DIMENSION AE(6,6), BE(6,4), CE(3,6), BE1(6,3), CE1(6,6)

DIMENSION A(5,5), A1T(5,5), Q(6,5), AKC(3,5), BAKC(5,5), Y(5,5), QC(5,15), ACOPY(5,5)

DIMENSION B(5,3), C(2,5), CT(5,2), QO(5,15), T(5), R(5,5), F(6,5), PSF(5,6), AL(5), OK1(4,3), OK2(4,3), OK(4,3)

DIMENSION H(3), G(5), CL(5,3), P(5,5), A1(5,5), D(6), AL1(5), BETA(6), E(6,7), PSE(7,6), X(7), CK1(4,3), CK2(4,3)

DIMENSION CK(4,3), ETA(2), OL(5,2), A2(6,6), AK1(3,2), ALFA2(6), AT(5,5), RR(9,9), AS(6), AK(3,2)

WRITE (6,315) “INPUT THE VALUES N, M, IR”

READ (5, 98) N,M,IR

98 FORMAT (3I1)

WRITE (6, 98) N,M,IR

\* Make a copy of matrix A, for later use in the self-test section

WRITE (6,315) “INPUT MATRIX A (N,N)”

READ (5,58) ((A(I,J), I=1,N), J=1,N)

WRITE (6,581) ((A(I,J), I=1,N), J=1,N)

DO 1000 I=1,N

DO 1000 J=1,N

1000 ACOPY(I,J)=A(I,J)

WRITE (6,315) “INPUT MATRIX B (N,IR)”

READ (5,580) ((B(I,J), I=1,N), J=1,IR)

WRITE (6,5801) ((B(I,J), I=1,N), J=1,IR)

WRITE (6,315) “INPUT MATRIX C (M,N)”

READ (5,5800) ((C(I,J), J=1,N), I=1,M)

WRITE (6,58001) ((C(I,J), J=1,N), I=1,M)

58 FORMAT (25 F1.0)

580 FORMAT (15 F1.0)

5800 FORMAT (10 F1.0)

581 FORMAT (25 F2.0)

5801 FORMAT (15 F2.0)

58001 FORMAT (10 F2.0)

\* Construct the controllability matrix QC(N, N\*IR)

CALL CONOBS (IR, B, QC, A, N)

NR=N\*IR

WRITE (6, 70) “MATRIX QC”, ((QC (I,J), J=1,NR), I=1,N)

\* Bring QC to the echelon reduced form in order to calculate the controllability index IC

CALL ESALON (QC, N, NR)

\* Determination of the controllability index IC

DO 19 J=1, NR

IF (QC(N,J)) 29,19,29

19 CONTINUE

WRITE (6, 315) “THE SYSTEM IS NOT COMPLETELY CONTROLLABLE”

WRITE (6, 70) “MATRIX QC”, ((QC (I,J), J=1,NR), I=1,N)

GO TO 1500

29 IC=(J-1)/IR

WRITE (6, 70) “MATRIX QC”, ((QC (I,J), J=1,NR), I=1,N)

70 FORMAT (20X, A30,/15 (1X,F5.2))

\* Construct the observability matrix QO(N,N\*M)

CALL TRAM(A,AT,N,N)

CALL TRAM(C,CT,M,N)

CALL CONOBS (M,CT, QO, AT, N)

NM=N\*M

\* Bring QO to the echelon reduced form in order to calculate the controllability index IO

CALL ESALON (QO, N, NM)

\* Determination of the observability index IO

DO 39 J=1,NM  
IF (QO(N,J)) 49,39,49

39 CONTINUE

WRITE (6, 315) “SYSTEM IS NOT COMPLETELY OBSERVABLE”

GO TO 1500

49 IO=(J-1)/M

WRITE (6, 90) “MATRIX QO” ,((QO(I,J), J=1, NM), I=1,N)

90 FORMAT (20X,A20 ,/10(1X, F8.2))

\* Generate matrix K1(R,M) that makes A+B\*K1\*C cyclic

DO 310 I=1,IR

DO 310 J=1,M

310 AK1 (I,J)=0

CALL ZADEH (A, N, AL)

CALL CQ (Q, N, AL)

K=1

NM=2\*N-K

CALL PRIM (RR, Q, N, NM, K)

CALL ESALON (RR, NM, NM)

IF (RR(NM, NM)) 311, 314, 311

\* We were successful in making A+B\*K1\*C cyclic

311 WRITE (6, 315) “MATRIX A IS CYCLICAL”

DO 313 I=1,N

DO 313 J=1,N

313 A1(I,J)=A(I,J)

GO TO 399

\* We were NOT successful in making A+B\*K1\*C cyclic, we need to apply the algorithm Davison-Wang

314 WRITE (6, 315) “MATRIX A IS NOT CYCLICAL, WE APPLY THE DAVISON ALGORITHM”

315 FORMAT (A60)

K=2

320 NM=2\*N-K

CALL PRIM (RR, Q, N, NM, K)

CALL ESALON (RR, NM, NM)

IF (RR(NM, NM)) 316, 317, 316

317 IF (K-N+1) 318, 319, 319

318 K=K+1

GO TO 320

319 ID1=N

GO TO 321

316 ID1=K

\* Generate AK(R,M)

321 MR=IR\*M

S=1.3

336 CALL HAZ (S, MR, AS)

DO 322 I=1,IR

DO 322 J=1,M

322 AK (I,J)=AS(J+(I-1)\*M)

\* Generate Y=A+B\*AK\*C

CALL PROMAT (AK, C, AKC, IR, M, N)

CALL PROMAT (B, AKC, BAKC, N, IR, N)

DO 323 I=1,N

DO 323 J=1,N

323 Y(I,J)=A(I,J)+BAKC(I,J)

\* Bring Y to the cyclic form

CALL ZADEH (Y,N, AL)

CALL CQ (Q, N, AL)

K=1

NM=2\*N-K

CALL PRIM (RR, Q, N, NM, K)

CALL ESALON (RR, NM, NM)

IF (RR(NM, NM)) 324, 325, 324

325 WRITE (6, 315) “MATRIX Y IS NOT CYCLICAL”

\* We failed to bring Y to the cyclic form in our first attempt, we can try 9 more times

K=2

331 NM=2\*N-K

CALL PRIM (RR, Q, N, NM, K)

CALL ESALON (RR, NM, NM)

IF (RR(NM, NM)) 327, 328, 327

328 IF (K-N+1) 329, 330, 330

329 K=K+1

GO TO 331

330 ID2=N

GO TO 332

327 ID2=K

332 IF (ID2-ID1) 333, 338, 338

333 ID1=ID2

DO 335 I=1,N

DO 335 J=1,N

335 A (I,J)=Y (I,J)

DO 337 I=1, IR

DO 337 J=1,M

337 AK1 (I,J)=AK1 (I,J)+AK (I,J)

GO TO 334

338 DO 339 I=1,N

DO 339 J=1,N

339 A (I,J)=Y (I,J)-BAKC (I,J)

334 S=S+1.

GO TO 336

\* We managed to bring Y to the cyclic form

324 WRITE (6, 315) “Y HAS BECOME CYCLICAL”

DO 341 I=1,N

DO 341 J=1, N

341 A1(I,J)=Y(I,J)

DO 342 I=1, IR

DO 342 J=1, M

342 AK1(I,J)=AK1(I,J)+AK(I,J)

399 CALL ZADEH (A1, N, AL1)

\* Generate the random vector G(N)=CT\*ETA that makes the pair (A,G) completely observable

K=1

S=1.7

405 CALL HAZ (S, M, ETA)

CALL TRAM (A1, A1T, N, N)

CALL PROMAT (CT, ETA, G, N, M, 1)

CALL CONOBS (1, G, QO, A1T, N)

CALL ESALON (QO, N, N)

IF (QO(N,N)) 401, 402, 401

402 IF (K-10) 403, 404, 404

403 K=K+1

S=S+1.

GO TO 405

\* We failed to find G in 10 tries, we have to give up or try more times

404 WRITE (6, 315) “G COULD NOT BE FOUND”

GO TO 1500

401 K=1

S=S+1.3

410 CALL HAZ (S, IR, H)

\* Generate the random vector T(N)=B\*H that makes the pair (A,T) completely controllable

CALL PROMAT (B, H, T, N, IR, 1)

CALL CONOBS (1, T, QC, A1, N)

CALL ESALON (QC, N, N)

IF (QC (N,N)) 406, 407, 406

407 IF (K-10) 408,409, 409

408 K=K+1

S=S+1.

GO TO 410

\* We failed to find T in 10 tries, we have to give up or try more times

409 WRITE (6,315) “T COULD NOT BE FOUND”

GO TO 1500

\* Determine the number of integrators L=min(IC,IO)

406 IF (IC-IO) 11, 13, 12

13 IF (IR-M) 11, 11, 12

11 L=IC

WRITE (6, 60) “THE NUMBER OF INTEGRATORS”, L , “L=IC”

60 FORMAT (20X,A30, I2, A5,10X)

\* Input a fixed BETA, for testing purposes only

\* BETA(1)=-2

\* BETA(2)=4

\* BETA(3)=1

\* BETA(4)=-3

\* BETA(5)=-5

\* BETA(6)=2

NL=N+L

\* Input a variable BETA , for the real design

WRITE (6,315) “INPUT BETA(N+L)”

READ (5,68) (BETA(I), I=1,NL)

WRITE (6,681) (BETA(I), I=1,NL)

68 FORMAT (6 F2.0)

681 FORMAT (6 F3.0)

GO TO 1

12 L=IO

WRITE (6, 80) “THE NUMBER OF INTEGRATORS”, L, “L=IO”

80 FORMAT (20X,A30, I2, A5,10X)

\* Input a fixed BETA, for testing purposes only

\* BETA(1)=-2

\* BETA(2)=4

\* BETA(3)=1

\* BETA(4)=-3

\* BETA(5)=-5

\* BETA(6)=2

\* Input a variable BETA , for the real design

WRITE (6,315) “INPUT BETA(N+L)”

READ (5,68) (BETA(I), I=1,6)

WRITE (6,681) (BETA(I), I=1,6)

68 FORMAT (6 F2.0)

681 FORMAT (6 F3.0)

GO TO 2

\* Construct matrix CL(N,IR)

1 DO 100 J=1,N

100 P(1,J)=G (J)

DO 200 I=2,N

DO 200 J=1,N

S=0.

DO 300 K=1, N

300 S=S+P(I-1,K)\* A1 (K, J)

200 P (I, J) = S+AL1 (N-I+2) \* G (J)

CALL PROMAT (P, B, CL, N, N, IR)

\* Construct matrix E(N+L, L+(L+1)\*IR)

IL=N+L

JC=L+(L+1)\*IR

DO 101 I=1,IL

DO 101 J=1,JC

101 E(I,J)=0.

DO 201 J=1,L

E (J,J)=1.

DO 201 K=1,N

201 E (J+K, J) = AL1 (N-K+1)

DO 301 I=1,N

DO 301 J=1,IR

E (L+I, L+J) = CL (I,J)

DO 301 K=1,L

301 E(L-K+I, L+K\*IR+J) = CL (I, J)

\* Construct matrix D(N+L)

DO 102 I=1,N

102 D(I)= BETA (L+N-I+1) - AL1 (N-I+1)

DO 103 I=1,L

\* Construct the pseudoinverse of matrix E, PSE(L+(L+1)\*IR, N+L)

103 D (N+I) = BETA (L-I+1)

CALL PS (E, IL, JC, PSE)

\* Construct the matrix X(L+(L+1)\*IR))= PSE(L+(L+1)\*IR, N+L)\*D(N+L)

CALL PROMAT (PSE, D, X, JC, IL, 1)

\* Construct matrices CK1(IR+L,M+L), C21(IR+L,M+L),CK=CK1+CK2

I1=IR+L

J1=M+L

DO 41 I=1,I1

DO 41 J=1,J1

CK2 (I,J)=0.

41 CK1 (I,J)=0.

DO 42 I=1,IR

DO 42 J=1,M

CK2(I,J)=-ETA(J)\* X(L+I+L\*IR)

42 CK1 (I,J)=AK1 (I,J)

DO 43 I=1,IR

DO 43 J=1,L

43 CK2 (I, M+J)=-X(L+I+(L-J)\*IR)+X(J)\*X(L+L\*IR+I)

DO 44 J=1,M

44 CK2 (IR+1,J)=ETA (J)

DO 45 J=1,L

45 CK2 (IR+1, M+J)=-X(J)

L1=L-1

IF (L1) 51, 51, 50

50 DO 46 J=1, L1

46 CK2 (J+IR+1, M+J)=1.

51 DO 47 I=1,I1

DO 47 J=1,J1

47 CK (I,J)=CK1 (I, J)+CK2 (I, J)

PRINT 59, “MATRIX CK”, CK

59 FORMAT (//20X, A20,// (3F13.6))

GO TO 500

\* Construct matrix OL(N,M)

2 DO 111 J=1,N

111 R (1,J)=T (J)

DO 112 I=2,N

DO 112 J=1,N

S=0.

DO 113 K=1,N

113 S=S+R(I-1,K)\*A1 (J,K)

112 R(I, J)=S+AL1(N-I+2)\*T(J)

CALL PROMAT (R, CT, OL, N, N, M)

\* Construct matrix F(N+L, L+(L+!)\*M)

IL=N+L

JC=L+(L+1)\*M

DO 121 I=1,IL

DO 121 J=1,JC

121 F(I,J)=0

DO 122 J=1,L

F(J,J)=1.

DO 122 K=1,N

122 F(J+K,J)=AL1 (N-K+1)

DO 123 I=1,N

DO 123 J=1,M

F(L+I, L+J)=OL(I, J)

DO 123 K=1,L

123 F(L-K+I, L+K\*M+J)=OL(I,J)

\* Construct matrix D(N+L)

DO 124 I=1,N

124 D(I)=BETA(L+N-I+1)-AL1(N-I+1)

DO 125 I=1,L

125 D(N+I)=BETA(L-I+1)

\* Construct the pseudoinverse of matrix F, PSF(L+(L+1)\*M, N+L)

CALL PS (F, IL, JC, PSF)

\* Construct the matrix X(L+(L+1)\*M))= PSF(L+(L+1)\*M, N+L)\*D(N+L)

CALL PROMAT (PSF, D, X, JC, IL,1)

\* Construct matrices OK1(IR+L,M+L), O21(IR+L,M+L),OK=OK1+OK2

I1=IR+L

J1=M+L

DO 141 I=1,I1

DO 141 J=1,J1

OK2 (I,J)=0.

141 OK1 (I,J)=0.

DO 142 I=1,IR

DO 142 J=1,M

OK1(I,J)=AK1(I,J)

142 OK2(I, J)=-H(I)\*X(L+L\*M+J)

DO 143 I=1,L

DO 143 J=1,M

143 OK2 (I, J)=-X(L+J+(L-I)\*M)+X(I)\*X(L+L\*M+J)

DO 144 I=1,IR

144 OK2(I, M+1)=H(I)

DO 145 J=1,L

145 OK2 (IR+1, M+J)=-X(J)

L1=L-1

IF (L1) 61, 61, 62

62 DO 146 J=1,L1

146 OK2 (J+IR+1, J+M)=1.

61 DO 147 I=1,I1

DO 147 J=1,J1

147 OK(I,J)=OK1(I,J)+OK2(I,J)

PRINT 59,”MATRIX OK”, OK

\* Algorithm self-check, form the extended matrices AE(N+L,N+L), BE(N+L,IR+L),CE(M+L,N+L), L=min(IC,IO)

\* IF IC<IO find the coefficients ALFA2(N+L) of the characteristic polynomial of matrix AE+BE\*CK\*CE

\* IF IC>IO find the coefficients ALFA2(N+L) of the characteristic polynomial of matrix AE+BE\*OK\*CE

\* IF IC=IO, you can choose either CK or OK

\* Compare ALFA2(N+L) with the target coefficients BETA(N+L), they must be equal

500 N1=N+L

IR1=IR+L

M1=M+L

DO 1001 I=1,N

DO 1001 J=1,N

1001 A(I,J)= ACOPY(I,J)

DO 130 I=1,N1

DO 130 J=1,N1

130 AE(I,J)=0.

DO 131 I=1,N

DO 131 J=1,N

131 AE(I,J)=A(I,J)

DO 132 I=1,N1

DO 132 J=1,IR1

132 BE(I,J)=0.

DO 133 I=1,N

DO 133 J=1,IR

133 BE(I,J)=B(I,J)

DO 134 I=1,L

134 BE(N+I, IR+I)=1.

DO 135 I=1,M1

DO 135 J=1,N1

135 CE (I, J)=0.

DO 136 I=1,M

DO 136 J=1,N

136 CE (I,J)= C(I,J)

DO 137 I=1,L

137 CE (M+I, N+I)=1.

IF (IC-IO) 139, 160, 140

160 IF (IR-M) 139, 139, 140

139 CALL PROMAT (BE, CK, BE1, N1, IR1, M1)

GO TO 150

140 CALL PROMAT (BE, OK, BE1, N1, IR1, M1)

150 CALL PROMAT (BE1, CE, CE1, N1, M1, N1)

DO 138 I=1,N1

DO 138 J=1,N1

138 A2(I,J)= AE(I,J) +CE1(I,J)

CALL ZADEH (A2, N1, ALFA2)

WRITE (6, 600) “ALGORITHM CHECK”

600 FORMAT (20X, A20)

WRITE (6,315) “ALFA2(N+L)”

WRITE (6,680) (ALFA2(I), I=1,N1)

680 FORMAT (6 F8.2)

1500 STOP

END