Chapter IV

DIGITAL COMPUTER PROGRAMS FOR DETERMINATION OF THE IMPULSE RESPONSE

4.1 Introduction

The digital computer programs have been written in basic FORTRAN IV to show how the impulse response g(t) can be evaluated by the methods explained in Chapter 2 and Chapter 3. In these programs, the models of the impulse responses are set up, and the time period $N\Delta t$ of the b.m.l.s. input signal is over five times the dominant time constant of the impulse response. The steady-state output signal y(t) which will be used to correlate with the input signal is obtained after applying the b.m.l.s. input signal one complete period.

4.2 Convolution Operation

The subprogram CONV performs the method of convolution integral which is derived in Appendix D. This subprogram will provide the intermediate value sequence of the steady-state output signal.

From Eqn. (D.8) in Appendix D, the sequence of the output signal at discrete time $t = i\Delta t+(\ell+1/2)\Delta t/m$ is

$$y(i\Delta t+\frac{\ell+1/2}{m}\Delta t) = \frac{1}{2m}\Delta t\sum_{j=0}^{2m\ell+2\ell} x(\frac{j}{2m}\Delta t+\frac{1}{4m}\Delta t)\,g(i\Delta t+\frac{\ell+1/2}{m}\Delta t-\frac{j+1}{m}\Delta t+\frac{1}{4m}\Delta t) \qquad (80)$$

Thus, the sampled input signal and the sampled impulse response are illustrated in Fig. 8a and 8b respectively. The result of the output signal y(t) obtained by the subprogram CONV is shown in Fig. 8c.

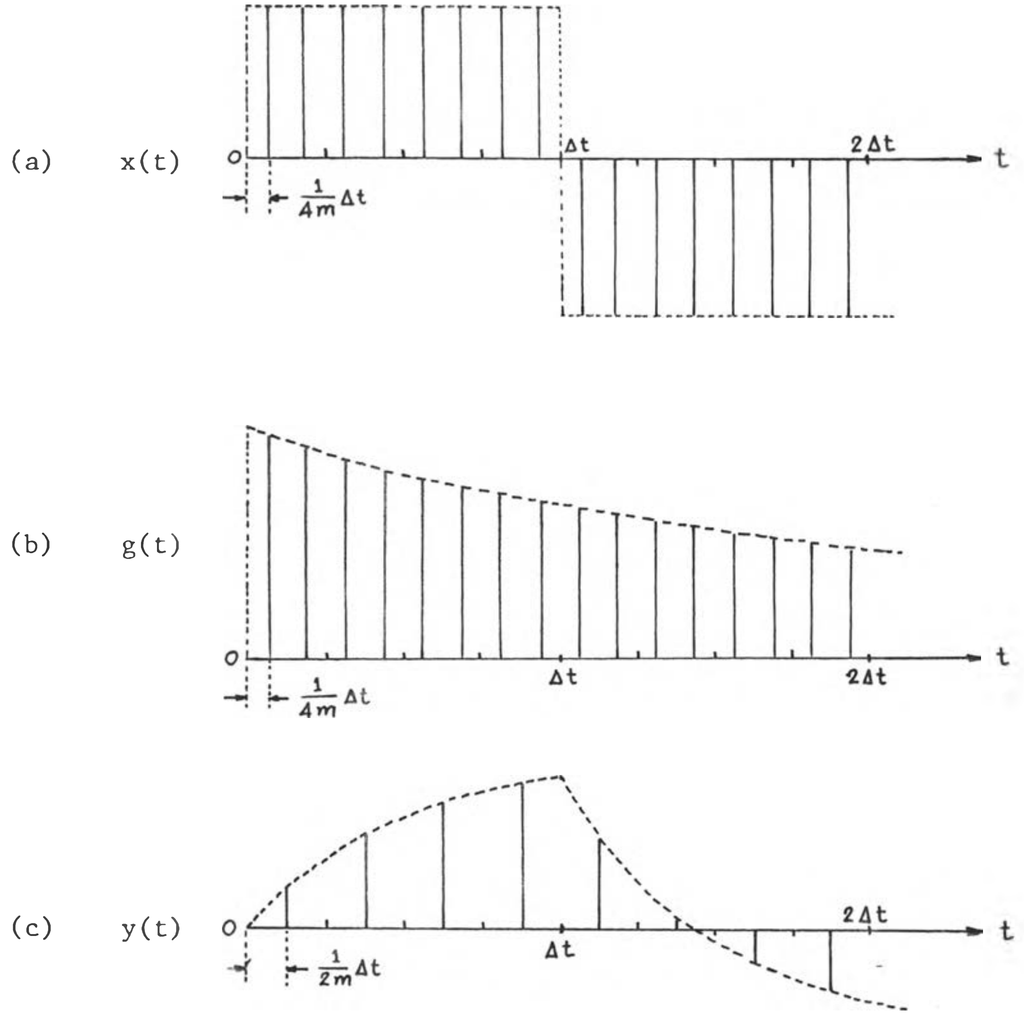

Fig. 8 Sampling points of x(t), g(t) and y(t) used in the subroutine CONV.

The subroutine CONV has been written in basic FORTRAN IV and presented in Appendix E.

4.3 Correlation Operation

The subprogram CORR , presented in Appendix E, is used to evaluate the cross-correlation between the input signal and the output signal by discrete method. The discrete cross-correlation at discrete time $t = i\Delta t+\ell\Delta t/m$ is

$$\emptyset_{xy}(i\Delta t+\frac{\ell}{m}\Delta t) = \frac{1}{N}\sum_{j=0}^{N-\ell} x(j\Delta t+\frac{1}{2m}\Delta t)y(i\Delta t+j\Delta t+\frac{\ell+1/2}{m}\Delta t) \tag{81}$$

Thus, the input signal and the output signal applied to this subprogram must be sampled as shown in Fig. 9a and 9b. The sampled cross-correlation $\emptyset_{xy}(t)$ performed by subroutine CORR is illustrated in Fig. 9c.

4.4 Program CHAINAN1

The digital computer models of the linear systems with the impulse responses $g(t) = e^{-t}$ and $g(t) = e^{-t}-e^{-10t}$ are written up. In this program, the errors due to the autocorrelation function of the b.m.l.s. input signal are considered. The error due to the d.c. offset in the autocorrelation function is reduced by applying the methods explained in Section 3.3. The iteration method in Section 3.4 is applied to remove the error due to the derivative terms of the impulse response. The procedure of the program CHAINAN1 is written step by step as follows:

(a) Read the number of sub-intervals m , timebit interval Δt , the accuracy in estimation the impulse response and the amplitude of the b.m.l.s. input a.

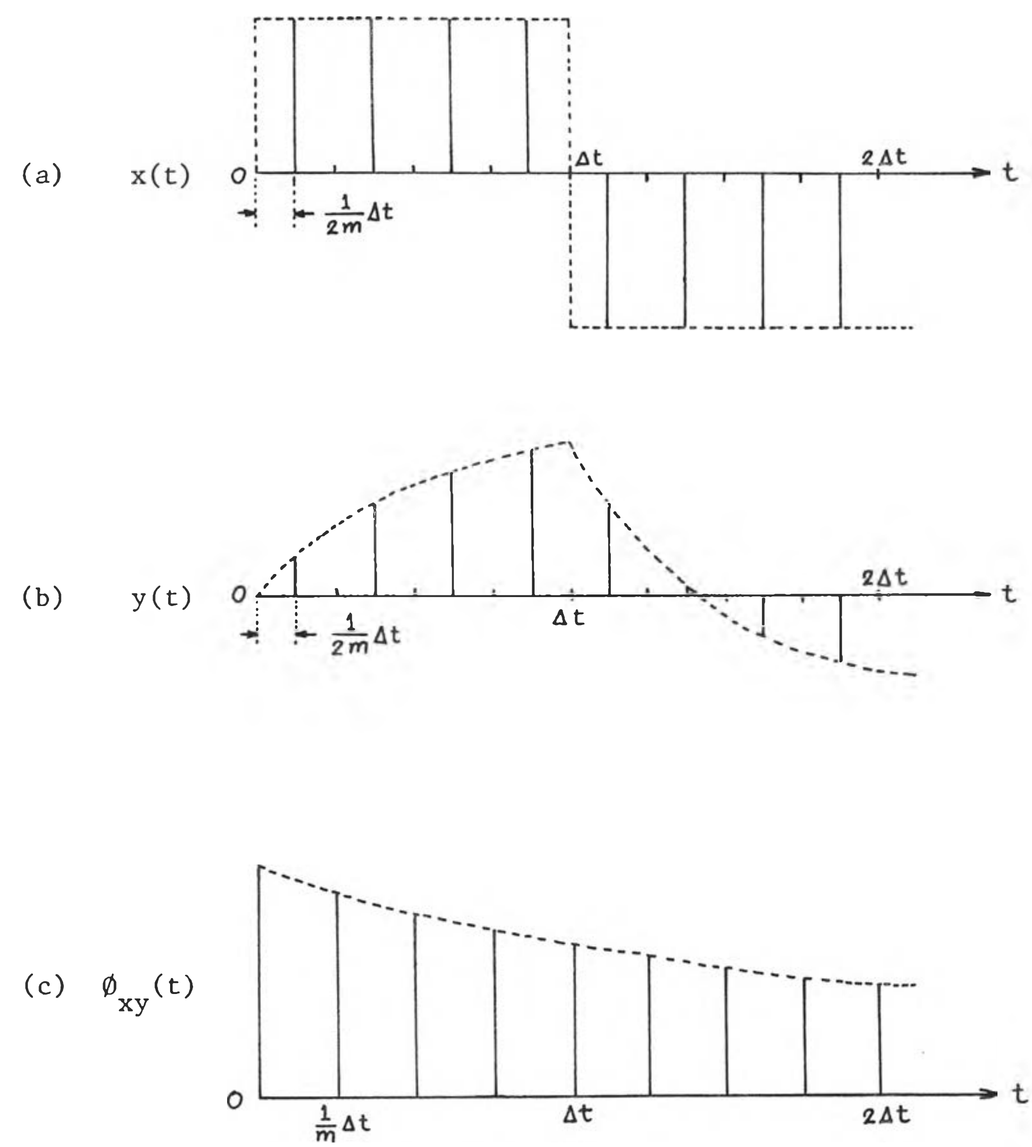

Fig. 9 Sampling points of x(t), y(t) and $\emptyset_{xy}(t)$ used in the subroutine CORR.

(b) Read the b.m.l.s. whose two states are +1 and 0, and multiply the amplitude by a.

(c) Generate the corresponding b.m.l.s. whose two states are +a and -a.

(d) Generate the sequence of the system model impulse response at discrete time as shown in Fig. 8b.

(e) From the subroutine CONV , the steady-state output sequence is determined by applying the b.m.l.s. generated in Step (c) as an input signal to the system model which the impulse response was generated in Step (d).

(f) Use the subroutine CORR to determine the discrete cross-correlation between the steady-state output sequence and the b.m.l.s. whose two states are +a and -a for the method of non-shifting the autocorrelation function and between the steady-state output sequence and the b.m.l.s. whose two states are +a and 0 for the method of shifting the autocorrelation function.

(g) Use the subroutine COREC , written in basic FORTRAN IV and shown in Appendix E, to determine the sequence of the impulse response from the discrete cross-correlation function and remove the error due to the derivative terms of the impulse response by the method explained in Section 3.4.

(h) List the discrete time, the discrete input signal, the discrete output signal, the discrete impulse response of the system model, the estimated discrete impulse response, and the error.

The program CHAINAN1 is written in basic FORTRAN IV and shown in Appendix E. The results of this program are presented in Appendix F.

4.5 Program CHAINAN2

The digital computer models of the linear systems with the impulse responses $g(t) = e^{-t}\sin t$, $g(t) = e^{-t}$, $g(t) = e^{-t}-e^{-10t}$ and $g(t) = e^{-t}\cos 2t$ are written up. In this program, the errors due to the auto-correlation function of the b.m.l.s. input signal, the error due to the polynomial drift in the output signal and the error due to the d.c. bias in the b.m.l.s. input signal are considered. The process which is presented in Section 3.5 is used to reduce these errors.

The procedure of the program CHAINAN2 is described step by step as follows:

(a) Read the number of sub-intervals m , time-bit interval Δt , the accuracy in estimation of the impulse response and the amplitude of the b.m.l.s. input a.

(b) Read the b.m.l.s. whose two states are +1 and 0, and multiply the amplitude by a.

(c) Generate the corresponding b.m.l.s. whose two states are +a and -a and the d.c. bias into it.

(d) Generate the sequence of the system model impulse response at discrete time as shown in Fig. 8b.

(e) Find the steady-state output sequence from the subroutine CONV.

(f) Add the polynomial drift into the output sequence.

(g) Use the subroutine DRIFT , written in basic FORTRAN IV and shown in Appendix E, to find the coefficients of the polynomial drift terms.

(h) Take the polynomial drift terms out of the steady-state output sequence.

(i) Determine the discrete cross-correlation between the steady-state output sequence and the b.m.l.s. input whose two states are +a and -a by using the subroutine CORR.

(j) Use the subroutine CORRECT , written in basic FORTRAN IV and shown in Appendix E, to determine the sequence of the impulse response from the discrete cross-correlation function and remove the error due to the system steady-state gain and the error due to the derivative terms of the impulse response.

(k) List the discrete time, the discrete input signal, the discrete output signal, the discrete impulse response of the system model, the estimated discrete impulse response, and the error.

The program CHAINAN2 is written in basic FORTRAN IV and shown in Appendix E. The results of this program are presented in Appendix G.