```
*****************************************************************
* MAIN ROUTINE TO SOLVE A SET OF ORDINARY REFERENTIAL           *
*                                                               *
* EQUATIONS IN THE FORM OF                                      *
*   DX(T)/DT=AX(T)+BU(T),     X(0)=X0                           *
*   Y(T)=CX(T)                                                  *
* WHERE                                                         *
*    X(T)  IS AN N-DIMENTIONAL VECTER                           *
*    U(T)  IS AN M-DIMENTIONAL VECTER                           *
*    Y(T)  IS AN L-DIMENTIONAL VECTER                           *
*    A IS AN N*N DIMENTIONAL SYSTEM COEFFICIENT MATRIX          *
*    B IS AN N*M DIMENTIONAL INPUT COEFFICIENT MATRIX           *
*    C IS AN L*N DIMENTIONAL OUTPUT COEFFICIENT MATRIX          *
* INPUT ARE :                                                   *
*         X(0)= THE INITIAL VALUE                               *
*         U(T)= THE CONTROL INPUTS                              *
*   OUTPUTS ARE :                                               *
*         Y(T)  THE OUTPUT OF THE SYSTEM                        *
*   PARAMETERS  :                                               *
*         TAU IS THE SAMPLING INTERVAL                          *
*         LIMIT IS THE NUMBER OF DATA SOLVED                    *
*****************************************************************
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図 2.34(1)　FORTRAN 77 による $\left\{ \begin{array}{l} \dfrac{d\boldsymbol{x}(t)}{dt} = \boldsymbol{A}\boldsymbol{x}(t) + \boldsymbol{B}\boldsymbol{u}(t) \\ \boldsymbol{x}(0) = \boldsymbol{x}_0,\ \boldsymbol{y}(t) = \boldsymbol{C}\boldsymbol{x}(t) \end{array} \right\}$ の解法ルーチン

```
      INTEGER N,M,L,LIMIT,I,K,J
      REAL    T1,T2,UMAG,TAU

      PARAMETER(N=4,M=1,L=1,LIMIT=100)
      REAL A(N,N),B(N,M),C(L,N),U(M,LIMIT),X(N),Y(L,LIMIT)
***
*   INPUT THE PARAMETERS OF THE SERVO SYSTEM
***

      READ(5,*) TAU,UMAG,T1,T2

*(1) SAMPLING INTERVAL=TAU
       WRITE(6,*) '                SAMPLING INTERVAL TAU=',TAU
*(2) MAGNITUDE OF STEP CONTROL INPUT U(0)
       WRITE(6,*) 'MAGNITUDE OF STEP CONTROL INPUT UMAG=',UMAG
*(3) PARAMETERS OF THE CONTROLLER T1 AND T2
       WRITE(6,*) '                          PARAMETER T1=',T1
       WRITE(6,*) '                          PARAMETER T2=',T2
      WRITE(6,1100)
***
*   GENERATION OF THE CONTROL INPUT U(K),K=1,2,...,LIMIT
***
      DO 100 I=1,M
        DO 100 K=1,LIMIT
          U(I,K)=UMAG
  100 CONTINUE
***
*   SET OF INITIAL VALUE OF THE STAE VARIABLES
***
      DATA X/N*0.0/
***
*   GENERATION OF THE A MATRIX A(N,N)
***
      DO 120 I=1,N
        DO 120 J=1,N
          A(I,J)=0.
  120 CONTINUE
      A(1,1)=-1./T1
      A(1,4)=(T2/T1-1.)/T1
      A(2,1)=20.
      A(2,2)=-4.
      A(2,4)=-20.*T2/T1
      A(3,2)=48.
      A(3,3)=-16.
      A(4,3)=1.
***
*   GENERATION OF B MATRIX B(N,M)
***
      DO 130 I=1,N
        DO 130 J=1,M
          B(I,J)=0.
  130 CONTINUE
      B(1,1)=-A(1,4)
      B(2,1)=-A(2,4)
***
*   GENERATION OF C MATRIX C(L,N)
***
      DO 140 I=1,L
        DO 140 J=1,N
          C(I,J)=0.
  140 CONTINUE
      DO 150 I=1,L
        C(I,N)=1.
  150 CONTINUE
```

図 2.34(2)　FORTRAN 77 による $\left\{ \dfrac{\mathrm{d}\boldsymbol{x}(t)}{\mathrm{d}t} = \boldsymbol{A}\boldsymbol{x}(t) + \boldsymbol{B}\boldsymbol{u}(t) \right\}$ の解法ルーチン
$\boldsymbol{x}(0) = \boldsymbol{x}_0,\ \boldsymbol{y}(t) = \boldsymbol{C}\boldsymbol{x}(t)$

```
***
*  PRINT OUT A,B,C  MATRIX
***
      WRITE(6,*) '       A MATRIX'
      DO 160 I=1,N
         WRITE(6,1000) (A(I,J),J=1,N)
  160 CONTINUE

      WRITE(6,*)
      WRITE(6,*) '       B MATRIX'
      DO 170 I=1,N
         WRITE(6,1000) (B(I,J),J=1,M)
  170 CONTINUE

      WRITE(6,*)
      WRITE(6,*) '       C MATRIX'
      DO 180 I=1,L
         WRITE(6,1000) (C(I,J),J=1,N)
  180 CONTINUE

***
*  SAMPLING OF SOLUTIONS                    TAU
*  NUMBER OF SOLUTIONS                      LIMIT
*  SEQUENCE OF CONTROL INPUTS               U(K),K=1,2,...,LIMIT
*  INITIAL CONDITION OF STATE VARIABLE      X(0)
*  MATRICES                                 A,B,C
*  HAVE BEEN SET. NEXT THE STATE EQUATION WILL BE SOLVED
*  BY USING THE SUBROUTINE TRAN
***
      CALL TRAN(N,M,L,TAU,LIMIT,A,B,C,U,X,Y)
***
*  THE STATE EQUATION HAS BEEN SOLVED.

***
***
*  PRINT OUT THE OUTPUT SOLUTION Y(L.LIMIT)
***
      DO 190 I=1,L
        WRITE(6,*)
        WRITE(6,*)'OUTPUT NUMBER='.I
        WRITE(6,1000)(Y(I,K),K=1,LIMIT)
  190 CONTINUE
 1000 FORMAT(1H ,6F13.5)
 1100 FORMAT(1HO)
      STOP
      END
```

図 2.34(3)　FORTRAN 77 による $\left\{\begin{array}{l}\dfrac{d\boldsymbol{x}(t)}{dt}=\boldsymbol{A}\boldsymbol{x}(t)+\boldsymbol{B}\boldsymbol{u}(t)\\ \boldsymbol{x}(0)=\boldsymbol{x}_0,\ \boldsymbol{y}(t)=\boldsymbol{C}\boldsymbol{x}(t)\end{array}\right\}$ の解法ルーチン

```
*****************************************************************
* SUBROUTINE TRAN                                               *
* INPUT PATAMETERS:                                             *
*       (1)      N: ORDER OF THE STATE EQUATION                 *
*       (2)      M: NUMBER OF THE CONTROL INPUT                 *
*       (3)      L: NUMBER OF THE MEASUREMENTS                  *
*       (4)    TAU: SAMPLING INTERVAL (TIME STEP)               *
*       (5) LIMIT: NUMBER OF DATA SOLVED                        *
*       (6)      A: N*N SYSTEM COEFFICIENT MATRIX               *
*       (7)      B: N*M INPUT COEFFICIENT MATRIX                *
*       (8)      C: L*N OUTPUT COEFFICIENT MATRIX               *
*       (9) U(K),K=1,2,...,LIMIT: INPUT CONTROL SEQUENCE       *
*      (10)      X: N*1 INITIAL CONDITION                       *
* OUTPUTS:                                                      *
*      (11) Y(K),K=1,2,...,LIMIT: OUTPUT OF THE SYSTEM          *
*****************************************************************
      SUBROUTINE TRAN(N,M,L,TAU,LIMIT,A,B,C,U,X,Y)
      INTEGER N,M,L,LIMIT,I,J,K,II
      REAL A(N,N),B(N,M),C(L,N),U(M,LIMIT),X(N),Y(L,LIMIT)
      REAL P(10,10),Q(10,10),H(10,10),XX(10)
      REAL TAU,SUM,TT

*** -(TAU/2)*A
      TT=-0.5*TAU
      DO 100 I=1,N
        DO 100 J=1,N
          H(I,J)=TT*A(I,J)
  100 CONTINUE
*** I-(TAU/2)*A
      DO 110 I=1,N
        H(I,I)=1.+H(I,I)
  110 CONTINUE
*** INVERSE OF (I-(TAU/2)*A)
      CALL INVERS(H,N)
*** TAU*(I-(TAU/2)*A)**(-1)
      DO 120 I=1,N
        DO 120 J=1,N
          H(I,J)=TAU*H(I,J)
  120 CONTINUE
*** A*TAU*(I-(TAU/2)*A)**(-1)
      DO 130 I=1,N
        DO 130 J=1,N
          P(I,J)=0.
          DO 130 K=1,N
          P(I,J)=P(I,J)+A(I,K)*H(K,J)
  130 CONTINUE
*** I+A*(I-(TAU/2)*A)**(-1)
      DO 140 I=1,N
        P(I,I)=1.+P(I,I)
  140 CONTINUE
*** Q=TAU*(I-(TAU/2)*A)**(-1)*B
      DO 150 I=1,N
        DO 150 J=1,M
          Q(I,J)=0.
          DO 150 K=1,N
            Q(I,J)=Q(I,J)+H(I,K)*B(K,J)
  150 CONTINUE
***
*  CALCULATION OF SOLUTION
***
      DO 160 I=1,L
        Y(I,1)=0.
```

図 2.34(4)　FORTRAN 77 による $\left\{\begin{array}{l}\dfrac{d\boldsymbol{x}(t)}{dt}=\boldsymbol{A}\boldsymbol{x}(t)+\boldsymbol{B}\boldsymbol{u}(t)\\ \boldsymbol{y}(t)=\boldsymbol{C}\boldsymbol{x}(t),\ \boldsymbol{x}(0)=\boldsymbol{x}_0\end{array}\right\}$ の解法ルーチン

```
  160 CONTINUE
      DO 200 II=2,LIMIT
         DO 170 I=1,N
            XX(I)=0.
            DO 170 J=1,N
               XX(I)=XX(I)+P(I,J)*X(J)
  170     CONTINUE
         DO 180 I=1,N
            SUM=0.
            DO 175 J=1,M
               SUM=SUM+Q(I,J)*U(J,I)
  175       CONTINUE
            X(I)=XX(I)+SUM
  180    CONTINUE
         DO 190 I=1,L
            Y(I,II)=0.
            DO 190 K=1,N
               Y(I,II)=C(I,K)*X(K)+Y(I,II)
  190    CONTINUE
  200 CONTINUE
      RETURN
      END
```

```
*****************************************************************
*  SUBROUTINE INVERS                                            *
*       INPUT:                                                  *
*              A(N,N) MATRIX                                    *
*                                                               *
*      OUTPUT:                                                  *
*              A(N,N) INVERSED                                  *
*****************************************************************
      SUBROUTINE INVERS(A,N)
      REAL A(10,10),W,W2
      INTEGER I,N,W1,K,J,PIVOT(2,10)
      DATA PIVOT/20*0/

      DO 160 I=1,N
         IF(N.EQ.I) GOTO 120
         W=ABS(A(I,I))
         W1=I
         DO 100 K=I+1,N
            IF(W.GE.ABS(A(K,I))) GOTO 100
            W1=K
            W=ABS(A(K,I))
  100    CONTINUE
         IF(W.EQ.0.0) THEN
            WRITE(6,*)'          CAN''T BE DONE '
            STOP
            ENDIF
         IF(W1.EQ.I) GOTO 120
         DO 110 J=1,N
            W2=A(I,J)
            A(I,J)=A(W1,J)
            A(W1,J)=W2
  110    CONTINUE
         PIVOT(1,I)=I
         PIVOT(2,I)=W1
  120    W=A(I,I)
         DO 130 J=1,N
            A(I,J)=A(I,J)/W
```

図 2.34(5)　FORTRAN 77 による $\left\{\begin{array}{l}\dfrac{d\boldsymbol{x}(t)}{dt}=\boldsymbol{A}\boldsymbol{x}(t)+\boldsymbol{B}\boldsymbol{u}(t)\\ \boldsymbol{x}(0)=\boldsymbol{x}_0,\ \boldsymbol{y}(t)=\boldsymbol{C}\boldsymbol{x}(t)\end{array}\right\}$ の解法ルーチン

```
130     CONTINUE
        A(I,I)=1./W
        DO 150 K=1,N
           IF (K.EQ.I) GOTO 150
           W=A(K,I)
           DO 140 J=1,N
              A(K,J)=A(K,J)-W*A(I,J)
140        CONTINUE
           A(K,I)=-W*A(I,I)
150     CONTINUE
160   CONTINUE

      DO 180 I=N,1,-1
         IF(PIVOT(1,I).EQ.0) GOTO 180
         DO 170 J=1,N
            W2=A(J,PIVOT(1,I))
            A(J,PIVOT(1,I))=A(J,PIVOT(2,I))
            A(J,PIVOT(2,I))=W2
170      CONTINUE
180   CONTINUE
      RETURN
      END
```

```
                  SAMPLING INTERVAL TAU=  0.5000000E-01
MAGNITUDE OF STEP CONTROL INPUT UMAG=   1.000000
                           PARAMETER T1=  0.1000000E-01
                           PARAMETER T2=  0.2000000


        A MATRIX
-99.99998       0.00000       0.00000    1899.99976
 20.00000      -4.00000       0.00000    -400.00000
  0.00000      48.00000     -16.00000       0.00000
  0.00000       0.00000       1.00000       0.00000

        B MATRIX
-1899.99976
  400.00000
    0.00000
    0.00000

        C MATRIX
  0.00000       0.00000       0.00000       1.00000

  OUTPUT NUMBER=             1
    0.00000       0.11785       0.44311       0.82948       1.10246       1.23531
    1.24345       1.17885       1.09138       1.01725       0.97254       0.95758
    0.96349       0.97901       0.99493       1.00600       1.01082       1.01055
    1.00741       1.00357       1.00047       0.99869       0.99818       0.99852
    0.99921       0.99988       1.00032       1.00049       1.00045       1.00030
    1.00013       1.00000       0.99993       0.99992       0.99994       0.99997
    0.99999       1.00001       1.00002       1.00001       1.00001       1.00000
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    1.00000       1.00000       1.00000       1.00000       1.00000       0.99999
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    0.99999       0.99999       0.99999       0.99999       0.99999       0.99999
    0.99999       0.99999       0.99999       0.99999
```

図 2.34(6)　FORTRAN 77 による $\left\{\begin{array}{l}\dfrac{d\boldsymbol{x}(t)}{dt}=\boldsymbol{A}\boldsymbol{x}(t)+\boldsymbol{B}\boldsymbol{u}(t)\\ \boldsymbol{x}(0)=\boldsymbol{x}_0,\ \boldsymbol{y}(t)=\boldsymbol{C}\boldsymbol{x}(t)\end{array}\right\}$ の解法ルーチン