Chapter 9

Computer and Experiment

9.1 Computer in Experiment

- Data Acquisition ; Acquire experimental data from experimental equipment and store in computer.
- Data Analysis ; Analyze the raw data to get physical data.
- Equipment Control ; Use the analyzed data to send controlling signal to experimental equipment. Useful not only for convenience but also for experiments at remote place or in an extreme environment such as very hot place, radioactive place, etc.

9.2 Connection of Computer and Experimental Equipment

- Interface ; General Purpose Interface Bus (GPIB) Board, USB.
- D/A Converter ; Convert a digital signal in computer to an analog signal to control experimental device.

  A simple D/A converter is a binary weighted resister D/A converter as shown in Fig.9.1 for 4-bit digital data. The current flowing through switch S_n is $2^{n-1}I_0$ when the switch is closed. The total current flowing through switches which are closed or opened according to the binary

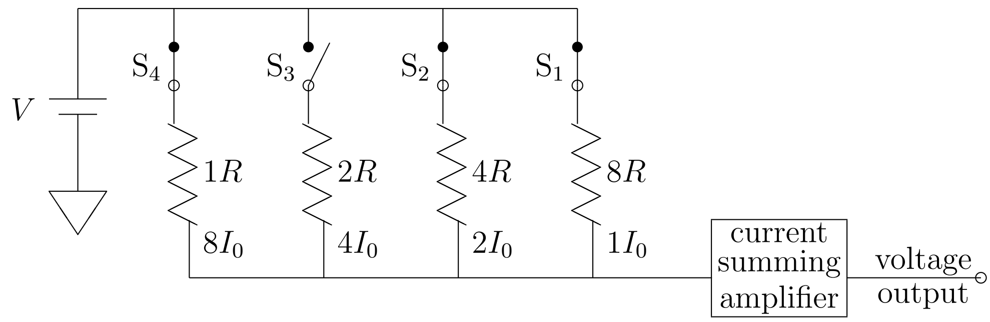

Figure 9.1: Binary weighted resister D/A converter. Here the switches are set to the binary code of 1011.

code is the current in analog signal. As an example, closing switches S_4, S_2, and S_1 represents binary number 1011 which is

$$1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 11. \quad (9.1)$$

This type of D/A converter is easy to understand the mechanism. However, since the resistance in switch S_n is $1/2^{n-1}$ of the resistance in switch S_1, the range of resistances would be too large to be practical for the typical number of digital bits.

By arranging resistors cleverly, we can use only two sizes of resistors for the resistance ladder arrangement of D/A converter such as shown in Fig.9.2. The resolution of the analog signal is about half of the value of the least significant bit, i.e., about 2^{-n} times the full scale value of analog output voltage for n-bit D/A converter.

- A/D Converter ; Convert an analog signal from experimental device to a digital signal for computer.

A 4-bit A/D converter for analog signal of 0 to 10 V has the binary

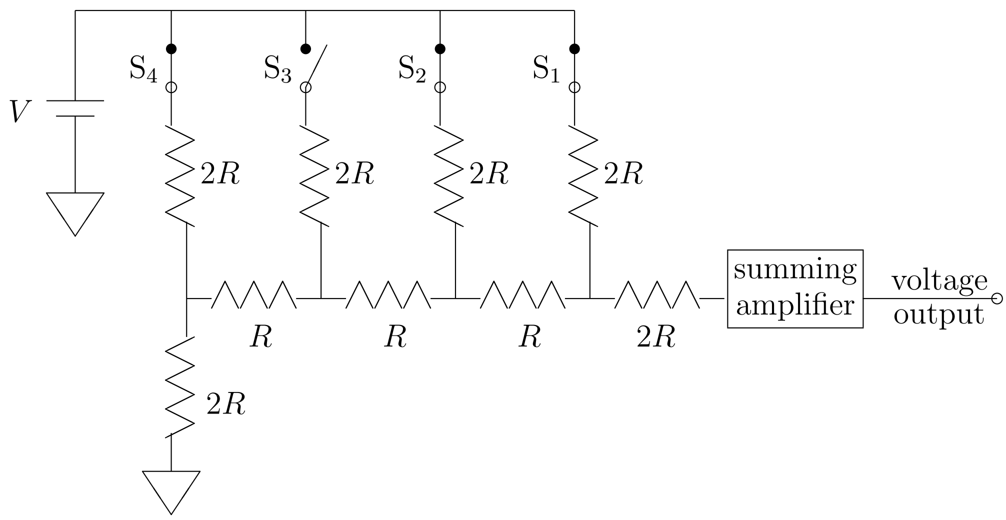

Figure 9.2: R–$2R$ network D/A converter. Here the switches are set to the binary code of 1011.

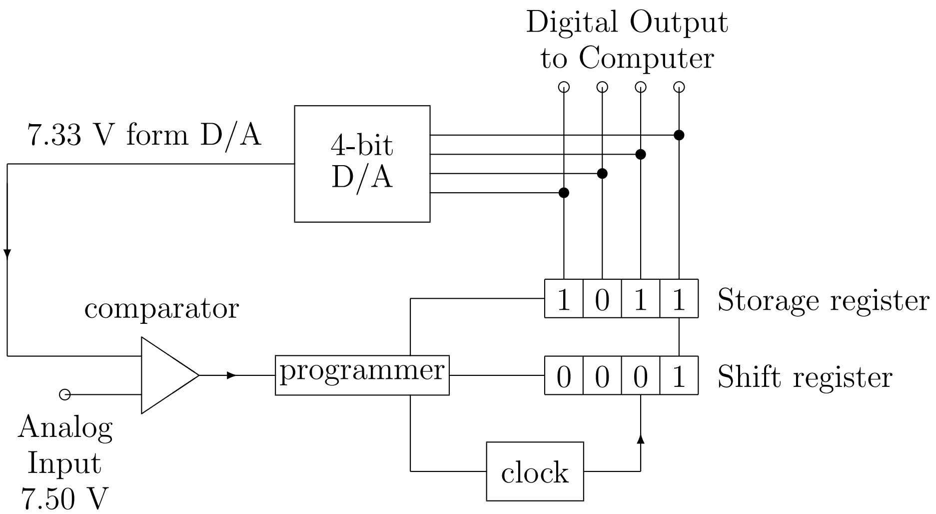

Figure 9.3: 4-bit A/D converter. The A/D converter shown here is in the state it would be at the time when the last bit is tested.

representation of

binary code	voltage	decimal value
1111	10.000 V	$2^4 - 1 = 15$
1000	5.333 V	$2^3 = 8$
0100	2.667 V	$2^2 = 4$
0010	1.333 V	$2^1 = 2$
0001	0.667 V	$2^0 = 1$
0000	0.000 V	0

To convert analog signal (7.50 V as an example) using 4-bit A/D converter as shown in Fig.9.3, compare the input analog signal with the signal converted from a digital signal in storage register. The converter consisted with a 4-bit storage register to store digitalized binary code, 4-bit D/A converter to convert binary code in the storage register, comparator to compare input analog signal with the signal converted from binary code, and programmer parts to perform comparison successively. Starting at the left-most (most significant) bit of storage register turned on:

1. Try binary code 1000 in storage register which is converted to 5.333 V by D/A converter. Since the analog signal 7.50 V is larger than 5.333 V, keep the most significant bit turned on.
2. Try binary code 1100 which is 8.000 V. Since the input signal 7.50 V is smaller than 8.000 V, turn off the second significant bit thus the storage register is 1000.
3. Try binary code 1010 which is 6.667 V. Since 7.50 V is larger than 6.667 V, keep the third significant bit turned on thus binary code is 1010.
4. Try binary code 1011 in storage register which is 7.333 V. Since 7.50 V is larger than 7.333 V, keep the fourth bit turned on thus the binary code is 1011.
5. The final binary code 1011 is the digital output of A/D converter representing the analog signal of 7.500 V in a 4-bit A/D converter.

The precision of n-bit A/D converter is one part in 2^n of full range. For a 10 V input signal in 4-bit A/D converter, the precision would be ± 0.625 V.

- Amplification and Noise ; Transmit signal effectively between computer and experimental equipment.

  Signal with a larger amplitude has a larger signal to noise ratio and thus has less affection from noise. A digital signal is less affective by the noise than an analog signal. Thus it is better to put the A/D converter and the D/A converter at the site of experimental equipment than at the computer site.