will need to use a simple assignment operator or write two lines of code.*

Timer/Counter 2 Control Register A Example 2

In this example,

- The wave generation mode of Timer/Counter 2 (WGM21:WGM20) is set to Phase Correct PWM (0b01),
- the compare match output A mode (COM2A1:COM2A0) is configured to set on compare match,
- while the configuration bits for output compare register B are **not modified** (COM2B1:COM2B0).
- This example makes **no assumption about the state of the bits within the WGM or COM2A bit fields**.

```
TCCR2A &= ~_BV(COM2A0) & ~_BV(WGM21);   // clear bits

TCCR2A |= _BV(COM2A1) | _BV(WGM20);     // set bits
```

Test Your Knowledge 4: Can you combine these two expressions into one?

Test Your Knowledge 5: If you are allowed to assume the location of the waveform generation mode (WGM2) and the compare match output A mode (COM2A) fields within the TCCR2A register, how would you write an expression that could set these two fields based on user defined variables `output_mode` and `waveform`? Hint: see the first example.

Test if a Bit is Set or Cleared

source: <avr/sfr_defs.h>: Special function registers

`#define`	`bit_is_set(sfr, bit) (_SFR_BYTE(sfr) & _BV(bit))`
`#define`	`bit_is_clear(sfr, bit) (!(_SFR_BYTE(sfr) & _BV(bit)))`
`#define`	`loop_until_bit_is_set(sfr, bit) do { } while (bit_is_clear(sfr, bit))`
`#define`	`loop_until_bit_is_clear(sfr, bit) do { } while (bit_is_set(sfr, bit))`

ADC Subsystem ADMUX Register Example

```
// ADSC is cleared when the conversion finishes
while (bit_is_set(ADCSRA, ADSC));
```

What is _SFR_BYTE(sfr)?

Source: Playing with Arduino _SFR_BYTE() and PORT

The **_SFR_BYTE()** is a macro that returns a byte of data of the specified address. The `_SFR_BYTE()` is defined in `hardware/tools/avr/avr/include/avr/sfr_defs.h` as below.

```
#define _SFR_BYTE(sfr) _MMIO_BYTE(_SFR_ADDR(sfr))
```

The **_SFR_ADDR()** is a macro that expands the _SFR_MEM_ADDR(sfr) macro. Both are defined in `hardware/tools/avr/avr/include/avr/sfr_defs.h` as below.

```
#define _SFR_ADDR(sfr) _SFR_MEM_ADDR(sfr)
```

The **_SFR_MEM_ADDR()** is a macro that returns the address of the argument.

```
#define _SFR_MEM_ADDR(sfr) ((uint16_t) &(sfr))
```

The **_MMIO_BYTE()** is a macro that dereferences a byte of data at the specified address. The `_MMIO_BYTE()` is defined in `hardware/tools/avr/avr/include/avr/sfr_defs.h` as below. The input is `mem_addr` and dereferences its contents.

```
#define _MMIO_BYTE(mem_addr) (*(volatile uint8_t *)(mem_addr))
```

Putting it all together, this is how the compiler would expand `_SFR_BYTE(sfr)`

```
_SFR_BYTE(sfr) *(volatile uint8_t * uint16_t &(sfr))
```

Let's take a closer look at this expanded macro definition. Starting from the inside and moving out. The ampersand sign (&) is known as a reference operator and lets the complier know that "sfr" is to be interpreted as an address (i.e., a pointer). Specifically, a 16-bit address (uint16_t).

The asterisk (*) sign in the uint8_t declaration of the pointer does not mean "value pointed by", it only means that it is a pointer (it is part of its type compound specifier). It should not be confused with the dereference operator, which come next, they are simply two different things represented with the same sign.

The final asterisk sign (*) at the beginning of the statement is a dereference operator. When the dereference operator is used you will get the "value pointed by" a pointer – the actual value of the register.

Mapping the 6-bit I/O address space into the 16-bit extended I/O address space

This works if the "special function register" is in the extended I/O address space but what if it is in the 64 byte I/O address space?

Let's assume `sfr` is within the I/O address space of the ATmega microcontroller, for example a GPIO Port. Each GPIO Port includes three registers PINx, DDRx, and PORTx. For the ATmega32U4 "x" would be B, C, D, E, and F

0x12 (0x32)	Reserved	-	-	-	-	-	-	-	-
0x11 (0x31)	PORTF	PORTF7	PORTF6	PORTF5	PORTF4	-	-	PORTF1	PORTF0
0x10 (0x30)	DDRF	DDF7	DDF6	DDF5	DDF4	-	-	DDF1	DDF0
0x0F (0x2F)	PINF	PINF7	PINF6	PINF5	PINF4	-	-	PINF1	PINF0
0x0E (0x2E)	PORTE	-	PORTE6	-	-	-	PORTE2	-	-
0x0D (0x2D)	DDRE	-	DDE6	-	-	-	DDE2	-	-
0x0C (0x2C)	PINE	-	PINE6	-	-	-	PINE2	-	-
0x0B (0x2B)	PORTD	PORTD7	PORTD6	PORTD5	PORTD4	PORTD3	PORTD2	PORTD1	PORTD0
0x0A (0x2A)	DDRD	DDD7	DDD6	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0
0x09 (0x29)	PIND	PIND7	PIND6	PIND5	PIND4	PIND3	PIND2	PIND1	PIND0
0x08 (0x28)	PORTC	PORTC7	PORTC6	-	-	-	-	-	-
0x07 (0x27)	DDRC	DDC7	DDC6	-	-	-	-	-	-
0x06 (0x26)	PINC	PINC7	PINC6	-	-	-	-	-	-
0x05 (0x25)	PORTB	PORTB7	PORTB6	PORTB5	PORTB4	PORTB3	PORTB2	PORTB1	PORTB0
0x04 (0x24)	DDRB	DDB7	DDB6	DDB5	DDB4	DDB3	DDB2	DDB1	DDB0
0x03 (0x23)	PINB	PINB7	PINB6	PINB5	PINB4	PINB3	PINB2	PINB1	PINB0
0x02 (0x22)	Reserved	-	-	-	-	-	-	-	-
0x01 (0x21)	Reserved	-	-	-	-	-	-	-	-
0x00 (0x20)	Reserved	-	-	-	-	-	-	-	-

To continue our example let's assume we are going to write to one of the PORT registers (not to be confused with the PORT itself – see figure above). The PORTB, PORTC and PORTD registers are defined in `hardware/tools/avr/avr/include/avr/iom32u4.h` as below.

```
#define PORTB _SFR_IO8(0x05)
#define PORTC _SFR_IO8(0x08)
#define PORTD _SFR_IO8(0x0B)
```

Again looking at the figure, we see that arguments 0x05, 0x07, and 0x0A are the I/O addresses of PORTB, PORTC and PORTD respectively. They call `_SFR_IO8()`. The _SFR_IO8() converts the I/O address to the memory address. It is a macro that returns a byte of data at an address of io_addr + __SFR_OFFSET. The _SFR_IO8() is defined in `hardware/tools/avr/avr/include/avr/sfr_defs.h` as below.

```
#define _SFR_IO8(io_addr) _MMIO_BYTE((io_addr) + __SFR_OFFSET)
#define __SFR_OFFSET 0x20
```

Again, **`_MMIO_BYTE()`** is a macro that dereferences a byte of data at the specified address.

```
#define _MMIO_BYTE(mem_addr) (*(volatile uint8_t *)(mem_addr))
```

Putting it all together we have the equivalent macro.

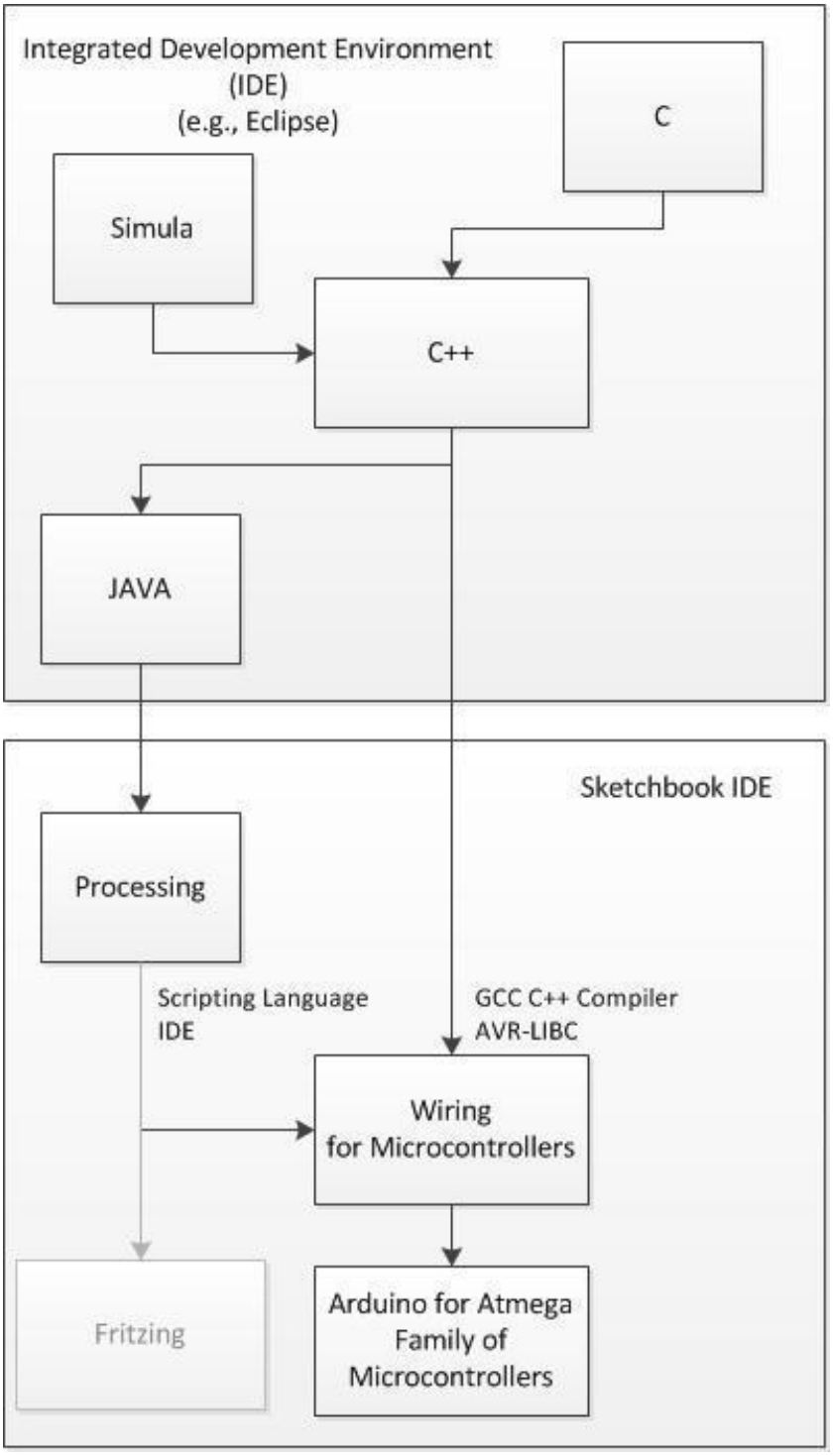
```
#define _SFR_IO8(io_addr) (*(volatile uint8_t *)(mem_addr)) + 0x20
```

Solutions to “Test Your Knowledge Questions”

1. `0x0A03`
2. `ADMUX = (analog_reference << 6) | (pin & 0x0f) | ((left_adjust & 0x01) << 5);`
   note: if left_adjust is zero `ADLAR` bit stays at zero.
3. `TCCR2A &= ~_BV(COM2A0)`
4. `TCCR2A = TCCR2A&~(_BV(WGM21)|_BV(COM2A0))|_BV(WGM20)|_BV(COM2A1);`
5. `TCCR2A |= (output_mode << 6) | (waveform & 0x03);    // analogRead`

APPENDIX A THE ARDUINO FAMILY TREE

The Arduino language (based on Wiring) is implemented in C/C++, and therefore has some differences from the Processing language, which is based on Java.



A Visual Paradigm for Programming - Processing

Source: Wikipedia - Processing (programming language)

- Processing was designed to get non-programmers (originally electronic artists) started with **software programming**, using a visual context, and to serve as the foundation for electronic sketchbooks.
    - The concept of "visual context" makes Processing comparable to Adobe's ActionScript and Lingo scripting based languages.
    - A "sketchbook", is a minimal alternative to an integrated development environment (IDE)
- Processing is an open source programming language and integrated development environment (IDE)
    - The project was initiated in 2001 by Casey Reas and Benjamin Fry, both formerly of the Aesthetics and Computation Group at the MIT Media Lab.
    - The language builds on the Java programming language, but uses a simplified syntax and graphics programming model.

From Programming to Microcontrollers - Wiring

- Wiring was design to teach non-programmers (originally electronic artists) how to **program microcontrollers**.
- Wiring, uses the Processing IDE (sketchbook) together with a simplified version of the C++ programming language (gcc compiler)
- There are now two separate hardware projects, Wiring and Arduino, using the Wiring IDE (sketchbook) and language.
- Fritzing is another software environment of the same sort, which helps designers and artists to document their interactive prototypes and to take the step from physical prototyping to actual product.

From Programming Microcontrollers to the Arduino

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.

- The C/C++ language is the foundation upon which the Arduino language (like Wiring on which it is based) is built.
- The C/C++ language is implemented using the GCC Compiler and links against the AVR C library AVR Libc and allows the use of any of its functions; see its user manual for details.
- The AVR C Library has its own family tree (nongnu, gcc)

APPENDIX B ARDUINO SCRIPTING LANGUAGE

Reference

Arduino Language Reference

Arduino programs can be divided in three main parts: *structure*, *values* (variables and constants), and *functions*.

Structure

- setup()
- loop()

Control Structures

- if
- if...else
- for
- switch case
- while
- do... while
- break
- continue
- return
- goto

Further Syntax

- ; (semicolon)
- {} (curly braces)
- // (single line comment)
- /* */ (multi-line comment)
- #define
- #include

Arithmetic Operators

- = (assignment operator)
- + (addition)
- - (subtraction)
- * (multiplication)
- / (division)
- % (modulo)

Comparison Operators

- == (equal to)
- != (not equal to)
- < (less than)
- > (greater than)
- <= (less than or equal to)
- >= (greater than or equal to)

Boolean Operators

- && (and)
- || (or)
- ! (not)

Pointer Access Operators

- * dereference operator
- & reference operator

Bitwise Operators

- & (bitwise and)
- | (bitwise or)
- ^ (bitwise xor)
- ~ (bitwise not)
- << (bitshift left)
- >> (bitshift right)

Compound Operators

- ++ (increment)
- -- (decrement)
- += (compound addition)
- -= (compound subtraction)
- *= (compound multiplication)
- /= (compound division)
- &= (compound bitwise and)
- |= (compound bitwise or)

Constants

- HIGH | LOW
- INPUT | OUTPUT
- true | false
- integer constants
- floating point constants

Functions - *Scripting Language*

Digital I/O

- pinMode() `// Writes to GPIO DDR register`
- digitalWrite() `// Writes to GPIO Port register`
- digitalRead() `// Reads GPIO Pin register`

Analog I/O

- analogReference() `// Writes to bits REFS1:REFS0 of ADMUX register`[2]
- analogRead() `// Reads ADC Data register (ADCH/ADCL)`
- analogWrite() `// Writes to OCRnA or OCRnB registers of Timers`

Advanced I/O

- tone()
- noTone()
- shiftOut() `// Software implementation of SPI MOSI interface`
- shiftIn() `// Software implementation of SPI MISO interface`
- pulseIn()

Time

- millis()
- micros()
- delay()
- delayMicroseconds()

Math

- min()
- max()
- abs()
- constrain()
- map()
- pow()
- sqrt()

Trigonometry

- sin()
- cos()
- tan()

Random Numbers

- randomSeed()
- random()

Bits and Bytes

- lowByte()
- highByte()
- bitRead()
- bitWrite()
- bitSet()
- bitClear()

[2] Actually sets variable `analog_reference` which is used to define these bits.

- bit()

External Interrupts

- attachInterrupt() `// Configures external interrupt pins INT1 and INT0`
- detachInterrupt() `// Clears EIMSK register bits INT1 and INT0`

Interrupts

- interrupts() `// Sets SREG I bit`
- noInterrupts() `// Clears SREG I bit`

Communication

- Serial

Standard Libraries

- EEPROM - reading and writing to "permanent" storage (**EEPROM**)
- Ethernet - for connecting to the internet using the Arduino Ethernet Shield
- Firmata - for communicating with applications on the computer using a standard serial protocol.
- LiquidCrystal - for controlling liquid crystal displays (LCDs)
- SD - for reading and writing SD cards
- Servo - for controlling servo motors
- SPI - for communicating with devices using the Serial Peripheral Interface (**SPI**) Bus
- SoftwareSerial - for serial communication on any digital pins
- Stepper - for controlling stepper motors
- Wire - Two Wire Interface (TWI/**I2C**) for sending and receiving data over a net of devices or sensors.

APPENDIX C C++ OPERATOR PRECEDENCE

When we start constructing compound assignment statements in order to assign values to fields within a peripheral subsystem register, also known as a special function register (SFR), it is important to remember operator precedence.

Level	Operator	Description	Grouping
1	::	scope	Left-to-right
2	() [] . -> ++ -- dynamic_cast static_cast reinterpret_cast const_cast typeid	postfix	Left-to-right
3	++ -- ~ ! sizeof new delete	unary (prefix)	Right-to-left
	* &	indirection and reference (pointers)	
	+ -	unary sign operator	
4	(type)	type casting	Right-to-left
5	.* ->*	pointer-to-member	Left-to-right
6	* / %	multiplicative	Left-to-right
7	+ -	additive	Left-to-right
8	<< >>	shift	Left-to-right
9	< > <= >=	relational	Left-to-right
10	== !=	equality	Left-to-right
11	&	bitwise AND	Left-to-right
12	^	bitwise XOR	Left-to-right
13	|	bitwise OR	Left-to-right
14	&&	logical AND	Left-to-right
15	||	logical OR	Left-to-right
16	?:	conditional	Right-to-left
17	= *= /= %= += -= >>= <<= &= ^= |=	assignment	Right-to-left
18	,	comma	Left-to-right

APPENDIX D: ARDUINO ANALOGREAD FUNCTION

```
int analogRead(uint8_t pin)
{
   uint8_t low, high;

   // set the analog reference (high two bits of ADMUX) and select the
   // channel (low 4 bits).  this also sets ADLAR (left-adjust result)
   // to 0 (the default).
   ADMUX = (analog_reference << 6) | (pin & 0x0f);

   // without a delay, we seem to read from the wrong channel
   //delay(1);

   // start the conversion
   sbi(ADCSRA, ADSC);

   // ADSC is cleared when the conversion finishes
   while (bit_is_set(ADCSRA, ADSC));

   // we hto read ADCL first; doing so locks both ADCL
   // and ADave CH until ADCH is read.  reading ADCL second would
   // cause the results of each conversion to be discarded,
   // as ADCL and ADCH would be locked when it completed.
   low = ADCL;
   high = ADCH;

   // combine the two bytes
   return (high << 8) | low;
}
```

APPENDIX E ADAFRUIT MOTOR SHIELD

Using the Motor Shield

DC Motors

```
#include <AFMotor.h>


// motor is an instance of the AF_DCMotor class

AF_DCMotor motor(2, MOTOR12_64KHZ); // create motor #2, 64KHz pwm

void setup() {
  Serial.begin(9600);           // set up Serial library at 9600 bps
  Serial.println("Motor test!");

  motor.setSpeed(200);          // set the speed to 200/255
}

void loop() {
  Serial.print("tick");

  motor.run(FORWARD);           // turn it on going forward
  delay(1000);

  Serial.print("tock");
  motor.run(BACKWARD);          // the other way
  delay(1000);

  Serial.print("tack");
  motor.run(RELEASE);           // stopped
  delay(1000);
}
```

Stepper Motor

```
#include <AFMotor.h>

// motor is an instance of the AF_Stepper class

AF_Stepper motor(48, 2);

void setup() {
  Serial.begin(9600);           // set up Serial library at 9600 bps
  Serial.println("Stepper test!");

  motor.setSpeed(10);  // 10 rpm

  motor.step(100, FORWARD, SINGLE);
  motor.release();
  delay(1000);
```

```
}

void loop() {
  motor.step(100, FORWARD, SINGLE);
  motor.step(100, BACKWARD, SINGLE);

  motor.step(100, FORWARD, DOUBLE);
  motor.step(100, BACKWARD, DOUBLE);

  motor.step(100, FORWARD, INTERLEAVE);
  motor.step(100, BACKWARD, INTERLEAVE);

  motor.step(100, FORWARD, MICROSTEP);
  motor.step(100, BACKWARD, MICROSTEP);
}
```

Library Header

What is a Library?

```
// Adafruit Motor shield library
// copyright Adafruit Industries LLC, 2009
// this code is public domain, enjoy!

#ifndef _AFMotor_h_
#define _AFMotor_h_

#include <inttypes.h>
#include <avr/io.h>

//#define MOTORDEBUG 1

#define MICROSTEPS 16                         // 8 or 16

#define MOTOR12_64KHZ _BV(CS20)            // no prescale
#define MOTOR12_8KHZ _BV(CS21)             // divide by 8
#define MOTOR12_2KHZ _BV(CS21) | _BV(CS20) // divide by 32
#define MOTOR12_1KHZ _BV(CS22)             // divide by 64

#define MOTOR34_64KHZ _BV(CS00)            // no prescale
#define MOTOR34_8KHZ _BV(CS01)             // divide by 8
#define MOTOR34_1KHZ _BV(CS01) | _BV(CS00) // divide by 64

#define MOTOR1_A 2
#define MOTOR1_B 3
#define MOTOR2_A 1
#define MOTOR2_B 4
#define MOTOR4_A 0
#define MOTOR4_B 6
#define MOTOR3_A 5
```

```
#define MOTOR3_B 7

#define FORWARD 1
#define BACKWARD 2
#define BRAKE 3
#define RELEASE 4

#define SINGLE 1
#define DOUBLE 2
#define INTERLEAVE 3
#define MICROSTEP 4

// Arduino pin names
#define MOTORLATCH 12
#define MOTORCLK 4
#define MOTORENABLE 7
#define MOTORDATA 8

class AFMotorController
{
  public:
      AFMotorController(void);
      void enable(void);
      friend class AF_DCMotor;
      void latch_tx(void);
};

class AF_DCMotor
{
 public:
  AF_DCMotor(uint8_t motornum, uint8_t freq =  MOTOR34_8KHZ);
  void run(uint8_t);
  void setSpeed(uint8_t);

 private:
  uint8_t motornum, pwmfreq;
};

class AF_Stepper {
 public:
  AF_Stepper(uint16_t, uint8_t);
  void step(uint16_t steps, uint8_t dir,  uint8_t style = SINGLE);
  void setSpeed(uint16_t);
  uint8_t onestep(uint8_t dir, uint8_t style);
  void release(void);
  uint16_t revsteps; // # steps per revolution
  uint8_t steppernum;
  uint32_t usperstep, steppingcounter;
 private:
```

```
  uint8_t currentstep;

};

uint8_t getlatchstate(void);

#endif
```

Adafruit Private Functions

latch_tx

```
#define _BV(bit) (1 << (bit))

/*
      Send data located in 8-bit variable latch_state to
      the 74HC595 on the Motor Shield.
*/
void AFMotorController::latch_tx(void) {
 uint8_t i;

 //LATCH_PORT &= ~_BV(LATCH);
 digitalWrite(MOTORLATCH, LOW);     // - Output register clock low

 //SER_PORT &= ~_BV(SER);
 digitalWrite(MOTORDATA, LOW);      // - Serial data bit = 0

 for (i=0; i<8; i++) {              // - Shift out 8-bits
      //CLK_PORT &= ~_BV(CLK);
      digitalWrite(MOTORCLK, LOW);  //    - Shift clock low

      if (latch_state & _BV(7-i)) { //    - Is current bit of
      //SER_PORT |= _BV(SER);              latch_state == 1
      digitalWrite(MOTORDATA, HIGH); //   -   Yes, serial data bit = 1
      } else {
      //SER_PORT &= ~_BV(SER);
      digitalWrite(MOTORDATA, LOW);  //   -   No, serial data bit = 0
      }
      //CLK_PORT |= _BV(CLK);
      digitalWrite(MOTORCLK, HIGH); //    - Shift clock high, rising edge
 }                                  //    shift bit into shift register
 //LATCH_PORT |= _BV(LATCH);
 digitalWrite(MOTORLATCH, HIGH);    // - Output register clock high, rising
}                                   //   edge sends the stored bits to the
                                    //   output register.
```

enable

```
/*
   Configure DDR Registers B and D bits assigned to
   the input of the 74HC595 on the Motor Shield. Output
   all zeros and enable outputs.
*/
```

```
void AFMotorController::enable(void) {
 // setup the latch
 /*
 LATCH_DDR |= _BV(LATCH);
 ENABLE_DDR |= _BV(ENABLE);
 CLK_DDR |= _BV(CLK);
 SER_DDR |= _BV(SER);
 */
 pinMode(MOTORLATCH, OUTPUT);
 pinMode(MOTORENABLE, OUTPUT);
 pinMode(MOTORDATA, OUTPUT);
 pinMode(MOTORCLK, OUTPUT);

 latch_state = 0;

 latch_tx();  // "reset"

 //ENABLE_PORT &= ~_BV(ENABLE); // enable the chip outputs!
 digitalWrite(MOTORENABLE, LOW);
}
```

Adafruit Motor Public Functions

run

```
void AF_DCMotor::run(uint8_t cmd) {
 uint8_t a, b;

 /* Section 1: choose two shift register outputs based on which
  * motor this instance is associated with.   motornum is the
  * motor number that was passed to this instance's constructor.
  */
 switch (motornum) {
 case 1:
      a = MOTOR1_A; b = MOTOR1_B; break;
 case 2:
      a = MOTOR2_A; b = MOTOR2_B; break;
 case 3:
      a = MOTOR3_A; b = MOTOR3_B; break;
 case 4:
      a = MOTOR4_A; b = MOTOR4_B; break;
 default:
      return;
 }
```

```
 /* Section 2: set the selected shift register outputs to high/low,
  * low/high, or low/low depending on the command.  This is done
  * by updating the appropriate bits of latch_state and then
  * calling tx_latch() to send latch_state to the chip.
  */
 switch (cmd) {
 case FORWARD:               // high/low
      latch_state |= _BV(a);
      latch_state &= ~_BV(b);
      MC.latch_tx();
      break;
 case BACKWARD:              // low/high
      latch_state &= ~_BV(a);
      latch_state |= _BV(b);
      MC.latch_tx();
      break;
 case RELEASE:               // low/low
      latch_state &= ~_BV(a);
      latch_state &= ~_BV(b);
      MC.latch_tx();
      break;
 }
}
```

setSpeed

```
void AF_DCMotor::setSpeed(uint8_t speed) {
 switch (motornum) {
 case 1:
      OCR2A = speed; break;
 case 2:
      OCR2B = speed; break;
 case 3:
      OCR0A = speed; break;
 case 4:
      OCR0B = speed; break;
 }
}
```

initPWM1

This is a brief excerpt of the AF_DCMotor constructor (`subroutine initPWM1(freq)`), which is initializing speed control for motor 1:

```
// use PWM from timer2A
TCCR2A |= _BV(COM2A1) | _BV(WGM20) | _BV(WGM21); // fast PWM, turn on oc0
TCCR2B = freq & 0x7;
OCR2A = 0;
DDRB |= _BV(3);
break;
```