Chapter V: System Control

1. Signal Conditioning

The output signal from the sensor of a measurement system has generally to be processed in some way to make it suitable for the next stage of the operation. The signal may be, for example, too small and have to be amplified, contain interference which has to be removed, be non-linear and require linearization, be analogue and have to be made digital, etc. All these changes can be referred to as **signal conditioning**.

1.1. Signal Conditioning Processes

The following are some of the processes that can occur in conditioning a signal:

1. Protection to prevent damage to the next element, e.g. a microprocessor, as a result of high current or voltage.
2. Getting the signal into the right type of signal. This means making the signal into a d.c. current or voltage. Ex) Wheatstone bridge.
3. Getting the level of the signal right. The signal from measurement devices often be just a few millivolts. Hence, it needs to be amplified upto a few volts for inputting to a microprocessor. Ex) operational amplifier.
4. Eliminating or reducing noise. Ex) filter such as high pass filter and low pass filter.
5. Signal manipulation, e.g. making it a linear function of some variable. The signals from some sensors are non-linear and thus a signal conditioner might be used to linearize these.

2. Digital Signal

The output from most sensors tends to be in analogue form. Where a microprocessor is used as part of the measurement or control system, the analogue output from the sensor has to be converted into a digital from before it can be used as an input to the microprocessor. Likewise, most actuators operate with analogue inputs and so the digital output from a microprocessor has to be converted into an analogue form before it can be used as an input by the actuator.

2.1. Binary system

The binary system (2진수) is based on just the two symbols or states 0 and 1. These are termed binary digits or bits.

2^0 (bit 0), 2^1 (bit 1), 2^2 (bit 2), 2^3 (bit 3) …

For example, the decimal number 15 is $2^0 + 2^1 + 2^2 + 2^3 = 1111$ in the binary system. In a binary number the bit 0 is termed the least significant bit (LSB) and the highest bit the most significant bit (MSB). The combination of bits to represent a number is termed a word. Thus 1111 is a four-bit word. The term byte is used for a group of 8 bits.

2.2. Analogue-to-digital conversion

Analogue-to-digital conversion involves converting analogue signals into binary words in below figure.

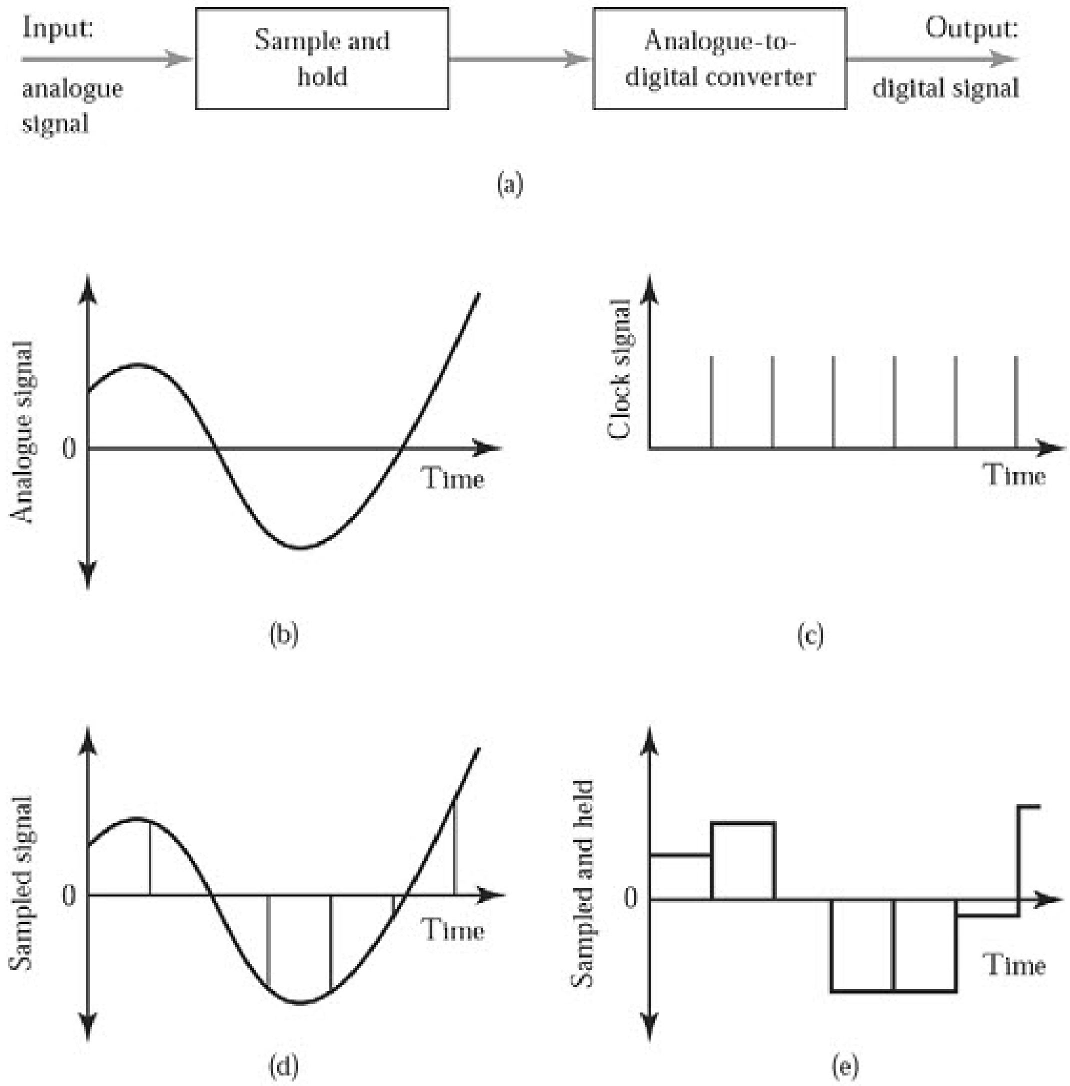


Figure: (a) Analogue-to-digital conversion, (b) analogue input, (c) clock signal (a clock supplies regular time signal pulses to the analogue-to-digital converter (ADC)), (d) sampled signal, (e) sampled and held signal

2.3. Digital-to-analogue conversion

The input to a digital-to-analogue converter (DAC) is a binary word. The output is an analogue signal.

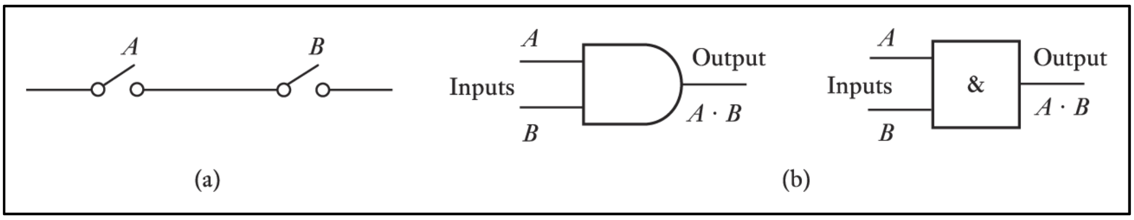
Ex) Consider the situation where a microprocessor gives an output of an 8-bit word. This is fed through an 8-bit digital-to-analogue converter to a control valve. The control valve requires 6 V to be fully open. If the fully open state is indicted by 11111111, what will be the output to the valve for a change of 1 bit? Answer is $6/2^8$=0.023 V.

3. Digital Logic

Many control systems are concerned with setting events in motion or stopping them when certain conditions are met. For example, with washing machine, the heater is only switched on when water in the drum reaches the prescribed level. Such control involves digital signals.

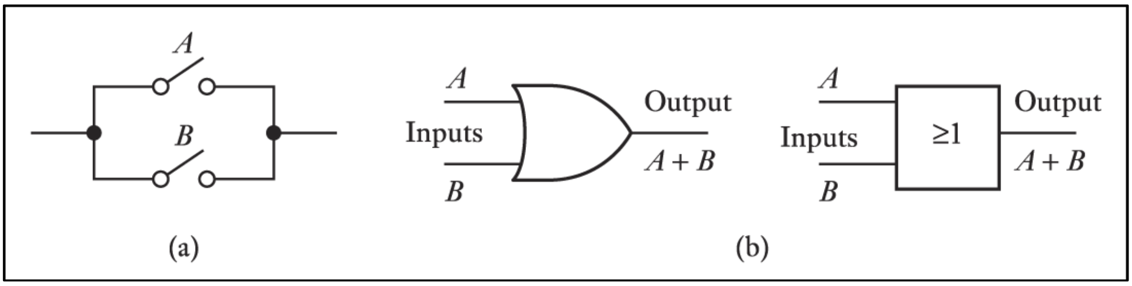
3.1. Logic gates

- AND gate



AND gate represented by: (a) switches, (b) symbols

- OR gate



- NOT, NAND, NOR, XOR gates, etc.

4. Microprocessors

If we take a simple control problem, e.g. the sequencing of the red, yellow, green lights at a traffic crossing, then it would be possible to solve it by an electronic control system involving combinational and sequential logic integrated circuits. However, for a more complex situation a microprocessor with software to make the 'interconnections' is highly demanded.

4.1. Microcomputer structure

Computer has three sections: a **central processing unit** (CPU) to recognize and carry out program instructions, **input and output circuitry/interfaces** to handle communications between the computer and outside devices, and **memory** to hold the program instructions and data. Digital signals move from one section to another along paths called buses. Note that a bus, in physical sense, is a number of conductors along which electrical signals can be carried.

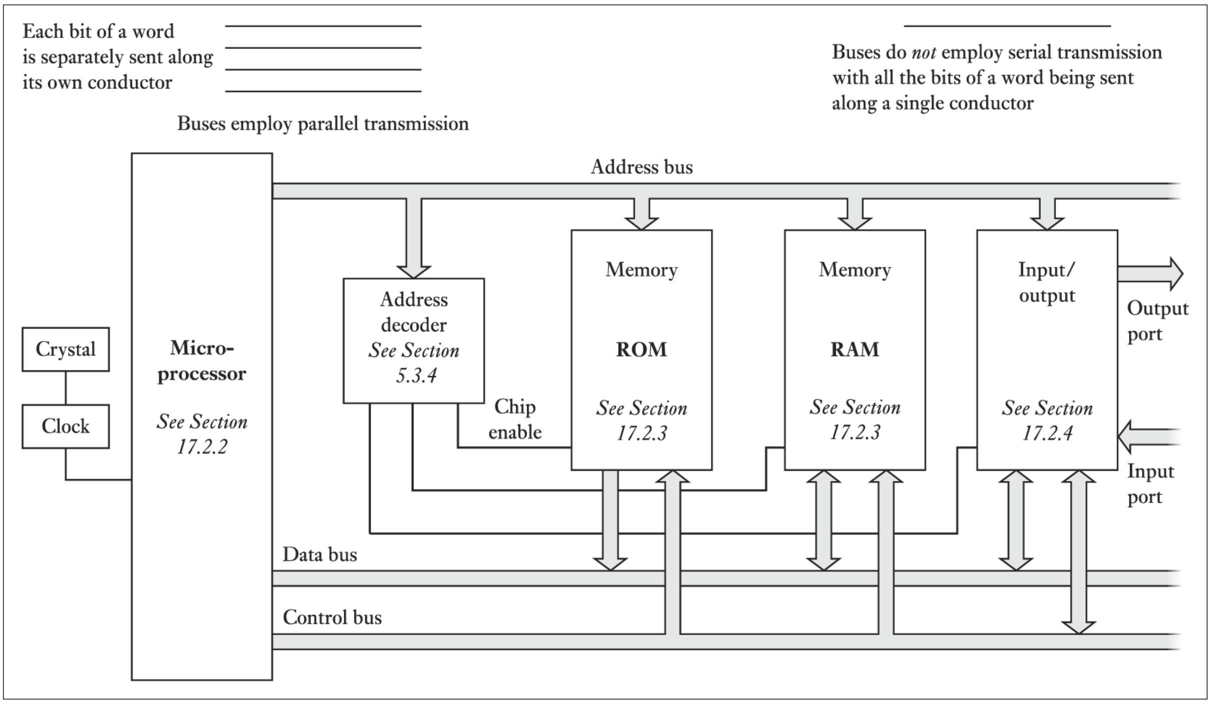


Figure: General form of a microprocessor system and its buses

5. Language

Software is the term used for the instructions that tell a microprocessor or microcontroller what to do. The collection of instructions that a microprocessor will recognize is its instruction set.

5.1. Assembly language

Microprocessors work in binary code. Instructions written in binary code are referred to as being on machine code. It is prone to errors because the program is just a series of 0s and 1s. Hence, easily comprehended form of shorthand code is used instead of 0s and 1s. Such a shorthand code is referred to as a mnemonic code (연산 기호 코드) such as “ADDA” instead of “ADDD#0020” for meaning “Add”. The term assembly language is used for such a code. However, the assembler program is required to convert assembly language into machine code since the microprocessor only recognizes the machine code.

5.1.1 Instruction sets

The following are commonly used example instructions that may be given to a microprocessor.

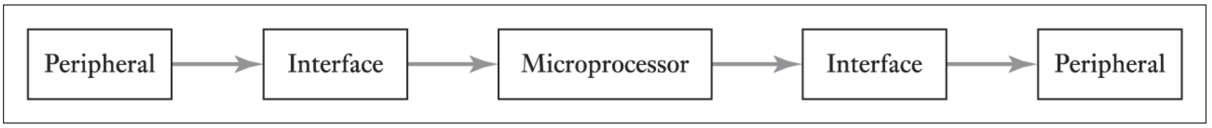
- LDAA $0010 for “data load” — Motorola microprocessor
- STA $0011 for “data store” — Motorola microprocessor
- MOV R5, A for “data move” — Intel microprocessor
- ADDD#0020 for “arithmetic add (더하기 연산)” — Motorola microprocessor
- ADD A,$10h for “arithmetic add (더하기 연산)” — Intel microprocessor

5.2. C language

C is a high-level language that is often used instead of assembly language for the programming of microprocessors. It has the advantages when compared with the assembly language of being easier to use and that the same program can be used with different microprocessors: all that is necessary for this is that the appropriate compiler is used to translate the C program into the relevant machine language for the microprocessor concerned. Assembly language is different for the different microprocessors while C language is standardized, the standard being that of the American National Standards Institute (ANSI).

6. Input/Output Systems

When a microprocessor is used to control some system it has to accept input information, respond to it and produce output signals to implement the required control action. Thus there can be inputs from sensors to feed data in and outputs to such external devices as relays and motors. The term peripheral is used for a device, such as a sensor, keyboard, actuator, etc. which is connected to a microprocessor. It is, however, not normally possible to connect directly such peripheral devices to a microprocessor bus system due to a lack of compatibility in signal forms and levels. Because of such incompatibility, a circuit known as an interface is used between the peripheral items and the microprocessor.



Learn it more through the class practice time.

7. Programmable Logic Controllers

A programmable logic controller (PLC) can be defined as a digital electronic device that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes. PLCs have the great advantage that it is possible to modify a control system without having to rewire the connections to the input and output devices. PLCs were first conceived in 1968. They are now widely used and extend from small self-contained units for use with 20 digital inputs/outputs to modular systems which can be used for large numbers of inputs/outputs, handle digital or analogue inputs/outputs.