2.4 MATLAB Laboratory Experiment on Signals

Purpose: This experiment introduces the graphical representation of common signals used in linear systems. Time shifting, time scaling, signal addition, and signal multiplication will also be demonstrated. It is important to emphasize that signals are mathematical functions—thus, the signal operations given in the following are known from calculus.

Part 1. Use MATLAB to plot the following continuous-time signals in the time interval $t \in [-10 \;\; 10]$.

1. $u(t)$ (unit step signal), $u(t-3)$, $u(t-5)$.

2. $p_6(t)$ (unit rectangular pulse), $p_6(t-3), p_6(t+5)$.

3. $r(t)$ (unit ramp signal), $r(t-3)$, $r(t+5)$

4. $\Delta_4(t)$ (unit triangular pulse), $\Delta_4(t-3)$, $\Delta_4(t+5)$.

Part 2. Plot approximations of the impulse delta signal and the sinc signal.

5. Plot an approximation for $\delta(t)$ (impulse delta signal). *Hint:* $\delta(t)$ can be approximated by a rectangular pulse of width τ and amplitude $1/\tau$ when $\tau \to 0$. Take $\tau = 0.3, 0.2, 0.1$.

6. Use $\mathrm{sinc}(t) = \sin(\pi t)/\pi t$ with `t=-5:0.1:5`; `t=-15:0.1:15`; `t=-30:0.1:30`. The sinc signal can be obtained as $\mathrm{sinc}(t) = \sin(\pi t)./\pi t$. (Note that the operation ./ stands for pointwise division.) MATLAB also has the built-in function `sinc`. To get information about any MATLAB function, type `help function name`; in this case type `help sinc`.

Part 3. In this part, we demonstrate time scaling and time shifting operations. Plot the signals given in the following. Take `t=0:0.1:6.28`.

7. $y_1(t) = \sin(t), y_2(t) = \sin(2t), y_3(t) = \sin(5t)$. Plot all three signals in the same figure. Use `plot(t,y1,'o',t,y2,'- -',t,y3)`.

8. $\sin(4(t-1))$, $\sin(2t-3)$. Explain the figures obtained in (7) and (8).

9. $e^{-at}\sin(at)$ for $a = 0.5, 1, 5$. Use $.*$ as pointwise multiplication. Comment on the effect of time scaling.

Part 4. Some signal operations. Plot the following signals.

10. $u(t) + r(t)$.

11. $p_2(t) + \Delta_3(t)$.

12. $\cos(5t + \sin(2t))$. Expand the time axis such that it includes one signal period.

Part 5. Calculate and plot the following discrete-time signals.

13. $u[k-1]$, $r[k+2]$.

14. $r[-k-1] * u[k-2]$

15. $(-0.5)^k u[k-2] * u[-k+10]$.

Submit a report composed of fifteen figures for fifteen problems and, where required, comment on the results obtained.

MATLAB Solution Program

```
% Experiment 2
%
% COMMENT: DUE TO THE LENGTH OF THE REQUIRED MATALAB PROGRAM, NOT NECESSARY
% ALL PARTS SHOULD BE ASSIGNED AS A LABORATORY EXPERIMENT
clear all
%
% PART 1
%
% 1.   Step signals
% u(t)
t1=-10:0; t2=0:10; t=[t1,t2]; u=[zeros(1,11) ones(1,11)];
% COMMENT: The step function can also be obtained using the MATLAB built in
% function stepfun(t,t0), but see the comment given in Example 2.12 about
% the use of the MATLAB function in the continuous-time domain.
```

```
%
figure (1)
subplot(221); plot(t,u); grid
xlabel('Time'); ylabel('Unit step signal u(t)'); axis([-10 10 -1 2])
% u(t-3)
t1=-10:3; t2=3:10; t=[t1 t2]; u3=[zeros(1,14) ones(1,8)];
subplot(222); plot(t,u3); grid
xlabel('Time [s]'); ylabel('Unit step signal u(t-3)'); axis([-10 10 -1 2])
% u(t-5)
t1=-10:5; t2=5:10; t=[t1 t2]; u5=[zeros(1,16) ones(1,6)];
subplot(223); plot(t,u5); grid
xlabel('Time [s]'); ylabel('Unit step signal u(t-5)'); axis([-10 10 -1 2])
% extra signal u(t+5)
t1=-10:-5; t2=-5:10; t=[t1 t2]; u5left=[zeros(1,6) ones(1,16)];
subplot(224); plot(t,u5left); grid
xlabel('Time [s]'); ylabel('Unit step signal u(t+5)'); axis([-10 10 -1 2])
print -deps figure2_1.eps
%
% 2.  Rectangular signals
% p6(t)
t1=-10:-3; t2=-3:3; t3=3:10; t=[t1 t2 t3];
p6=[zeros(1,8) ones(1,7) zeros(1,8)];
%
figure (2)
subplot(221); plot(t,p6); grid
xlabel('Time'); ylabel('Rectangular pulse p6(t)'); axis([-10 10 -1 2])
% p6(t-3)
t1=-10:0; t2=0:6; t3=6:10; t=[t1 t2 t3];
p6right=[zeros(1,11) ones(1,7) zeros(1,5)];
subplot(222); plot(t,p6right); grid
xlabel('Time'); ylabel('Rectangular puls p6(t-3)'); axis([-10 10 -1 2])
% p6(t+5)
t1=-10:-8; t2=-8:-2; t3=-2:10; t=[t1 t2 t3];
p6left=[zeros(1,3) ones(1,7) zeros(1,13)];
subplot(223); plot(t,p6left); grid
xlabel('Time'); ylabel('Rectangular puls p6(t+5)'); axis([-10 10 -1 2])
print -deps figure2_2.eps
%
% 3.  Ramp signals
% r(t)
t1=-10:-1; t2=0:10; t=[t1 t2]; r=[zeros(1,10) t2];
%
figure (3)
subplot(221); plot(t,r); grid
xlabel('Time'); ylabel('Ramp signal'); axis([-10 10 -2 10])
% r(t-3)
t1=-10:2; t2=3:10; t=[t1 t2]; rright=[zeros(1,13) t2-3];
subplot(222); plot(t,rright); grid
xlabel('Time'); ylabel('Ramp signal r(t-3)'); axis([-10 10 -2 10])
% r(t+5)
t1=-10:-6; t2=-5:10; t=[t1 t2]; rleft=[zeros(1,5) t2+5];
subplot(223); plot(t,rleft); grid
xlabel('Time'); ylabel('Ramp signal r(t+5)'); axis([-10 10 -2 10])
print -deps figure2_3.eps
```

```
%
% 4.   Triangular signals
% tri4(t)
t1=-10:-3; t2=-2:0; t3=0:2; t4=3:10; t=[t1 t2 t3 t4];
tri4=[zeros(1,8) 0.5*t2+1 1-0.5*t3 zeros(1,8)];
%
figure (4)
subplot(221); plot(t,tri4); grid
xlabel('Time'); ylabel('Triangular pulse tri4(t)'); axis([-10 10 -1 2])
% tri4(t-3)
t1=-10:0; t2=1:3; t3=3:5; t4=6:10; t=[t1 t2 t3 t4];
tri4right=[zeros(1,11) 0.5*(t2-1) 0.5*(5-t3) zeros(1,5)];
subplot(222); plot(t,tri4right); grid
xlabel('Time'); ylabel('Triangular pulse tri4(t-3)'); axis([-10 10 -1 2])
% tri4(t+5)
t1=-10:-8; t2=-7:-5; t3=-5:-3; t4=-2:10; t=[t1 t2 t3 t4];
tri4left=[zeros(1,3) 0.5*(t2+7) -0.5*(t3+3) zeros(1,13)];
subplot(223); plot(t,tri4left); grid
xlabel('Time'); ylabel('Triangular pulse tri4(t+5)'); axis([-10 10 -1 2])
print -deps figure2_4.eps
%
% PART 2
%
% 5.  Delta impulse signal approximation by a rectangular pulse
t1=-1:0.05:-0.15; t2=-0.15:0.05:0.15; t3=0.15:0.05:1; ta=[t1 t2 t3];
apprdeltaa=[zeros(1,18) ones(1,7) zeros(1,18)]/0.3;
t1=-1:0.05:-0.1; t2=-0.1:0.05:0.1; t3=0.1:0.05:1; tb=[t1 t2 t3];
apprdeltab=[zeros(1,19) ones(1,5) zeros(1,19)]/0.2;
t1=-1:0.05:-0.05; t2=-0.05:0.05:0.05; t3=0.05:0.05:1; tc=[t1 t2 t3];
apprdeltac=[zeros(1,20) ones(1,3) zeros(1,20)]/0.1;
%
figure (5)
plot(ta,apprdeltaa,tb,apprdeltab,tc,apprdeltac); grid
xlabel('Time'); ylabel('Delta impulse signal approximations');
axis([-1 1 -1 11])
print -deps figure2_5.eps
%
% 6.   Sinc signal
t=-5:0.1:5; sinct=sin(pi*t)./(pi*t);
%
figure (6) subplot(221); plot(t,sinct); grid
xlabel('Time'); ylabel('Sinc signal')
t=-15:0.1:15; sinct=sinc(t);
subplot(222); plot(t,sinct); grid
xlabel('Time'); ylabel('Sinc signal')
t=-30:0.1:30; sinct=sinc(t);
subplot(223); plot(t,sinct); grid
xlabel('Time'); ylabel('Sinc signal')
print -deps figure2_6.eps
%
% PART 3
%
% 7.   Sinusiodal signals and time scaling
t=0:0.05:6.28; y1=sin(t); y2=sin(2*t); y3=sin(5*t);
```

```
%
figure (7)
plot(t,y1,'o',t,y2,'--',t,y3); grid
xlabel('Time'); ylabel('Time scaling for sinusoidal signals');
axis([0 6.28 -1.1 1.1])
print -deps figure2_7.eps
%
% 8.  Sinusoidal signals with time scaling and time shifting
y4=sin(4*t); y4scaledshifted=sin(4*(t-1)); y5=sin(2*t);
y5scaledshifted=sin(2*t-3);
%
figure (8)
subplot(211); plot(t,y4,t,y4scaledshifted,'--'); grid
xlabel('Time'); ylabel('Sinusoidal signal y4'); axis([0 6.28 -1.1 1.1])
subplot(212); plot(t,y5,t,y5scaledshifted,'--'); grid
xlabel('Time'); ylabel('Sinusoidal signal y5'); axis([0 6.28 -1.1 1.1])
print -deps figure2_8.eps
%
% 9.  Damped sinusiodal signals and time scaling
y6=exp(-0.5*t).*sin(0.5*t); y7=exp(-1.5*t).*sin(1.5*t);
%
figure (9)
plot(t,y6,t,y7,'--'); grid
xlabel('Time'); ylabel('Damped sinusoidal signals'); axis([0 6.28 -0.1 0.4])
print -deps figure2_9.eps
%
% PART 4
%
% 10.   Signal addition
% Note that signals to be added must be represented
% by vectors of the same dimensions
t1=-10:0; t2=0:10; t=[t1,t2]; u=[zeros(1,11) ones(1,11)];
t1=-10:0; t2=0:10; t=[t1 t2]; r=[zeros(1,11) t2]; s=u+r;
%
figure (10)
plot(t,u,t,r,'--',t,s,'o'); grid
xlabel('Time'); ylabel('Signal addition');
print -deps figure2_10.eps
%
% 11.   Signal addition
t=-3:0.001:3; p2=stepfun(t,-1)-stepfun(t,1);
tri3=(2/3)*(t+1.5).*stepfun(t,-1.5)-(4/3)*t.*stepfun(t,0)+
...(2/3)*(t-1.5).*stepfun(t,1.5); s=p2+tri3;
% tri3(t)=(2/3)r(t+1.5)-(4/3)r(t)+(2/3)r(t-1.5)
%
figure (11)
plot(t,tri3,t,p2,'--',t,s,'.'); grid
xlabel('Time'); ylabel('Signal addition p2(t)+tri3(t)')
print -deps figure2_11.eps
%
% 12.   Composite signal
t=0:0.01:2*pi; y=cos(5*t+sin(2*t));
%
figure(12)
```

```
plot(t,y); grid
xlabel('Time'); ylabel('Composite signal'); axis([0 2*pi -1.1 1.1])
print -deps figure2_12.eps
%
% PART 5:  DISCRETE-TIME SIGNALS
%
% 13.   Step and ramp signals
k=-10:1:10; du=stepfun(k,1); dr=(k+2).*stepfun(k,-2);
%
figure (13)
plot(k,du,'*',k,dr,'o'); grid
xlabel('Discrete-time'); ylabel('Discrete-time shifted step and ramp signals')
print -deps figure2_13.eps
%
% 14.   Product of discrete-time signals
k0=-1; dy1=(-k-1).*[(-k+k0)>=0]; dy2=stepfun(k,2); dy=dy1.*dy2;
%
figure (14)
plot(k,dy1,'o',k,dy2,'x',k,dy,'*'); grid
xlabel('Discrete time'); ylabel('A product of two signals')
print -deps figure2_14.eps
%
% 15.   Product of discrete-time signals
k=-15:1:15; k0=10; dy1=[(-k+k0)>=0]; dy2=((-0.5).^k).*stepfun(k,2);
dy=dy1.*dy2;
%
figure (15)
plot(k,dy1,'o',k,dy2,'x',k,dy,'*'); grid
xlabel('Discrete time'); ylabel('A product of two signals')
print -deps figure2_15.eps
```

MATLAB Solution Program Generated Figures

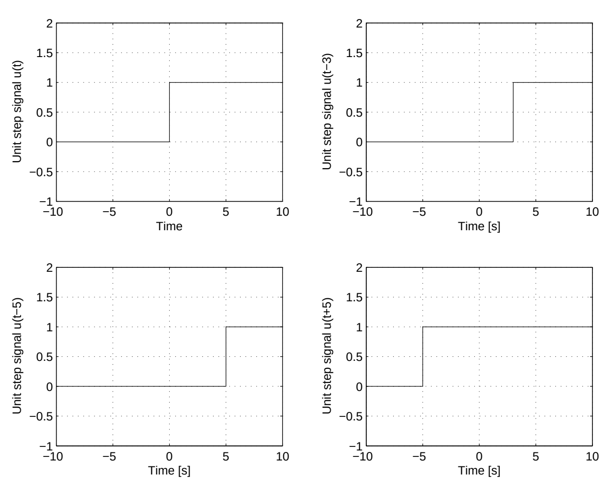

Figure 2.1

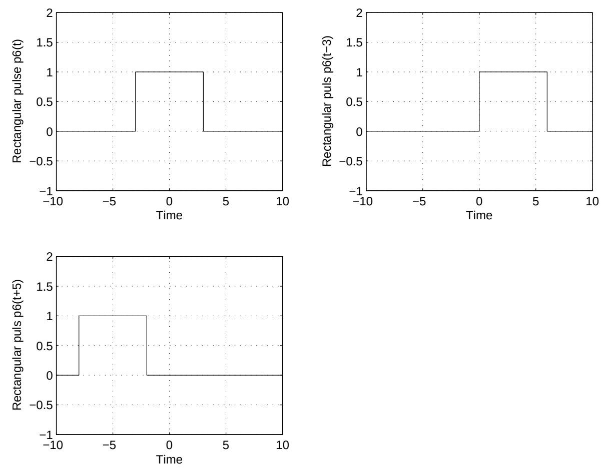

Figure 2.2

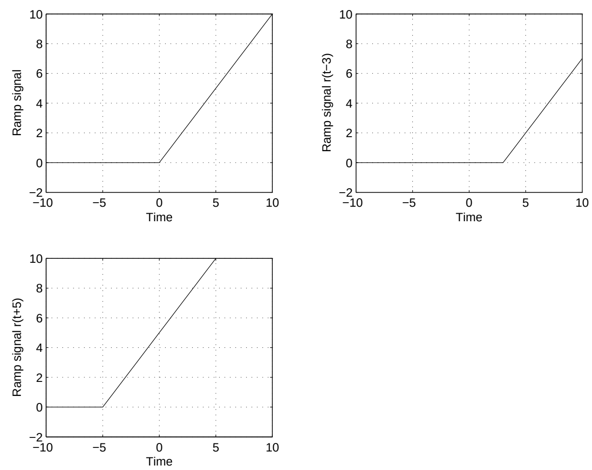

Figure 2.3

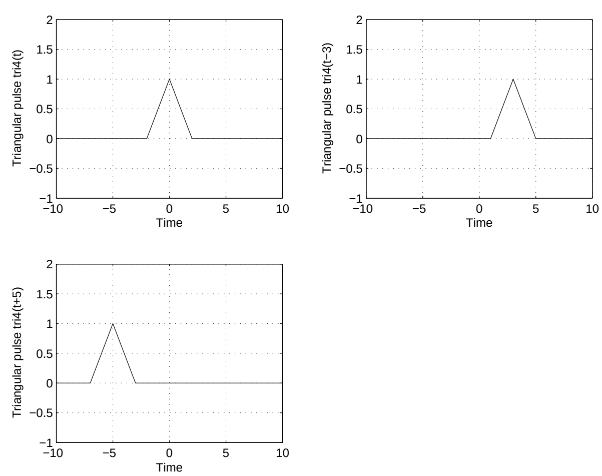

Figure 2.4

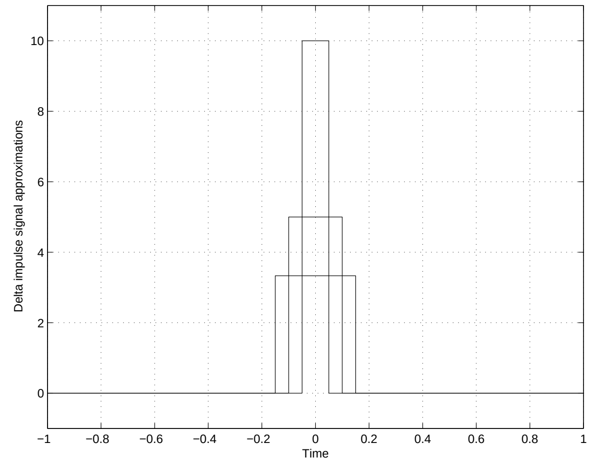

Figure 2.5

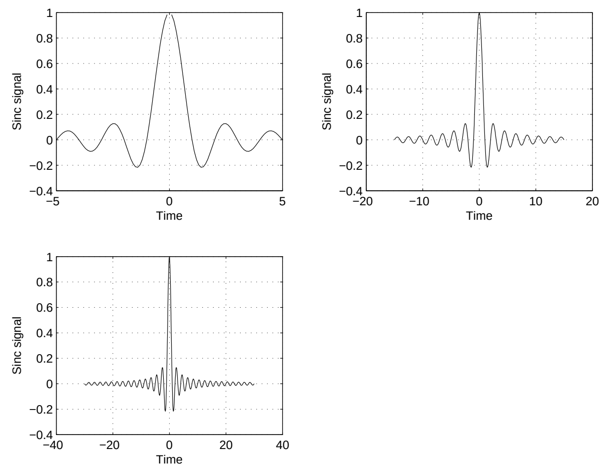

Figure 2.6

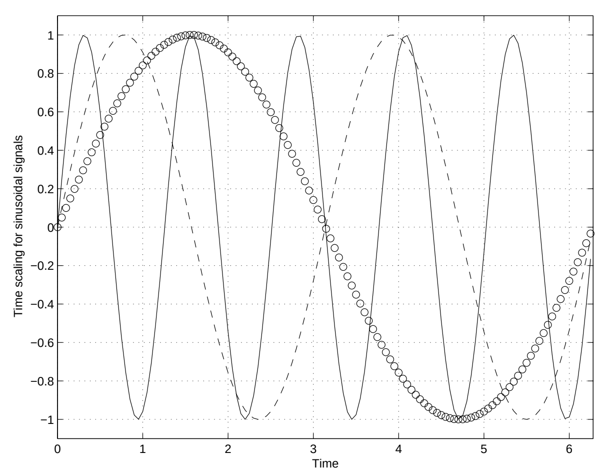

Figure 2.7

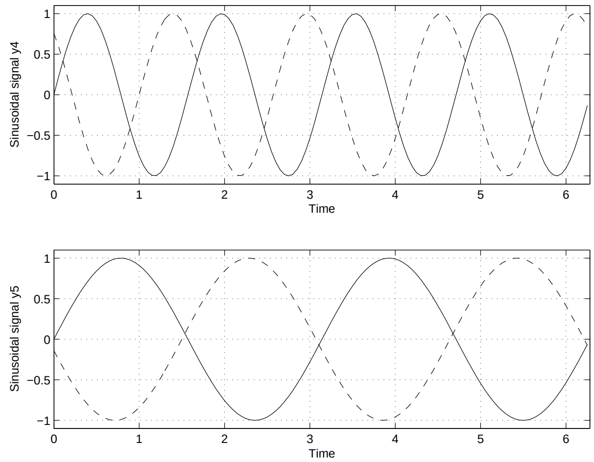

Figure 2.8

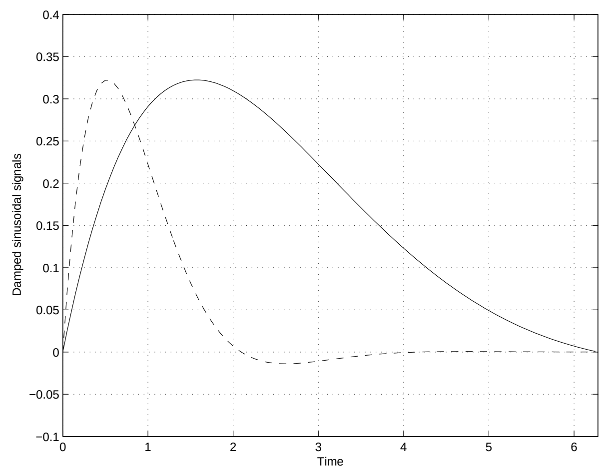

Figure 2.9

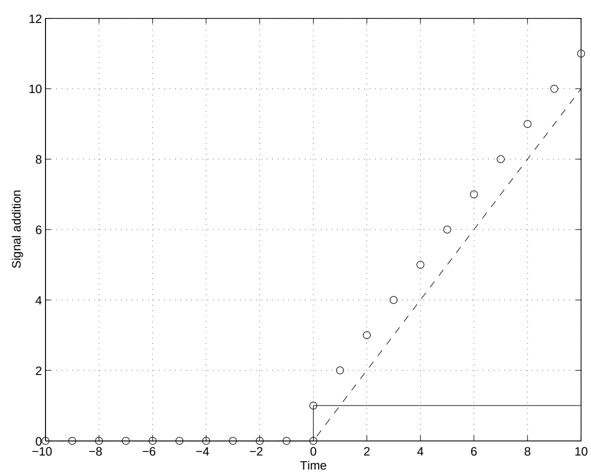

Figure 2.10

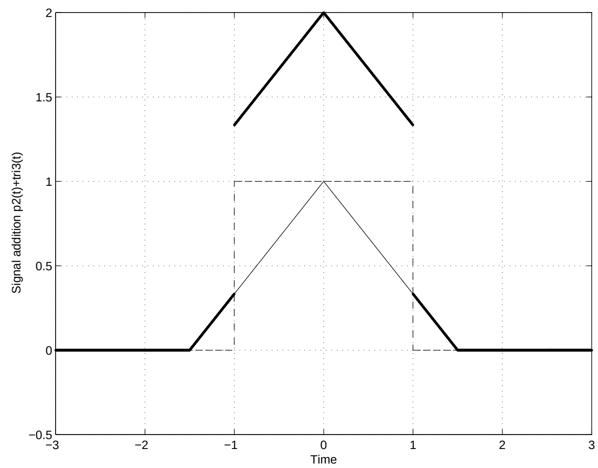

Figure 2.11

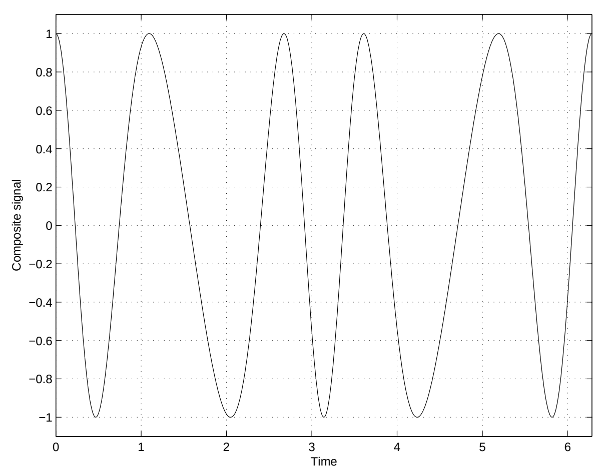

Figure 2.12

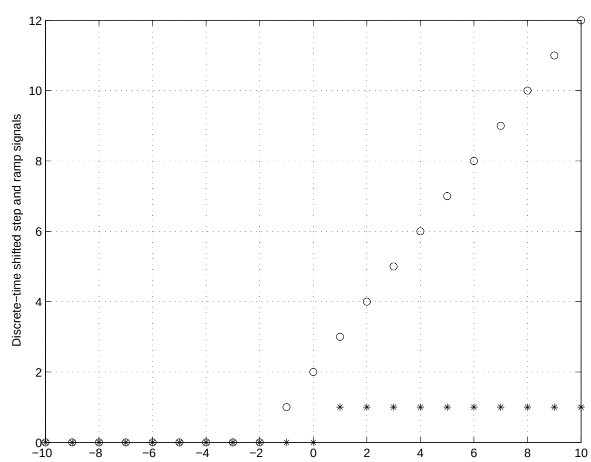

Figure 2.13

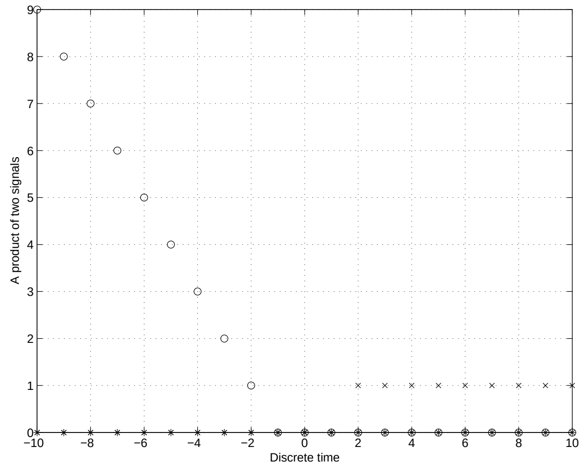

Figure 2.14

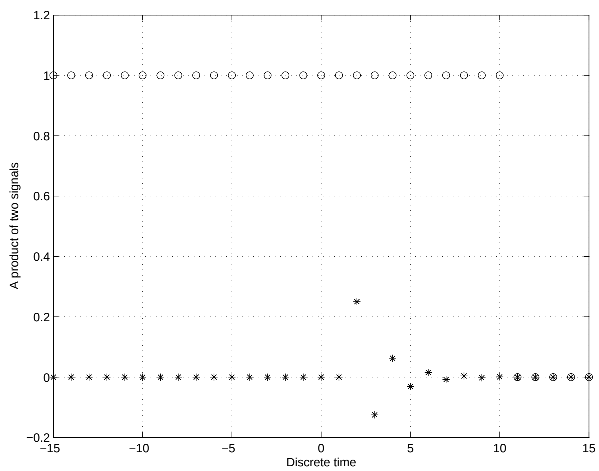

Figure 2.15