# Challenge 2

**Notes on Challenge 2**

Challenge #2 focuses on two main concepts.

(1) Applying bitwise logic and shift operators to manipulate data from registers of an "Hypothetical CNC (computer numeric control) Machine"
(2) Producing a "Velocity Profile" using data extracted from registers of the "Hypothetical CNC Machine"

**Bitwise Operators:**

The use of bitwise logic and shift operators an essential part of computer programing. They are part of the IDE of all programming languages. A knowledge these operators is essential especially when interfacing sensors and other register-based devices to microcontrollers. They are the main elements used to "extract and manipulate data".

**Velocity Profiles:**

One area of computer science/engineering is the application of microcontrollers to produce motion called CNC. Machines like lathes milling machines, balancing robots, 3d printers, are all around us. At the core of these devices lie **servo controllers** that activate motors, solenoids and other mechanical devices to create motion. Motion in these devices is controlled and regulated by a "velocity profile" that defines three main types of motion: motion with acceleration, deceleration and constant velocity.

**Why "Hypothetical CNC Machine"?**

The idea of selecting a "Hypothetical CNC Machine" in Challenge 2 arose from one of my projects. The project included the design, prototype, construction and printed circuit board of a servo controller with full PID to control small DC motors with optical feedback. In addition to hardware, there were software challenges one being **how to create and feed velocity profiles** to the servo controller. It's interesting to note that CNC machines like lathes, milling machines, 3-D printers, use G-codes in programming movement. However, G-codes are only **preparatory words** in specifying movement. It's the **motion controllers** of CNC machines that **interprets the G-codes** to produce **trapezoidal motion**.

G-codes, M-codes are the mnemonics of CNC programming analogous to the mnemonics of an assembly program.

**G-codes, M-codes mnemonics -> (motion)velocity profiles, assembler mnemonics ->executable machine code**

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Below is a short summary of what you need to know or review in order to complete Challenge2.

Bitwise Logic Operators in C/C++ (your language compiler/interpreter may use different syntax)

- & - AND
- | - OR
- ^ - XOR
- ~ - bitwise NOT
- >> shift right
- << shift left

| Truth Table of Bitwise Operators | | | | | |
|---|---|---|---|---|---|
| In C++ boolean *true* is 1 and *false* is 0 | | | | | |
| **a** | **b** | **a & b** | **a \| b** | **a ^ b** | **~ a** |
| 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 1 | 0 | 0 |

**Setting and Resetting Bits**

- Bits are set or reset using bitwise **OR /AND** operators
- A bit is **set** when a specified bit in a byte/word is forced to a **1** without changing the other bits
- A bit is **reset** when a specified bit in a byte/word is forced to a **0** without changing the other bits
- Set/Reset work on multiple bits

**Examples**

Consider the byte variable A= b7 b6 b5 b4 b3 b2 b1 b0 , where b0 -least, b7 -most significant bit

(1) Set b5
(2) Reset b1
(3) Determine the value of b3 b2 b1 b0

**Set b5:**

A = b7 b6 b5 b4 b3 b2 b1 b0

B = 0 0 1 0 0 0 0 0 = $32_{10}$= $20_{hex}$

A |B = b7 b6 1 b4 b3 b2 b1 b0 (all other bits unchanged)

**Reset b1:**

A = b7 b6 b5 b4 b3 b2 b1 b0

B = 1 1 1 1 1 1 0 1 = $253_{10}$= $FD_{hex}$

A &B = b7 b6 b5 b4 b3 b2 0 b0 (all other bits unchanged)

**Value of b3 b2 b1 b0**: (using & and shift operators)

Say, A = 1 0 1 0 1 1 1 0 1 = $93_{10}$ =$5D_{hex}$

B = 0 0 0 0 1 1 1 1 1 = $31_{10}$ =$1F_{hex}$

A = A &B A = 0 0 0 0 1 1 1 0 1 = $29_{10}$ =$1D_{hex}$

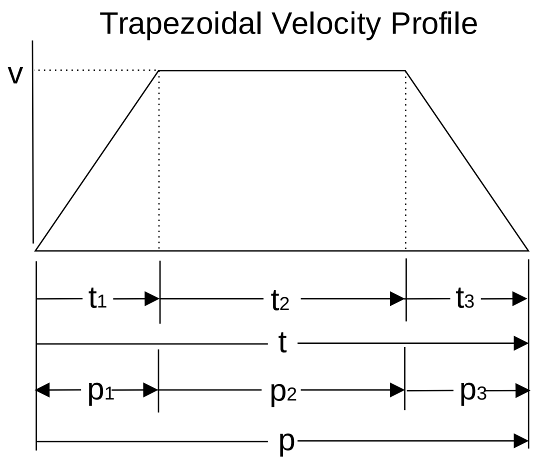
Or

A=A<< 4 A = 1 1 0 1 0 0 0 0 0 = $208_{10}$=$D0_{heex}$

A=A>>4 A = 0 0 0 0 1 1 1 0 1 = $29_{10}$ =$1D_{hex}$ as before

**The Trapezoid Velocity Profile**

The motion of a tool in a CNC machine is controlled by a sequence of one or more "velocity profiles" to achieve movement. As shown below, movement starts from zero and accelerates for a period of t1 seconds to reach a desired velocity, v. Motion continuous from that point at constant velocity v for a period of t2 seconds then deaccelerates for t3 seconds coming to rest having completed the desired movement.  For mechanical reasons the acceleration and the deceleration are made equal so that t1=t3.




since $t_1 = t_3$ & $p_1 = p_3$, then $t = 2t_1 + t_2$, $p = 2p_1 + p_2$
a: acceleration cm/sec$^2$
v: velocity in cm/sec after $t_1$ seconds
$t_1$: time travelling with constant acceleration a
$t_2$ time travelling with constant velocity v
$t_3$ time travelling with constant deceleration a
$p_1$, $p_2$, $p_3$ distances covered in cm
p: total distance travelled

**Solution of profile:**

In the profile **a, v, p** and **t** are **positive** known (given) quantities leaving $t_1$ and $t_2$ as unknown. Solving for first for $t_1$:

$p_1 = \frac{1}{2}at_1^2$ ----(1), where t1 >0

$p_2 = vt_2$ ------(2), where t2 >0, $p = 2p_1 + p_2$, $t = 2t_1 + t_2$

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