Tutorial 2

1. What is a programmer’s model? Draw the model for M68k CPU.

A programmer’s model is an abstract or conceptual view of the structure and operation of a computing system. A microprocessor’s programming model shows the registers inside the microprocessor, such as its data, address and special registers. The programming model for M68k shows the registers inside the M68k as follows:

2. What are the 5 data types supported by M68k? Which of these types are common to most computers?

The M68k processor supports binary, octal, decimal, hexadecimal, and ASCII characters. The most common data type is binary, since all computers interpret instructions and data in binary form (machine code).

3. What is meant by a register being accessible to the programmer? Is the Program Counter (PC) accessible to the programmer in M68k? Why or why not?

If a register is accessible to the programmer, it means that it can be directly modified (by replacing it with a new value). The PC is not accessible to the programmer, since it cannot be assigned a new value just by replacing it with a new one. This is because PC is an important register that controls the flow of the program, and any changes can significantly effect program execution. However, there are M68k instructions that can indirectly change the PC, such as the branch (BRA) or jump (JMP) command.

4. What is the purpose of the Status Register (SR)? Can the programmer access the SR?

The SR stores important control and status bits during M68k execution. The bits stored in the SR are:
- Trace bit (T): If activated, M68k executes instructions step-by-step. It is used for program debugging.
- Supervisor bit (S): Used to activate user/supervisor modes. If S = 0, user mode is activated. If S = 1, supervisor mode is activated.
• Interrupt Mask bits (I₂, I₁, I₀): Stores the interrupt level currently being serviced by M68k.
  New interrupts are compared to this value to determine whether it should be serviced immediately or whether it needs to wait until the current interrupt is finished.

• Condition Code Registers (CCR): The final 5-bits of the SR. Used to test the results of previously executed instructions. X is used to test the last bit pushed out during shift and rotate instructions, and to test whether BCD operations are outside acceptable range. N tests the MSB to determine whether the result is a negative number. Z tests whether the result of the executed instruction is zero. V tests whether a signed overflow has occurred. C tests whether the last instruction has caused a carry/borrow to occur.

The programmer can access the SR, but the bits that can be changed depend on the S bit. In user mode (S = 0) the programmer can only modify the CCR (only X, N, Z, V, C). In supervisor mode (S = 1), the programmer can modify all the bits in SR.

5. How many bits are needed to address the highest (largest number) address byte in the M68k? How many bits are in the address register? Why the discrepancy?

Since the address bus size 24-bits, 24-bits are needed to address the highest address byte in M68k. However, the address registers inside the M68k is 32-bit long, which is 8-bit longer than the address bus length. The reason for this design is that Motorola wanted the M68k to be forward-compatible with its future microprocessor designs. Since the address register is already 32-bit, future versions with 32-bit address bus can easily be upgraded based on the original M68k design.

6. Why is it necessary to have a separate supervisory mode and user mode? Give an example.

User and supervisor modes are important to control the user’s level of access to critical instructions and registers. By defining two types of user modes (User and Supervisor), M68k can protect the system by limiting inexperienced users from executing certain instructions and changing critical memory areas. For example, memory locations $000000 to $000003FF are usually reserved as the vector addresses that are used to handle exceptions. Any unintentional changes in these locations may cause exceptions not to be handled properly, which would result in system instability. M68k protects these critical memory locations by not allowing them to be accessed if the S bit in Status Register is 0 (User Mode).

7. List and define the 5 flags of the Condition Code Register.

The CCR is a set of 5 bits contained in the Status Register. Its purpose is to store the condition results after the execution of M68k instructions. The CCR contains five bits:
X = Extend bit, used for shift, rotate and multi-precision BCD operations.
N = Negative bit, indicates a negative result has occurred (MSB = 1).
Z = Zero bit, indicates the result is zero.
V = Overflow bit, indicates a signed overflow has occurred.
C = Carry bit, indicates an arithmetic overflow (carry/borrow) has occurred.

8. What is the purpose of so many addressing modes in M68k?

M68k has 14 addressing modes altogether. The many addressing modes are intended to give the programmer more flexibility in writing their programs.

9. How are signed numbers represented in M68k?

Signed numbers are represented in M68k using the 2’s complement method.
10. What is the range of signed and unsigned numbers that can be used in numerical computations with M68k? Give answers for byte, word and long word operations.

The range of unsigned numbers can be calculated using the following formula: $0 \leq x \leq 2^n$. The range of signed numbers can be calculated using the following formula:

$$-2^{n-1} \leq x \leq +(2^{n-1} - 1),$$

where $n$ is the number of bits. For byte data ($n = 8$), the range for unsigned numbers is $0 \leq x \leq 256$, and the range for signed numbers is $-128 \leq x \leq 127$. For word data ($n = 16$), the range for unsigned numbers is $0 \leq x \leq 65,536$, and the range for signed numbers is $-32,768 \leq x \leq 32,767$. For long word data ($n = 32$), the range for unsigned numbers is $0 \leq x \leq 4,294,967,296$, and the range for signed numbers is $-2,147,483,648 \leq x \leq 2,147,483,647$.

11. Assume that a microcomputer system uses 24-bit instructions and registers. What range of signed numbers can be represented by the system?

Based on Q11, the range for signed numbers when $n = 24$ is $-8,388,608 \leq x \leq 8,388,607$. 