

• • , • •

<<

• • •

>>

• •

, • •

681.396

/ . . , . . . - .  
 . - : . . - « . . - »,  
2006. - 65 .

,  
 . -  
 , -  
 . -  
 . -  
 “ -  
 ” “ ” ” -  
 ” ,

.4. .11. .:7 .

: - . . . ,  
 - . , . . .

©

«

. . . .  
», 2006

	.....	5
1.	.....	7
1.1.	.....	7
1.1.1.	.....	8
1.1.2.	.....	9
1.2.	.....	10
1.2.1.	.....	11
1.2.2.	.....	11
1.2.3.	.....	12
1.2.4.	.....	13
1.2.5.	.....	13
1.2.6.	.....	14
1.3.	.....	15
1.3.1.	.....	15
1.3.2.	.....	16
1.3.3.	.....	16
1.3.4.	.....	17
1.3.5.	.....	17
1.3.6. Z-	.....	19
1.4.	.....	21
1.4.1.	.....	21
1.4.2.	.....	25
1.4.3.	.....	27
2.	.....	28
2.1.	.....	28
2.2.	.....	30
2.3.	.....	30
2.4.	.....	31

2.5.	.....	33
2.6.	.....	35
2.7.	.....	40
2.8.	.....	40
2.9.	.....	41
2.10.	.....	42
2.11.	.....	43
2.12.	.....	44
3.	.....	45
3.1.	.....	45
3.2.	( . 3.7).....	47
3.3.	( . 3.8).....	48
3.4.	.....	48
4.	.....	49
1.	.....	49
2.	.....	52
3.	.....	55
4.	.....	58
5.	.....	-
	.....	61
	.....	64



— —

.

.

:

,

,

( ),

,

,

,

:

,

,

:

( );

( ) ( ) ;

( ) ;

;

;

.

—

« » :

,

,

,

—

.





1.1.1.

,

. 1.1.

1.1

	-
	( - )
	-
	-
	-
	( )
	-
	-

,

.

- ,

-

.

- ,

.

- ,

$$x(t+T) = x(t)$$

$T$  - .

- ,

( -

) .

- ,

( -

) .

$$\int_{-\infty}^{\infty} (x(t))^2 dt < \infty,$$

$$t > t_0.$$

### 1.1.2.

. 1.2.

1.2

	( )	
-	$x(t) = 1(t) = \begin{cases} 0, & t < 0 \\ 0.5, & t = 0 \\ 1, & t > 0 \end{cases}$	>> y = (t > 0);
	$\delta(t) = \begin{cases} = 0, & t \neq 0 \\ \neq 0, & t = 0 \end{cases}$ $\int_{-\infty}^{\infty} f(\tau) \delta(\tau - t) dt = f(t)$	-
-	$\delta(k-l) = \begin{cases} = 1, & k = l \\ = 0, & k \neq l \end{cases}$	-
	$x(t) = A \cos(\omega t)$ $x(t) = A \cos(\omega t + \varphi)$	>> t = 0:0.1*pi:4*pi; y = sin(t); >> Tk=2*pi; = 2*pi; Ts = 0.1*2*pi; >> [y,t] = gensig('sin',T,Tk,Ts);
c -	$x(t) = A \sin((\omega_0 + \Delta\omega)t)$	>>t = 0:0.01:10; >>y = chirp(t,1,10,5);

	( )	
- - -	$x(t) = A \text{sign}(\sin(\omega t))$ $x(t) = A \text{sign}(\sin(\omega t + \varphi))$	>> [y,t] = gensig('square', 2*pi);
( )	$x(t) = \frac{2A}{T_s}(1 - kT_s)$ $(k - \frac{1}{2})T_s < t < (k + \frac{1}{2})T_s$	>>t = 0:0.1*pi:5*pi; >>y = sawtooth(t);
- -	$x(t) = A \left(1 - 4 \frac{ t - kT_s }{T_s}\right)$ $(k - \frac{1}{2})T_s < t < (k + \frac{1}{2})T_s$	-
- -	$x(t) = \begin{cases} A, & kT - \frac{1}{2}T_s < t < kT + \frac{1}{2}T_s \\ 0, & \text{else} \end{cases}$	>> [y,t] = gensig('pulse',2,10,0.1);
.	$x(t) = \sin(Nx0.5) / Nx0.5$ $x(t) = \sin c(t) = \sin(\pi x) / \pi x$	>> x = 0:0.01:1;y = diric(x,50); >>x = 0:0.01:10;y = sinc(x);
« »	$0 < x(t) < 1$	>>y = rand(1,100); plot(1:100,y)
« »	$M[x(t)] = 0, \quad M[(x(t))^2] = 1$	>>y = randn(1,100); plot(1:100,y)

1.2.

### 1.2.1.

1.  $|x(t)| < \infty$

2. ( )

3.

$[t_1; t_2]$

$|x(t_1) - x(t_2)| < c|t_1 - t_2|$  c.

### 1.2.2.

« » 1664 .

( ).

:

$$x(t) = \frac{a_0}{2} + \sum_{k=1}^{\infty} a_k \cos(k\omega_1 t) + b_k \sin(k\omega_1 t); \quad \omega_1 = \frac{2\pi}{T};$$

$$a_0 = \frac{2}{T} \int_0^T x(t) dt; \quad a_k = \frac{2}{T} \int_0^T x(t) \cos(k\omega_1 t) dt; \quad b_k = \frac{2}{T} \int_0^T x(t) \sin(k\omega_1 t) dt.$$

:

$$x(t) = \frac{1}{2} \sum_{k=-\infty}^{\infty} \bar{A}_k e^{jk\omega_1 t}, \quad \bar{A}_k = \frac{2}{T} \int_0^T x(t) e^{-jk\omega_1 t} dt .$$

1.2.3.

. 1.3.

1.3

( k- )	$\bar{A}_k = a_k - jb_k = \frac{2}{T} \int_0^T x(t) \exp(-jk\omega_1 t) dt$
	$ \bar{A}_k  = \sqrt{a_k^2 + b_k^2}, k = 1, 2, \dots$
	$\varphi_k = \text{arctg}(b_k / a_k), k = 1, 2, 3, \dots$
	$\bar{A}(\omega) = \frac{2}{T} \int_0^T x(t) \exp(-j\omega t) dt = A(\omega) \exp(-j\varphi(\omega))$
	$\varphi(\omega), \omega \in [0; \infty]$
	$\omega \in [\omega_0; \omega_1], A(\omega) > A$

1.

$$\omega_1 = 2\pi/T$$

2.

$$\omega_1 = 2\pi/T.$$

3.

$$\omega = 0.$$

4.

$$b_k = 0, k = 1, 2, \dots,$$

$$a_k = 0, k = 1, 2, \dots$$

5.

$$P_{cp} = \frac{1}{T} \int_0^T |x(t)|^2 dt = \frac{A_0}{2} + \frac{1}{2} \sum_{n=1}^{\infty} A_n^2.$$

6. 
$$\frac{1}{T} \int_0^T |x(t)|^2 dt < \frac{A_o}{2}^2 + \frac{1}{2} \sum_{n=1}^M A_n^2, M < \infty.$$

1.2.4.

$$X(j\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t} dt, \quad x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(j\omega)e^{j\omega t} d\omega.$$

. 1.4.

1.4

	$X(j\omega) = \int_{-\infty}^{\infty} x(t) \exp(-j\omega t) dt$
	$S(\omega) =  X(j\omega) ^2 = X(j\omega)X^*(j\omega)$
	$A(\omega) =  X(j\omega)  =  U(\omega) + jV(\omega)  = (X(j\omega)X^*(j\omega))^{1/2}$
	$\varphi(\omega) = \arg(X(j\omega)) = \arctg\left(\frac{V(\omega)}{U(\omega)}\right)$
	$\omega \in [\omega_0; \omega_1], \quad A(\omega) > A$

1.2.5.

:

1. 
$$F\{x_1(t) + x_2(t) + x_3(t) + \dots + x_m(t)\} = X_1(j\omega) + X_2(j\omega) + X_3(j\omega) + \dots + X_m(j\omega),$$

$$F\{\alpha x(t)\} = \alpha F\{x(t)\} = \alpha X(j\omega).$$

2. 
$$F\{x(t - t_0)\} = X(j\omega)e^{-j\omega t_0}.$$

3. 
$$F^{-1}\{X(j(\omega - \omega_0))\} = x(t)e^{j\omega_0 t}.$$

4. 
$$F\{x(\alpha t)\} = \frac{1}{\alpha} X\left(\frac{j\omega}{\alpha}\right).$$

5. 
$$F\{\dot{x}(t)\} = j\omega X(j\omega).$$

6.  $x_1(t) = \int_{-\infty}^t x(\tau) d\tau$  ,  $F\{x_1(t)\} = \frac{1}{j\omega} X(j\omega)$ .

7.  $x(t) * h(t) \leftrightarrow X(j\omega)H(j\omega)$ .

8.  $\int_{-\infty}^{\infty} |x(t)|^2 dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} |X(j\omega)|^2 d\omega$ .

9.  $x(-t) = X(-j\omega) = X^*(j\omega)$ .

10.  $x(t) \leftrightarrow X(j\omega)$ ,  $X(t) \leftrightarrow x(-j\omega)$ .

11.

$$F\{x(t) \cos(\omega_0 t)\} \Leftrightarrow \frac{1}{2} X(-j(\omega - \omega_0)) + \frac{1}{2} X(-j(\omega + \omega_0)).$$

:

1.  $A(-\omega) = A(\omega)$  - ,

$\varphi(-\omega) = -\varphi(\omega)$  - .

2.  $x(t)$  - ,

-

3.  $x(t)$  - ,

-

4.  $E = \frac{1}{2\pi} \int_{-\infty}^{\infty} |X(j\omega)|^2 d\omega = \int_{-\infty}^{\infty} |x(t)|^2 dt$ .

**1.2.6.**

. 1.5.

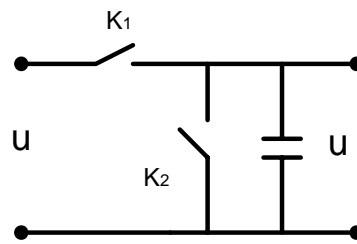
1.5

	$P(t) = x^2(t)$
	$E = \int_0^T x^2(t) dt$
$E < \infty$	$P = \frac{1}{T_0} \int_{t_0}^{t_0+T_0}  x(t) ^2 dt$
$E = \infty$	$P_0 = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T x^2(t) dt$

### 1.3.

#### 1.3.1.

( .1.1).

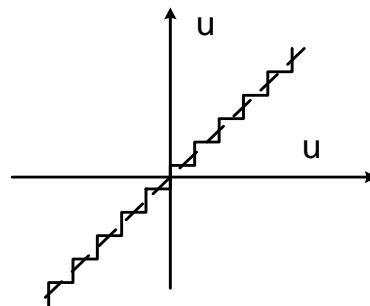


. 1.1

1

(  $T_s$  )

2



. 1.2

( . 1.2).

$$u(t) = u(t) + \Delta u(t), \quad \Delta u(t) - , n = 2^n - 1 -$$

$$( ) q = \frac{2U_{\max}}{2^n} .$$

$$\sigma^2 = \frac{q^2}{12} .$$



### 1.3.2.

, , .  
( ) -

$$x^*(t) = x(t) \delta_T(t) = x(t) \sum_{k=1}^{\infty} \delta(t - kT_s) = \sum_{k=1}^{\infty} x(kT_s) \delta(t - kT_s).$$

( ),

$$x_T(t) = x(0)1(t) - x(0)1(t - T_s), \quad 1(t) -$$

$$L\{x_T(t)\} = \frac{1 - e^{-T_s s}}{s} x(0),$$

$$\frac{L\{x_T(t)\}}{L\{x(0)\delta(t)\}} = \frac{1 - e^{-T_s s}}{s} = W(s).$$

### 1.3.3.

$$X^*(j\omega) = \frac{1}{T_s} \sum_{k=-\infty}^{\infty} X(j(\omega + \frac{2\pi k}{T_s})),$$

:

1. - -

$$2\pi T_s^{-1}.$$

2. -  $2\pi T_s^{-1}$ .

3. - - : -

- , -

4.

1.3.4.

...

$$\left( \begin{array}{c} \omega_c \\ \dots \end{array} \right) \quad T_c = 1/2\omega_c.$$

1.

$\text{sinc}(x)$

:

$$x(t) = \sum x(-kT) \frac{\text{sinc}(\omega t + k\pi)}{\omega_c t + k\pi}.$$

2.

$2\omega_c,$

$$T_s = \frac{2\pi}{2\omega_c} = \frac{1}{2f_c}$$

$$[0; t_k] \quad N = \frac{t_k}{T_s} = 2f_c t_k.$$

3.

$T_s$

$$\omega_c = \frac{2\pi}{T_s}.$$

1.3.5.

$$X(k) = \sum_{n=0}^{N-1} x(n) W_N^{-nk}, \quad k = \overline{0, N-1}, \quad x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k) W_N^{nk}, \quad n = \overline{0, N-1},$$

$$W_N = e^{-j\frac{2\pi}{N}}, \quad W_N^{nk} = e^{-j\frac{2\pi nk}{N}}, \quad W_N^N = 1, \quad W_N^{kN+i} = W_N^i,$$

( ).

:

1.

( )

2. « » ( -  
 « »  
 ).

3. .

1. - .

2.  $X(k)$  .

3. ,  
 $N/2$ .

4.  $2^k$ , -

:

- ,

;

- « »,

« » ( -

« »);

- ,

« ».

,

. 1.6.

1.6

- -	
- « - »	« » « » « » ,
- « - »	. - -

1.3.6. Z-

Z-

$$x^*(t) = \sum_{n=0}^{\infty} x(nT_s) \delta(t - nT_s),$$

$$X(s) = \int_0^{\infty} \sum_{n=0}^{\infty} x(nT_s) \delta(t - nT_s) e^{-st} dt = \sum_{n=0}^{\infty} x(nT_s) \int_0^{\infty} \delta(t - nT_s) e^{-st} dt = \sum_{n=0}^{\infty} x(nT_s) e^{-snT_s}.$$

$$z = e^{sT_s}, \quad Z-$$

$$X(z) = \sum_{n=0}^{\infty} x(nT_s) z^{-n} \quad Z\{x(nT_s)\} = X(z).$$

Z-

. 1.7.

1.7

	$Z\{x_1(nT_s) + x_2(nT_s)\} = X_1(z) + X_2(z)$
	$a^n x(nT_s) \xleftarrow{Z} X(a^{-1}z)$
	$x(nT_s - mT_s) \xleftarrow{Z} z^{-m} X(z)$
$z$	$x(nT_s) \xleftarrow{Z} X(z) = q_0 + q_1 z^{-1} + q_2 z^{-2} + \dots$ $q_n = x(nT_s)$
	$x(0) = \lim_{z \rightarrow \infty} X(z), \quad x(\infty) = \lim_{z \rightarrow 1} (1 - z^{-1}) X(z)$

Z-

:

1.

$$x^*(t).$$

2.

$$x^*(t).$$

3.

$$X(z) = \frac{b_m z^m + b_{m-1} z^{m-1} + \dots + b_0}{a_n z^n + a_{n-1} z^{n-1} + \dots + a_0}.$$

Z-

$$x(kT_s) = \frac{1}{2\pi j} \int_{\sigma-j\infty}^{\sigma+j\infty} X^*(s) e^{skT_s} ds.$$

1.

Z-

$$X(z) = \frac{a(z)}{b(z)} = q_0 + q_1 z^{-1} + q_2 z^{-2} + \dots, \quad q_0 = x(0), \quad q_1 = x(T_s), \quad q_2 = x(2T_s), \dots$$

2.

$$X(z) = \frac{A}{1 - \alpha z^{-1}} + \frac{B \alpha z^{-1} \sin(T_s)}{1 - 2\alpha z^{-1} \cos(T_s) + \alpha^2 z^{-2}} + \frac{C \alpha z^{-1}}{(1 - \alpha z^{-1})^2} \dots,$$

$$x(t) = 1(kT_s) + \cos(kT_s) + k\alpha^k.$$

3.

$$x(n\Delta t) = \frac{1}{2\pi j} \oint_C X(z) z^{n-1} dz,$$

$$\frac{1}{2\pi j} \oint_C X(z) z^{n-1} dz = \sum \operatorname{Res} s X(z) z^{n-1}$$

$X(z),$

$z = a$

$$\text{Res}_a X(z) = \frac{1}{(k-1)!} \lim_{z \rightarrow a} \frac{d^{k-1}}{dz^{k-1}} [(z-a)^k X(z)].$$

Z-

. 1.8.

1.8

$x(t)$	Z -	$X(z)$
$1(kT_s)$		$\frac{1}{1-z^{-1}}$
$kT_s$		$\frac{z^{-1}}{(1-z^{-1})^2}$
$\alpha^k$		$\frac{1}{1-\alpha z^{-1}}$
$k\alpha^k$		$\frac{\alpha z^{-1}}{(1-\alpha z^{-1})^2}$
$\sin(kT_s)$		$\frac{z^{-1} \sin(T_s)}{1-2z^{-1} \cos(T_s) + z^{-2}}$
$\alpha^k \cos(kT_s)$		$\frac{\alpha z^{-1} \sin(T_s)}{1-2\alpha z^{-1} \cos(T_s) + \alpha^2 z^{-2}}$

## 1.4.

### 1.4.1.

$p(x(t_1), x(t_2), \dots, x(t_n)).$

$$p(x(t_1+t), x(t_2+t), \dots, x(t_n+t)) = p(x(t_1), x(t_2), \dots, x(t_n))$$

$t,$

. 1.9.

1.9

	$F_X(x) = \{ P_{x_1}, P_{x_2}, P_{x_3}, \dots, P_{x_N} \}$ $P_{x_N} = P(X = x_N)$	$F(x_i) \geq F(x_{i-1})$ $0 \leq F(x_i) \leq 1$
	$\bar{x} = M[x] = \sum_{i=1}^N x_i P_{x_i}$	$\bar{x} = M[ax] = aM[x]$ $a -$
	$\sigma^2 = M[(x - \bar{x})^2] = \sum_{i=1}^N (x_i - \bar{x})^2 P_{x_i}$	$\sigma^2 \geq 0, \sigma = \sqrt{\sigma^2} -$
k-	$M[(x)^k] = \sum_{i=1}^N (x_i)^k P_{x_i}$	-
k-	$M[(x - \bar{x})^k] = \sum_{i=1}^N (x_i - \bar{x})^k P_{x_i}$	-

. 1.10.

1.10

	$F_X(x) = \{ P(X < x), -\infty < X < \infty \}$	$F(\infty) = 1, F(-\infty) = 0$ $0 \leq F(\infty) \leq 1$
( - )	$p_X(x) = dF(x)/dx$	$p_X(x) \geq 0, \int_{-\infty}^{\infty} p_X(x) dx = 1$ $F_X(x_1 < x < x_2) = \int_{x_1}^{x_2} p_X(x) dx$
		$F_X(X = x) = p_X(x) dx$ $y = f(x), p_Y(y) = p_X(f^{-1}(y))$
-	$M[x] = \int_{-\infty}^{\infty} xp_X(x) dx$	$M[x_1 + x_2] = M[x_1] + M[x_2]$

. 1.10

$\sigma^2$	$M[(x-\bar{x})^2] = \int_{-\infty}^{\infty} (x-\bar{x})^2 p_X(x) dx$	$\sigma^2 \geq 0, \sigma = \sqrt{\sigma^2}$
k-	$M[(x)^k] = \int_{-\infty}^{\infty} (x)^k p_X(x) dx$	-
k-	$M[(x-\bar{x})^k] = \int_{-\infty}^{\infty} (x-\bar{x})^k p_X(x) dx$	$x -$ - $M[(x)^k] = 0$ - $k \geq 3, 5, 7, \dots$ -

. 1.11.

1.11

-		
	$p_X(x) = \begin{cases} \frac{1}{b-a}, & x \in [a, b] \\ 0, & x \notin [a, b] \end{cases}$	$M[x] = \frac{b-a}{2},$ $\sigma^2 = \frac{(b-a)^2}{12}$
	$p_X(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp -\frac{(x-\bar{x})^2}{2\sigma^2}$	$M[x] = \bar{x}, \sigma^2 = \sigma^2$ $M(x-\bar{x})^k = \begin{cases} 1 \cdot 3 \dots (k-1) \sigma^k, & k=2, 4 \\ 0, & k=1, 3, 5 \end{cases}$
	$y = \sqrt{\sum_{i=1}^N x_i^2}, p_Y(y) = \frac{y}{\sigma^2} e^{-\frac{y^2}{2\sigma^2}}$	$M[y] = \sqrt{2\sigma^2} (1 + \frac{1}{2} k)$ $\sigma_y^2 = 2 - \frac{1}{2} \pi \sigma^2$
	$p_X(x) = \frac{1}{\sqrt{2\pi \det(Q_x)}} e^{-\frac{1}{2}(x-\bar{x})^T Q_x^{-1}(x-\bar{x})}$	$M[(x-\bar{x})(x-\bar{x})^T] = Q_x$ $M[x] = \bar{x}$

.1.12.



-	$P(X < x, Y < y)$ $F_{XY}(x, y) = \begin{matrix} -\infty < X < \infty \\ -\infty < Y < \infty \end{matrix}$	$F(\infty, \infty) = 1, F(-\infty, -\infty) = 0$ $0 \leq F(\infty, \infty) \leq 1$
( - )	$p_{XY}(x, y) = d^2 F(x, y) / dx dy$	$p_{XY}(x, y) \geq 0$ $\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} p_{XY}(x, y) dx dy = 1$ $\int_{-\infty}^{\infty} \int_{-\infty}^{\infty} p_{XY}(x, y) dx dy = 1$ $p_{XY}(x, y) = p_X(x)p_Y(y)$
( - )	$p(x/y) = p(x, y) / p_Y(y)$ $p(y/x) = p(x, y) / p_X(x)$ $p(x, y) = p(x/y)p_Y(y) = p(y/x)p_X(x)$	$\int_{-\infty}^{\infty} p_{XY}(x, y) dx = p_Y(y)$ $\int_{-\infty}^{\infty} p_{XY}(x, y) dy = p_X(x)$
-	$M[x] = \int_{-\infty}^{\infty} xp(x/y) dx$	$M[x_1 + x_2] = M[x_1] + M[x_2]$
-	$M[(x)^k (y)^m] =$ $= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x)^k (y)^m p_{XY}(x, y) dx dy$	-
-	$M[(x - \bar{x})^k (y - \bar{y})^m] =$ $= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x - \bar{x})^k (y - \bar{y})^m p_{XY}(x, y) dx dy$	-
	$M[xy] = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} xyp_{XY}(x, y) dx dy$	$M[xy] = 0$
	$M[(x - \bar{x})(y - \bar{y})] =$ $= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x - \bar{x})(y - \bar{y})p_{XY}(x, y) dx dy$	$M[(x - \bar{x})(y - \bar{y})] =$ $= M[(x - \bar{x})]M[(y - \bar{y})]$
	$r_{XY} = \frac{M[(x - \bar{x})(y - \bar{y})]}{\sqrt{M[(x - \bar{x})^2]M[(y - \bar{y})^2]}}$	$-1 \leq r_{XY} \leq 1$ $r_{XY} = 0$

1.4.2.

. 1.13.

1.13

-	$M[x(t)] = \int_{-\infty}^{\infty} xp_X(x, t) dx$	$M[x(t_1) + x(t_2)] = M[x(t_1)] + M[x(t_2)]$
k-	$M(x(t))^k = \int_{-\infty}^{\infty} (x(t))^k p(x, t) dx$	
-	$M[x(t_1)x(t_2)] = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x_1x_2 p(x_1, t_1; x_2, t_2) dx_1 dx_2$	
-	$M(x(t_1) - \bar{x}(t_1))(x(t_2) - \bar{x}(t_2)) = K_{xx}(t_1, t_2)$	$K_{xx}(t_1, t_2) = K_{xx}(t_1 - t_2)$ $K_{xx}(0) = M[(x(t))^2] = \sigma_t^2$ $K_{xx}(\tau) = K_{xx}(-\tau)$ $K_{xx}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t)x(t+\tau) dt$
-	$M(x(t_1) - \bar{x}(t_1))(y(t_2) - \bar{y}(t_2)) =$ $= \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x_1 - \bar{x}_1)(y_2 - \bar{y}_2) p_{XY}(x_1, t_1; y_2, t_2) dx_1 dy_2 =$ $= K_{XY}(t_1, t_2)$	$K_{XY}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t)y(t+\tau) dt$
	$r_{XY}(t_1, t_2) = \frac{K_{XY}(t_1, t_2)}{\sqrt{K_{XX}(t_1, t_1)K_{YY}(t_2, t_2)}}$ $r_{XX}(t_1, t_2) = \frac{K_{XX}(t_1, t_2)}{\sqrt{K_{XX}(t_1, t_1)K_{XX}(t_2, t_2)}}$	$-1 \leq r_{XY}(t_1, t_2) \leq 1$ $r_{XY}(t_1, t_2) = r_{XY}(t_2, t_1)$
	$\bar{x}_t = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t) dt$	$\bar{x}_t = M[x(t)]$
-	$\overline{x_t^2} = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x^2(t) dt$	$\overline{x_t^2} = M[x^2(t)]$

-		
-	$S_x(j\omega) = \int_{-\infty}^{\infty} K_{xx}(\tau) e^{-j\omega\tau} d\tau =$ $= 2 \int_0^{\infty} K_{xx}(\tau) \cos(\omega\tau) d\tau$	$K_{xx}(\tau) = \int_{-\infty}^{\infty} S_x(j\omega) e^{j\omega\tau} d\omega =$ $= 2 \int_0^{\infty} S_x(\omega) \cos(\omega\tau) d\omega$ $\sigma^2 = K_{xx}(0) = \frac{1}{2\pi} \int_{-\infty}^{\infty} S_{K_{xx}}(j\omega) d\omega$ $S_{K_{xx}}(\omega) -$
«	»	»
	$K_{xx}(\tau) = \frac{N_x}{2} \delta(\tau)$	$S_{K_{xx}}(\omega) = N_x$

.1.14.

1.14

(	$\bar{x}_t = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t) dt$	$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$
)	$\overline{x_t^2} = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T (x(t) - \bar{x}_t)^2 dt$	$\sigma_x^2 = \frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2$
-	$\overline{x(t)x(t+\tau)} =$ $= \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t)x(t+\tau) dt$	$K_{xx}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n-1} (x_i - \bar{x})(x_{i+n} - \bar{x})$
-	$\overline{x(t)y(t+\tau)} =$ $= \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T x(t)y(t+\tau) dt$	$K_{xy}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n-1} (x_i - \bar{x})(y_{i+n} - \bar{y})$

1.4.3.

. 1.15.

1.15

( - )	$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$	>> x=[1 3 5 7 9]; >> mean(x) >> x=[1 3 5 7 9;0 0 1 1 1]; >>mean(x)
	$\sigma_x^2 = \frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2$	>> x=[1 3 5 8 9];std(x)^2 >> x=[1 3 5 8 9;0 0 1 1 1]; >> std(x)^2
-	$K_{xx}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n-1} (x_i - \bar{x})(x_{i+n} - \bar{x})$	>> x=[1 3 5 8 9]; >> xcov(x)
- -	$K_{xy}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n-1} (x_i - \bar{x})(y_{i+n} - \bar{y})$	>> x=[1 3 5 8 9]; >> y=[0 0 0 0 1]; >> xcov(x,y)
	$r_{xy} = \frac{K_{xy}(0)}{\sigma_x \sigma_y}$	>> corrcoef(x,y)

1.4.3.

. 1.15.

1.15

( - )	$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i$	>> x=[1 3 5 7 9]; >> mean(x) >> x=[1 3 5 7 9;0 0 1 1 1]; >>mean(x)
	$\sigma_x^2 = \frac{1}{N-1} \sum_{i=1}^N (x_i - \bar{x})^2$	>> x=[1 3 5 8 9];std(x)^2 >> x=[1 3 5 8 9;0 0 1 1 1]; >> std(x)^2
-	$K_{xx}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n-1} (x_i - \bar{x})(x_{i+n} - \bar{x})$	>> x=[1 3 5 8 9]; >> xcov(x)
- -	$K_{xy}[n] = \frac{1}{N-n} \sum_{i=1}^{N-n-1} (x_i - \bar{x})(y_{i+n} - \bar{y})$	>> x=[1 3 5 8 9]; >> y=[0 0 0 0 1]; >> xcov(x,y)
	$r_{xy} = \frac{K_{xy}(0)}{\sigma_x \sigma_y}$	>> corrcoef(x,y)



$$\frac{Y(s)}{U(s)} = \frac{\sum_{l=0}^n b_l s^l}{\sum_{k=0}^n a_k s^k}.$$

( )

$$W(s) = \frac{\sum_{l=0}^n b_l s^l}{\sum_{k=0}^n a_k s^k}.$$

$$F\{u(t)\} = U(j\omega), \quad F\{y(t)\} = Y(j\omega)$$

$$U(j\omega) = A_u(\omega)e^{j\varphi_u}, \quad Y(j\omega) = A_y(\omega)e^{j\varphi_y}.$$

( )

:

$$K(j\omega) = \frac{A_y(\omega)}{A_u(\omega)} e^{j(\varphi_y - \varphi_u)},$$

$$K(j\omega) = W(s)|_{s=j\omega}.$$

$$y[nT_s] = -\sum_{k=1}^n a_k y[(n-k)T_s] + \sum_{l=0}^n b_l y[(m-l)T_s],$$

Z-

$$Y(z) = -\sum_{k=1}^n a_k z^{-k} Y(z) + \sum_{l=1}^m b_l z^{-k} U(z)$$

$$\frac{Y(z)}{U(z)} = \frac{\sum_{l=1}^m b_l z^{-k}}{1 + \sum_{k=1}^n a_k z^{-k}}.$$

( )

z-

$$W(z) = \frac{\sum_{l=1}^m b_l z^{-kT_s}}{\sum_{k=0}^n a_k z^{-kT_s}} .$$

### 2.2.

### 2.3.

$u(t)$

$v(t),$

$$y(t) = u(t) + v(t).$$



»

$$h(t) = \sum_{i=1} a_i \psi_i(t, \varphi_i), \quad \psi_i(t, \varphi_i) -$$

$$\psi_i(t, \varphi_i) = \sin(0,5 * \Delta\omega t - \varphi_i).$$

## 2.4.

1.

$$y(t) = L^{-1}\{W(s)U(s)\}.$$

2.

$$y(t) = \int_0^{\infty} h(\tau)u(t - \tau)d\tau.$$

3.

$$Y(j\omega) = W(j\omega)U(j\omega).$$

$$y(t) = F^{-1}\{W(j\omega)U(j\omega)\}.$$

4.

$$y(t) = \int_0^{\infty} h(\tau)1(t - \tau)d\tau.$$

$$y(t) = \int_0^{\infty} h(\tau)\delta(t - \tau)d\tau = h(t).$$

$$T\dot{y}(t) + y(t) = u(t) \quad : \quad y(t) = e^{-\frac{t}{T}} y_0 + \int_0^t e^{-\frac{(t-\tau)}{T}} u(\tau) d\tau .$$

## 2.5.

$$u(t) = A_u \cos(\omega t + \varphi_u) = \operatorname{Re} \left[ A_u e^{j\omega t} e^{j\varphi_u} \right] .$$

$$y(t) = A_y \cos(\omega t + \varphi_y) = \operatorname{Re} \left[ A_y e^{j\omega t} e^{j\varphi_y} \right] .$$

$K(\omega)$

$$K(\omega) = \frac{A_y}{A_u} e^{j\varphi_y - j\varphi_u} .$$

$$K(\omega) = \frac{F\{y(t)\}}{F\{u(t)\}} = W(s)|_{s=j\omega}.$$

$$Y(j\omega) = W(j\omega)U(j\omega). \quad -$$

$$( \quad ) \quad -$$

$$K(\omega) = A(\omega)e^{j\varphi(\omega)}, \quad A(\omega) = |K(\omega)|, \quad \varphi(\omega) = \arg K(\omega),$$

$$A(\omega), \varphi(\omega), K_{\text{Re}}(\omega), K_{\text{Im}}(\omega), \quad A(\omega) \quad - \quad -$$

$$( \quad ); \quad \varphi(\omega) \quad - \quad ( \quad );$$

$$K_{\text{Re}}(\omega) = \text{Re}[K(\omega)] \quad - \quad ;$$

$$K_{\text{Im}}(\omega) = \text{Im}[K(\omega)] \quad - \quad .$$

$$L(\omega) = 20 \lg A(\omega) \quad \lg \omega. \quad 20 \quad - \quad ( \quad ) \quad -$$

$$( \quad ) \quad -$$



. 2.2

-	$ W(j\omega)  = \frac{k}{\sqrt{(T\omega)^2 + 1}}$
	$\varphi(\omega) = -\arctan(T\omega)$
-	<code>&gt;&gt;nyquist(tf([1],[1 1]),grid)</code>
-	<code>&gt;&gt;bode(tf([1],[1 1]),grid)</code>

. 2.3.

2.3

	$\frac{dy(t)}{dt} = ku(t)$
	$W(s) = \frac{k}{s}$
	$h(t) = k t$
	$w(t) = k \cdot 1(t)$
-	$ W(j\omega)  = \frac{k}{\omega}$
	$\varphi(\omega) = -\frac{\pi}{2}$
-	<code>&gt;&gt;nyquist(tf([1],[1 0]),grid)</code>
-	<code>&gt;&gt;bode(tf([1],[1 0]),grid)</code>

. 2.4.

2.4

	$y(t) = k \frac{du(t)}{dt}$
	$W(s) = k s$
	$h(t) = k \delta(t)$
	-
-	$ W(j\omega)  = k\omega$
	$\varphi(\omega) = \frac{\pi}{2}$
-	>>nyquist(tf([1 0],[0 1]),grid) :
-	>>bode(tf([1 0],[0 1]),grid) :

. 2.5.

2.5

	$y(t) = k T \frac{du(t)}{dt} + 1$
	$W(s) = k(Ts + 1)$
	$h(t) = k \delta(t)$
	-
-	$ W(j\omega)  = k\sqrt{1 + (T\omega)^2}$
	$\varphi(\omega) = \arctan(T\omega)$
-	>>nyquist(tf([1 1],[0 1]),grid) :
-	>>bode(tf([1 1],[0 1]),grid) :

-	$\frac{d^2 y(t)}{dt^2} + a_1 \frac{dy(t)}{dt} + a_0 y(t) = b_0 u(t)$
	$W(s) = \frac{k \omega_0^2}{s^2 + 2\xi \omega_0 s + \omega_0^2}$
	$h(t) = 1(t) - \frac{1}{\sqrt{1-\xi^2}} e^{-\xi \omega_0 t} \sin(\omega_0 \sqrt{1-\xi^2} t + \varphi)$
	$w(t) = -\frac{\omega_0}{\sqrt{1-\xi^2}} e^{-\xi \omega_0 t} \sin(\omega_0 \sqrt{1-\xi^2} t)$
-	-
	$ W(j\omega)  = \frac{k}{\sqrt{(\omega_0^2 - \omega^2)^2 + (2\xi \omega \omega_0)^2}}$
	-
	$\varphi(\omega) = -\arctan \frac{2\xi \omega \omega_0}{\omega_0^2 - \omega^2}$
-	:
	<pre>&gt;&gt;om0=2*pi*10;ksi=0.01; &gt;&gt;nyquist(tf([om0^2],[1 2*ksi*om0 om0^2]),grid</pre>
-	:
-	-
	<pre>&gt;&gt;om0=2*pi*10;ksi=0.01; &gt;&gt;bode(tf([om0^2],[1 2*ksi*om0 om0^2]),grid</pre>



. 2.7.

2.7

	$y(t) = u(t - \tau)$
	$W(s) = e^{-s\tau}$
	$h(t) = 1(t - \tau)$
	$w(t) = \delta(t - \tau)$
-	$ W(j\omega)  = 1$
	$\varphi(\omega) = -\tau\omega$

. 2.8.

2.8

	-
	$W(s) = \begin{cases} k, & \omega \in [0, \omega_c] \\ 0, & \omega \notin [0, \omega_c] \end{cases}$
	$h(t) = \frac{\omega_c}{\pi} \int_{t_0}^t \frac{\sin(\omega_c(\tau - t_0))}{\omega_c(\tau - t_0)} d\tau$
	$w(t) = \frac{\omega_c}{\pi} \frac{\sin(\omega_c(t - t_0))}{\omega_c(t - t_0)}$
-	$A(\omega) = \begin{cases} k, & \omega \in [0, \omega_c] \\ 0, & \omega \notin [0, \omega_c] \end{cases}$
	$\varphi(\omega) = 0$



2.7.

$$: y(t) = k u(t - \tau).$$

$$u(t) = 0, t < 0,$$

$$Y(s) = k e^{-s\tau} U(s).$$

$$W(s) = k e^{-s\tau}.$$

$$\theta(\omega) = -\frac{\partial \varphi(\omega)}{\partial \omega},$$

2.8.

$$[\omega_0; \omega_1],$$

$$\omega_0 \neq 0, \omega_1 \neq \infty,$$

$$; \quad \omega_0 = 0, \omega_1 \neq \infty,$$

$$; \quad \omega_0 \neq \infty, \omega_1 \rightarrow \infty,$$

$$\omega_1$$

$$K(j\omega) = A(\omega) e^{-j\varphi(\omega)}, \quad A(\omega) = \begin{cases} 1, & |\omega| \leq \omega_1 \\ 0, & |\omega| > \omega_1 \end{cases}.$$

( )

$$: w(t) = \frac{\omega_c}{\pi} \text{sinc}(\omega_c(t - t_0)).$$

## 2.9.

$$y(t) = \int_0^{\infty} h(t - \tau) u(\tau) d\tau,$$

:

$$M[y(t)] = \int_0^{\infty} h(t - \tau) M[u(\tau)] d\tau;$$

$$M[y(t_1) y(t_2)] = \int_0^{\infty} \int_0^{\infty} h(t_1 - \tau_1) h(t_2 - \tau_2) K_u(\tau_1 - \tau_2) d\tau_1 d\tau_2;$$

$$M[y^2(t)] = \sigma_u^2 \int_0^{\infty} \int_0^{\infty} h(t - \tau_1) h(t - \tau_2) K_u(\tau_1 - \tau_2) d\tau_1 d\tau_2;$$

$$M[y(t_1) u(t_2)] = \int_0^{\infty} h(t_1 - \tau_1) K_u(\tau_1 - t_2) d\tau_1.$$

:

$$S_y(\omega) = K(j\omega) * K(-j\omega) * S_u(\omega).$$

$$\sigma_y^2 = \frac{1}{\pi} \int_0^\infty S_y(\omega) d\omega = \frac{1}{\pi} \int_0^\infty K(j\omega) * K(-j\omega) * S_u(\omega) d\omega.$$

«

$$\gg S_u(\omega) = S_u = const$$

$$\sigma_y^2 = \frac{1}{\pi} \int_{\omega_0}^{\omega_1} k_f^2 S_u(\omega) d\omega = \frac{k_f^2 S_u}{\pi} (\omega_1 - \omega_0).$$

## 2.10.

$$e(t) = u(t) - \hat{y}(t),$$

:

$$\sigma_e^2 = \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T e^2(t) dt.$$

2.11.

$$W_f(s) = A(\omega)e^{-s\tau}, \quad A(\omega) = \begin{cases} k_f, & |\omega| \leq \Delta\omega \\ 0, & |\omega| > \Delta\omega \end{cases}$$

$\Delta\omega$

:  $U(s)$  –

;  $X(s) = k_o e^{-s\tau} U(s)$  –

;  $Y(s) = U(s) + V(s)$  –

;  $V(s)$  –

;  $\hat{Y}(s)$  –

;  $E(s) = X(s) - \hat{Y}(s)$  –

$$E(s) = X(s) - W_f(s)(U(s) + V(s)), \quad W_f(s) –$$

$$S_e(\omega) = |k_o e^{-j\omega\tau} - W_f(j\omega)|^2 S_u(\omega) + |W_f(j\omega)|^2 S_v(\omega),$$

$$W_f(s) = \begin{cases} K_f, & |\omega| < \Delta\omega \\ 0, & |\omega| > \Delta\omega \end{cases}$$

$$\sigma_e^2 = \frac{k_o^2}{\pi} \int_{-\Delta\omega}^{\Delta\omega} S_u(\omega) d\omega + \frac{k_o^2}{\pi} \int_0^{\Delta\omega} S_v(\omega) d\omega.$$

$\Delta\omega,$

2.12.

$$\hat{y}(t) = \int_0^{\infty} h_f(t - \tau) y(\tau) d\tau,$$

$$h_f(t) = \begin{cases} h_f(t), & t \geq 0 \\ 0, & t < 0 \end{cases},$$

$$M[e^2(t)] = K_x(0) - 2 \int_0^{\infty} h(\tau) K_{xy}(\tau) d\tau + 2 \int_0^{\infty} \int_0^{\infty} h(\tau_1) h(\tau_2) K_y(\tau_1 - \tau_2) d\tau_1 d\tau_2.$$

[7]:

$$K_{xy}(t) = \int_0^{\infty} h(\tau) K_y(t - \tau) d\tau,$$

$$S_{xy}(\omega) = W(j\omega) S_{yy}(\omega),$$

$$W_{opt}(j\omega) = \frac{S_{xy}(\omega)}{S_{yy}(\omega)}$$

$$h_{opt}(t) = \frac{1}{2\pi} \int_0^{\infty} W_{opt}(j\omega) e^{j\omega t} d\omega.$$

$$W_{opt}(j\omega) = \frac{S_{xx}(\omega)}{S_{xx}(\omega) + S_{vv}(\omega)}.$$

### 3.

#### 3.1.

( )

« » -

,

- ( )

( . 3.1).

3.1

>> t=0:0.1:1;	% 0 1 0.1
>> fs=1000; t=0:1/fs:10;	% 1 0 10
>> To=1; Tk=100; Ts=1; >> t=To:Ts:Tk;	% 1 100 - 1

( . 3.2).

3.2

>> t=0:0.1:1; fi=pi/4; omega=2*pi*100; >> x1=cos(omega*t+fi); plot(x1);	% 45 100
>> alpha=1000; t=0:1/fs:10; >> x2=exp(-alpha*t); plot(t,x2);	% 1 0 10

( . 3.3).



>> t=0:0.1:10; >> x1=1.*(t>1); plot(t,x1);	% " " - 1
>> al=1000; t=0:1:10;T=5; >> x2=al*t/T.*(t>0).*(t<T); plot(t,x2);	% - 5

( .3.4)

>> t=0:0.1:10; T=1; >> x=rectpuls(t,T); plot(t,x);	% - 0.5
>> t=0:1:10;T=5;skew=1; >> x2=tripuls(t,T, skew); plot(t,x2);	% - 5 2.5
>> t=-10:0.1:10; >> x=sinc(t/pi); plot(t,x);	% c 20
>> t=-10:0.1:10;fc=1000;bw=0.5;bwr=-6; >> x=gauspuls(t,fc,bw,bwr); plot(t,x);	% c - : fc - ; bw - - ( , ) ; bwr - -

( .3.5)

>> T=1;Tf=10;Ts=0.01; >>[x,t]=gensig('sin',T,Tf,Ts); plot(t,x);	% - 10 1 100
>> T=1; Tf=10;Ts=0.01; >>[x,t]=gensig('square',T,Tf,Ts); plot(t,x);	% 10 1 100
>> T=1; Tf=10;Ts=0.01; >>[x,t]=gensig('pulse',T,Tf,Ts); plot(t,x);	% - 10 1 100

. 3.5

>> t=0:0.001:10;f0=1;f1=100;t1=10; >>x=chirp(t,f0,t1,f1); plot(t,x);	% - 10 1 100
>> t=0:0.001:10;dvt=50; >>x=square(t,dvt); plot(t,x);	% , dvt -

( . 3.6)

3.6

>>n=100;x=rand(1,n);plot(x);	% - (0;1)
>>n=100;x=randn(1,n);plot(x);	% - ( - 0, - 1)
>> n=25;hist(x,n)	% 25 -

3.2.

( . 3.7)

3.7

>>n=128;Fs=200;X=fft(x,n); >>plot(abs( ),(0:n-1)/(n-1)*Fs);	% 128 ,
>> n=256;x=ifft(X,n);	% 256 -

**3.3.**

( **.3.8**)

3.8

>>a=[2 3 1];b=[1 0];X=freqs(b,a);	%	-
>>a=[2 3 1];b=[1 0]; [X,w]=freqs(b,a); >>plot(w,abs(X)); grid on	%	- -
>>a=[2 3 1];b=[1 0]; [X,w]=freqs(b,a); >>plot(w, unwrap (angle(X))*180/pi)	%	- -
>>a=[2 3 1];b=[1 0]; sys=tf(b,a); >> bode(sys)	%	

**3.4.**

( **.3.9**)

3.9

>>a=[2 3 1];b=[1 0];sys=tf(b,a);	%	( )
>>z=[2 3 1];p=[1 0];k=[1]; >>sys=zpk(z,p,k);	%	( ) ,
>>[z,p,k]=tf2zp(b,a)	%	TF ZPK
>>[num.den]=zp2tf(z,p,k)	%	ZPK TF

( **.3.10**)

3.10

>>a=[2 3 1];b=[1 0];Ts=0.1; >>sys=tf(b,a,Ts);	%	( - )
>>z=[2 3 1];p=[1 0];k=[1]; Ts=0.1; >>sys=zpk(z,p,k);	%	( - ) ,
>>[z,p,k]=tf2zpk(b,a)	%	TF ZPK

## 4.

### 1

«

»

. 4.1.

1. ( . .1).

2.

3.

4.

5.

6.

7.

8.

Sources.

9.

Sinks

-				
		-	,	,
1	(« »)	10	-	10
2	(« »)	100	-	50
3	(« »)	1	-	10
4	- (« »)	10	1	10
5	- (« »)	1	10	1
6	- (« »)	10	100	0.1
7	- (« »)	0.1	1 000	0.01
8		0.5	10	1
9		1	100	0.1
10		10	1 000	0.01
11		0.1	1 0000	0.001
12		1	10	1
13		10	100	0.1
14		0.1	1000	0.01
15		1 10	10	10
16		100 500	1 00	0.1
17		0.01 1	1 000	0.01
18		1	1 10	1
19		5	10 100	0.1
20		10	100 300	0.1
21		* - 1 * - 0.5	-	1
22		- 10 - 1		0.1
23		- 100 - 5	-	0.1
24		- 0 - 0.1	-	1

\* — , — .

simulink

-

Sinks, Source

«

»

Start.

1.

2.

3.

4.

5.

6.

7.

8.

. 3.2.

«

»

( .4.2).

1. ( . . 2).

2. .

3. .

4. - .

5. .

6. .

7. .

8. Power

Spectral Density, Averaging Power Spectral Density

Simulinks Extras – Additional Sinks.

9. .

10. .

-				
			,	-
1	( )	10	-	1
2	( )	100	-	0.2
3	( )	1	-	0.01
4	- (« »)	10	1	0.1
5	- (« »)	1	10	0.02
6	- (« »)	10	100	0.0005
7	- (« »)	0.1	1 000	0.00003
8		0.5	10	0.03
9		1	100	0.004
10		10	1 000	0.000025
11		0.1	1 0000	0.00001
12		1	10	0.02
13		10	100	0.003
14		0.1	1000	0.0002
15		1 10	10	0.005
16		100 500	1 00	0.00004
17		0.01 1	1 000	0.00003
18		1	1 10	0.01
19		5	10 100	0.001
20		10	100 300	0.0003
21		- 1 - 0.5	-	0.1
22		- 10 - 1		0.1
23		- 100 - 5	-	0.1
24		- 0 - 0.1	-	0.1

\* -

, -

.



simulink

Sinks, Source

Simulinks Extras

«

»

Start.

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.
- 8.
- 9.
- 10.
- 11.

?

(

).

?

?

. 3.3.

```

1.
t = 0:0.001:0.6; %время
x = sin(2*pi*50*t)+sin(2*pi*120*t); %сигнал
y = x + 2*randn(size(t)); %сигнал с ошибкой
plot(1000*t(1:50),y(1:50)); %график сигнала
xlabel('time (milliseconds)');
Y = fft(y,512); %преобразование Фурье
Pyy = Y.* conj(Y) ; %модуль преобразования Фурье
f = 1000*(0:256)/512; %вектор половины частоты дискретиза-
%ции

plot(f,Pyy(1:257)); %график амплитудного спектра на половине частоты
title('Frequency content of y')
xlabel('frequency (Hz)')

2.
t = 0:1/100:10-1/100; %время
x = sin(2*pi*15*t) + sin(2*pi*40*t); %сигнал
y = fft(x); %преобразование Фурье
m = abs(y); %модуль комплексного спектра
p = unwrap(angle(y)); %фаза комплексного спектра
f = (0:length(y)-1)*100/length(y); % частота в герцах
subplot(2,1,1), plot(f,m),
ylabel('Abs. Magnitude'), grid on
subplot(2,1,2), plot(f,p*180/pi)
ylabel('Phase [Degrees]'), grid on
xlabel('Frequency [Hertz]')

```

.

-

.4.2.

1.

.

2.

.

3.

-

.

4.

.

5.

,

.

6.

.

7.

.

.

.

-

-

-

.

-

.

-

-

-

:

1.

2.

2.

.

3.

.

4.

.

.

.

-

.

1. .
2. ?
3. ?
4. ?
5. -
6. ?
7. ?

```

t = 0:0.001:0.512;           %время
x = sin(2*pi*5*t)+sin(2*pi*12*t); %сигнал
y = x + 0*randn(size(t));   %сигнал с ошибкой
n=512;                       %число отсчетов
figure(1)
plot(t(1:n),y(1:n));grid;    %график сигнала
title('Signal Corrupted with Zero-Mean Random Noise');
xlabel('time (milliseconds)');
Y = fft(y,n);               %преобразование Фурье
Pyy = Y.* conj(Y) / n;      %модуль преобразования Фурье
f = 1000*(0:n)/n;          %половина частоты дискретизации
figure(2)
plot(f(1:100),Pyy(1:100));grid; %график АЧХ
title('Frequency content of y')
xlabel('frequency (Hz)')
%***** обратное преобразование Фурье*****
N=100;
Y1=[Y(1:N) zeros(1,n-N)];   %усечение спектра сигнала
figure(3)
x1=ifft(Y1,n);              %обратное преобразование Фурье
plot(t(1:n),2*x1(1:n),t(1:n),y(1:n)),grid;

```

: , , -  
, , -  
, , .

## 4

« »

- -

SP Toolbo ks.

- -  
, , -  
. 4.3.

1. .
2. .
3. - .
4. .
5. .

1. , -  
plot. , -
2. ( -  
) hist.

3.

:

-

,

,

,

.

4.3

1	0.1	1.5	
2	1.0	2.0	
3	5.0	1.0	
4	10.0	1.0	
5	20.0	5.0	
6	30.0	10.0	
7	3.0	1.0	
8	5.0	2.0	
9	7.0	8.0	
10	9.0	5.0	
11	10.0	6.0	
12	1.5	0.1	
13	2.0	1.0	
14	1.0	5.0	
15	1.0	10.0	
16	5.0	20.0	
17	10.0	30.0	
18	1.0	3.0	
19	2.0	5.0	
20	8.0	7.0	
21	5.0	9.0	
22	6.0	10.0	
23	1.5	0.1	
24	2.0	1.0	

4.

:

-

-

5.

(

-

)

disttool.

1.

.

- 2.
- 3.
- 4.
- 5.
- 6.
7. ?
8. ?
- 9.
- 10.

```

t = 0:0.001:0.512;           %время
x1 =rand(size(t));          %сигнал 1
x2 =rand(size(t));          %сигнал 2
n=512;
figure(1)
plot(t(1:n),x1(1:n),t(1:n),x2(1:n));grid;      %графики сигналов
title('Signal Corrupted');
xlabel('time (milliseconds)');
figure(2)
subplot(1,1,1)
hist(x1,20);hist(x2,20)      % функции плотности по данным сигналов
x1m=mean(x1);x2m=mean(x2); % математическое ожидание (1-й момент)
x1_std=std(x1);x2_std=std(x2);      % СКО
x1_disp=x1_std^2;x2_disp=x2_std^2;  % дисперсия
x1_cov=cov(x1);x2_cov=cov(x2);     %ковариация (2-й момент)
R = corrcoef(x1,x2);              %коэффициент корреляции
figure(3)
subplot(2,1,1)
X_corr=xcov(x1);              % корреляционная функция
plot(X_corr/n/x1_disp);
subplot(2,1,2)
X1X2_cor=xcov(x1,x2)/(x1_std*x2_std)/n; %взаимная корреляционная
plot(X1X2_cor)                % функция

```

5

«

»

. 4.4.

- 1.
- 2.
- 3.
- 4.
- 5.

```
tf;
zpk;
(
step,      impuls);
(
freq,      bode).
```



## 4.4

1	0.1	$(1.5s + 1)(3s + 1)^2$
2	1.0	$((\frac{1}{5}s)^2 + 2 \cdot \frac{1}{5} \cdot 0.1s + 1)(3s + 1)$
3	5.0	$((\frac{1}{5}s)^2 + 2 \cdot \frac{1}{5} \cdot 0.1s + 1)s$
4	10.0	$(2.5s + 1)(5s + 1)^2$
5	20.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)(5s + 1)$
6	30.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)s$
7	3.0	$(0.1s + 1)^2 (0.3s + 1)$
8	5.0	$((5s)^2 + 2 \cdot 5 \cdot 0.1s + 1) (5s + 1)$
9	7.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)s^2$
10	s+1	$(1.5s + 1)(3s + 1)^2$
11	(s+2)(s-1)	$((\frac{1}{5}s)^2 + 2 \cdot \frac{1}{5} \cdot 0.1s + 1)(3s + 1)$
12	(s+5)(s-2)	$((\frac{1}{5}s)^2 + 2 \cdot \frac{1}{5} \cdot 0.1s + 1)s$
13	(s+1)(s-1)	$(2.5s + 1)(5s + 1)^2$
14	$((\frac{1}{30}s)^2 + 2 \cdot \frac{1}{30} \cdot 0.1s + 1)$	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)(5s + 1)$
15	1.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)s$
16	5.0	$(0.1s + 1)^2 (0.3s + 1)$
17	$((3s)^2 + 2 \cdot 3 \cdot 0.1s + 1)$	$((5s)^2 + 2 \cdot 5 \cdot 0.1s + 1) (5s + 1)$
18	(s+1)^2	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)s^2$
19	(1.5s+1)(3s+1)	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.1s + 1)s^2$
22	8.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.4s + 1)(5s + 1)$
23	5.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.4s + 1)s$
24	6.0	$(0.1s + 1)^2 (0.3s + 1)$
25	1.5	$((5s)^2 + 2 \cdot 5 \cdot 0.4s + 1) (5s + 1)$
26	2.0	$((\frac{1}{50}s)^2 + 2 \cdot \frac{1}{50} \cdot 0.4s + 1)s^2$

\* s –

1.

?

2.

3.

4.

5.

6.

7.

8.

9.

. 3.3 3.4.

```
clc
clf
Num=[1 2];Den=[4 5 6];
sys_tf=tf(Num,Den) % форма tf
[z,p,k]=tf2zpk(Num,Den);
sys_zpk=zpk(z,p,k) % форма zpk
figure(1)
step(sys_tf) % переходная функция
damp(sys_tf) % полюса системы

figure(2)
impz(sys_tf) % импульсная функция

[X,w]=freqs(Num,Den); % комплексный коэффициент передачи
figure(3)
subplot(2,1,1)
plot(w,abs(X)),grid on % АЧХ
subplot(2,1,2)
plot(w,unwrap(angle(X))*180/pi),grid on % ФЧХ
figure(4)
bode(sys_tf),grid on % ЛАЧХ
nyquist(sys_tf) % АФЧХ
```

- :
- ,
- 
- ,
- 
- .
1. . . . - ∴ . ,  
1970. – 276 .
  2. . . . - ∴ , 2002. –  
608 .
  3. . . . -  
. - . - - ∴ , 2003. – 1099 .
  4. . . . - ∴ , 2000. – 964 .
  5. . . . : . . - ∴ . , 1974. – 344 .
  6. . . . :  
: 2 . - ∴ " , 2003.  
- .1 – 345 . - .2. – 356 .
  7. : / . . ,  
. . , . . , . . , . . - : -  
, 2003. – 608 .



...

. , 2006  
01.02.2006  
60 84 1/16. . . 2. . .  
. . . 3,6. .- . . 4,06. . 50 . 76.

...

« . . . »  
61070, -70, . , 17  
<http://www.khai.edu>  
61070, -70, . « » , 17  
[izdat@khai.edu](mailto:izdat@khai.edu)

