11038

STAT

STATUS REPORT

for Period

1 March through 31 March 1970

U. S. GOVERNMENT

[redacted]

STAT

File No. 11038

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This document is presented as the Monthly Status Report under Contract to the U. S. Government,

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The report period represented herein covers the period 1 March through 31 March 1970.

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APPENDICES

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PROGRAM STATUS SUMMARY

Scheduled Percentage of Completion	87.5%
Actual Percentage this Date	81.6%

The [redacted] coordinator and electronic test supervisor are presently at [redacted] preparing for the optical testing. STAT STAT

A meeting was held on March 9 with [redacted] [redacted] regarding the image analysis system and acceptance test procedures. A tentative schedule for acceptance testing is week of April 13, 1970. STAT STAT

TASK 11

STAGE DRIVES

Scheduled percentage of completion	100%
Actual percentage this date	96%

Further investigation into the stage drives has uncovered a problem with the printed circuit motor, specifically the brush holders' inability to firmly hold the brushes against side forces created by the armature.

An Inland motor was tried in place of the P.C. motor to prove this point. The Inland motor is a lower speed motor and to compensate for this, the threadless leadscrew nut will have to be rebuilt to create a greater pitch to maintain the stage speed.

The above rework is in process now on one axis.

Tasks 16, 17 & 18

VIEWING OPTICS, VIEWING ILLUMINATION, RETICLE PROJECTOR and ILLUMINATION

Scheduled percentage of completion	97%
Actual percentage this date	96%

The [redacted] coordinator to [redacted] and his electronics STAT
test supervisor are presently at [redacted] engaged in preliminary STAT
work in preparation for the acceptance tests of the optical assembly. Tests are scheduled to begin on April 3, 1970.

[redacted] Progress Report for February 1970 appears STAT
as Appendix I.

Task 22

INTERFEROMETER ASSEMBLY

Scheduled percentage of completion	100%
Actual percentage this date	75%

A new interferometer p.c. board has been tested using the photo field effect transistor in a follower configuration. This, together with increased gain in the line driver, appears quite satisfactory. Alignment of the Y axis interferometer has been started and is now adequate for partial tests of the Y axis under computer control.

Task 24

IMAGE ANALYSIS SYSTEM

Scheduled percentage of completion	95%
Actual percentage this date	95%

A meeting was held with [redacted] personnel at [redacted] on March 9th. Present from [redacted] STAT STAT STAT

The test plan was reviewed in detail [redacted] and changes were made to reflect the tests required [redacted] As part of the revised test plan [redacted] is required to provide additional calibrated photography and test in greater detail the critical parameters of the equipment. STAT STAT STAT

The test of the completed system is scheduled to begin during the week of April, 13th and is dependent on the availability of the calibrated test photography.

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Task 25

OVERALL SYSTEM LOGIC

Scheduled percentage of completion	85%
Actual percentage this date	90%

The changes referred to in the last report have been wired and partially introduced into the system with satisfactory results. Work has been cautious due to the necessity of having the system performing for program testing.

TASK 43

COMPUTER PROGRAMMING & SERVICES

Scheduled percentage of completion	95%
Actual percentage this date	87%

The sine-wave, frequency analysis, scheme of testing was incorporated in the program CRSTOK, and the entire program was finally made operational. A number of cases were run - both with the frequency analysis tests and the transient pull-in tests. It appears that insofar as the program simulates the optics and the correlator, the method of computation is basically stable - with the proper set of multiplicative constants introduced. At least tentatively, a set of values has been determined for these multiplicative constants, and it appears that the <u>same</u> values may work over the whole range of optical settings - a surprising conclusion. These results are sufficiently encouraging that priority for this type of testing has been greatly downgraded, and the tests discontinued - at least for the time being.

Because of the complexity of the computer-correlator system for controlling the optics, a number of quite drastic simplifying assumptions were necessary in order to formulate a practical scheme for the sine-wave testing. The image analysis system (correlator) compares two nearly similar

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images and outputs four analog signals which represent four respects in which the two images differ from one another: X-scale factor, X-skew factor, Y-scale factor, and Y-skew factor. The computer translates these four signals into commands for controlling the four basic elements of each optical projection system: magnification, anamorphic ratio, image rotation, and anamorph rotation. As a result the optical elements should move in such directions as to make the two scale factors approach the value one and the two skew factors approach the value zero. Thus the optics-computer-correlator combination may be looked on as constituting four inter-linked negative feedback loops.

The computational scheme is based on an algebraically "exact" solution of the first order projection equations for the optical system. The solution is not computed directly, however, but is first differentiated and then integrated. The differentiation is done analytically, but the integration is done digitally by the computer. Thus the net effect should be that the integration cancels the differentiation, except possibly for some additive constants, and the results should be substantially the same as would be obtained by direct computation.* Consequently it seems reasonable to assume that if there were no crosstalk between

*The purpose in performing differentiation and integration is to separate the computations into a background portion and a foreground portion.

the four output signals from the correlator then the four interrelated feedback loops should be separable at the points of driving the optical elements. This was one of the basic assumptions in setting up the sine-wave method for testing the computational scheme.

Appendix III shows a listing of the program CRSTOK with its subroutines STATIC, OPSET, OPCOMP, and MONITR. CRSTOK and OPCOMP contain the computational scheme which is used in the Stereocomparator. STATIC and the statements in CRSTOK from the top of page 2 down to statement 50 (CONTINUE) simulate the correlator. OPSET simulates the projection optics and provides for teletype input of initial settings for the simulated optics. MONITR provides for operator interface via the teletype.

Statement #120 in MONITR provides the driving signals for the sine-wave tests. This statement is the analytical equivalent of opening the four feedback loops at the driving points for the optical elements. Were these feedback loops not opened then XSI (J, 2) would be the settings of the slave optical elements: anamorph ratio, magnification, image rotation, and anamorph rotation. With statement #120, XSI (J, 2) become the driven values of these same optical settings and XSS (J) are the corresponding response values for the optical settings after going around the feedback loops to just ahead of where the loops are broken. BETA (J) are feedback factors which can be adjusted to control the degree of opening the feedback loops: BETA = 0 corresponds to no

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feedback, or the loop completely open; BETA = 1 corresponds to 100% feedback or the loop completely closed; and intermediate values of BETA correspond to the feedback loop being partly open. AMPL (J) are the amplitudes of the sinusoidal driving functions in the respective loops and (ANGL) is the angular frequency. XSD (J) are the d-c values about which the sinusoidal fluctuations take place.

Appendix IVa shows a small sampling of slightly over thirty such sine-wave tests which were run. The remainder of the curves are not included since they are all virtually identical to one or another of the curves which are included. The very great similarity of curves obtained for different optical settings was a surprising feature of the tests, and ultimately led to the conclusion that one or more of the assumptions underlying this method of testing must be invalid. Consequently the sine-wave scheme of testing was discontinued and the transient pull-in scheme was taken up instead. The latter scheme will be discussed later, but first a little more should be said about the results of the sine-wave tests.

The computer program tests which are being reported here came about as a result of a realization that the portion of the computer program which computes the optics settings corresponding to particular correlator signals was possibly unstable as originally designed. The original scheme was hence modified by introducing GAINFR (K) into statement 30 of OPCOMP, where previously the fixed value one had existed implicitly. This modification then raised the problem of determining optimum values for GAINFR (K), and it seemed likely that the optimum values would be (non-constant) functions of the optical settings. Hence arose the need to determine the nature of these functions. The sine-wave type of testing was intended to be a systematic way of handling the very large number of different cases which occur. Thus GAINFR (K), (K = 1, 2, 3, 4), is thought of as being like a gain control by which the loop gain of each of the four feedback loops can be set. Linear feedback theory gives some well known criteria for examining curves of open loop gain and phase shift versus frequency and judging what the closed loop performance is apt to be.

Figures 1 through 4 are four curves selected from a large number of tests intended to show the effects of varying anamorphic ratio and the two rotation angles while maintaining magnification constant - at the value 12. The results turned out to be that the effects were negligible. Figure 1 is highly typical of all the tests in this series except those presented as Figures 2, 3, and 4. The latter are the cases which varied most from all the rest. Even the variation among these extreme cases is not enough to be of any significance. The theory behind tests of this type says that the thing to look at is the phase shift at the frequency at which loop gain passes through zero db. In these curves zero db gain occurs at about 1.6 radians/sec. and the

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phase shift at this frequency is 110 degrees. Since 110 degrees is considerably less than the danger value - 180° - it appears that the GAINFR for the magnification channel might be made slightly, but not much, larger than the value .05 at which the tests were run. The surprising indication of this series of tests is that the optimum value of GAINFR for the magnification channel (at least at the value 12X) does not appear to be effected by the optical settings for the other three channels.

Figure 5 is typical of the curves run in the second series of tests - similar to the first series - but with the magnification held at the value 60X. All the curves in this series turned out to be nearly identical. Although this series included a smaller number of individual cases that the first series, the results again indicated that the optimum value of GAINFR for the magnification channel does not appear to be effected by settings in the other three channels. Furthermore the indication seems to be that the optimum value for 60X is not appreciably different from that for 12X - another surprising result.

Figures 6 through 9 are curves obtained in the third and last series of sine-wave tests. This series was run to check the dawning suspicion that the sine-wave tests, at least as being run, weren't accomplishing the purpose for which they were intended. This series was one with the optical settings held constant, but with GAINFR for the magnification channel varied directly. Since GAINFR is one of the factors making up the loop gain, linear feedback theory says the various gain curves in this series should be similar in shape, to one another, but shifted parallel to themselves, when GAINFR is varied. Comparing the curves obtained shows that they shift, qualitatively, in the right direction, but, quantitatively, by an amount which is much too small. Thus a change in GAINFR by a factor of 10 should produce a 20 db. vertical-shift in the loop gain curves. Figures 6 and 9 have over a 10/1 factor in GAINFR but show a shift of well under 10 db. Figures 8 and 9 should show a shift of 6 db. but have virtually none at all. Thus it seems that the very much simplified assumptions underlying this particular method of testing are of questionable validity and any conclusions which might be drawn from them would hence also be questionable. Thus the sine-wave method of testing was not proving to be a short path to optimum values for GAINFR. Rather than trying to perfect this method of testing, the simpler, but seemingly less systematic, transient pull-in scheme of testing was returned to.

The transient pull-in scheme of testing had been tried earlier, but was somewhat unsuccessful due to the large number of individual cases and the long time required for typing the results of each case - as originally set up. Read-out problems of earlier versions of the program CRSTOK were solved only after the part of the program dealing with teletype output was broken out into a separate subroutine - MONITR.* Several

*See Task 43 of Status Report (Job 342) for January 1970.

revisions of MONITR finally resulted in the present version, which gives the operator complete control of how much or how little data is typed out, and with flexibility to change the amount during the coarse of a particular run. It is somewhat coincidental that this same version of MONITR also incorporates the sine-wave scheme of testing.

A key factor in reducing the amount of data which must be typed out, however, was devising a criterion by which the computer could "recognize" an "end point" for a particular run. It then became necessary only to type out final values at the end of each run, thus eliminating the time consuming process of typing intermediate values throughout the progress of each test. An operator can, however, specify additional type-out to verify that any particular run is really valid.

Appendix IVb is a tabulation of the "end-point" values obtained from a number of individual runs. In each test the first three lines, XSI (1), XSI (2), and GAINFR, are inputs to the program - typed by the operator. The last two lines, XSI (2), and N are final values for the particular run - typed by the computer. XSI (1) and XSI (2) stand for master and slave optical settings: anamorph ratio, magnification, image rotation, and anamorph rotation. GAINFR are the same parameters, discussed previously, for which optimum values are being sought. N is the number of iterations which the program makes in order to arrive at the program determined "end point" of the particular run. Thus, in this scheme of testing, the values of

GAINFR are strictly trial and error operator inputs. The value criterion for any particular set of GAINFR are the accuracy with which line 4 approaches line 1 and the smallness of N. A rough idea of the significance of a particular value of N may be obtained by dividing the value by 30 and considering the result to be the time, in seconds, for the Stereocomparator to "pull-in" from the optical settings given in lines 1 and 2. It should be remembered, however, that this mathematical model of the optics and correlator is probably a pretty poor representation of the Stereocomparator hardware.

The cases which have been run to date, and shown in Appendix IVb, are not an exhaustive coverage of the possible optical settings, but are a pretty good sampling over the possible range of settings. The indications are that the same values of GAINFR are fairly satisfactory over the whole range - which was not expected to be the case. At any rate there does not seem to be much doubt that suitable values can be found. Consequently priory for running these tests has been down graded to the extent that such tests are not presently being run, but may be resumed when the computer is in less demand.

In conclusion, there is probably some value in speculating as to why the sine-wave testing did not go as expected - even though there are no plans for trying to perfect the method. A likely possibility is that the assumption of separability of the four inter-related feedback loops is not valid. Under this assumption the tests were run with the values for BETA set to 1 on the three channels being treated as inactive in each particular test. This was thought to be the condition most like that which would exist in the Stereocomparator. Apparently, however, the four feedback loops are so closely linked together that these values of BETA exerted a strong influence on the channel being tested (magnification in the cases which were run). It may be that lower values of BETA on the "inactive" channels would have resulted in the tested channel behaving more nearly as expected. Tests with low values of BETA on all channels would require careful interpretation however. Thus it may be that the sine-wave method of testing would be alright for a single feedback loop, but is not very useful for a set of inter-linked feedback loops.

Applicable sections of [redacted] progress STAT report for the period of Feb. 16 to Feb. 28 are included as Appendex II of this report.

APP. I

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 STAT

NM/ST
MONTHLY PROGRESS REPORT
February 1970

S T E R E O C O M P A R A T O R

During the month of February, our efforts have been essentially devoted to the adjustments on the reticle branch.

As it has been mentionned in our January Report, it has been found that the optical field was too large in certain cases of magnification and anamorph ratio and that it cannot fit with the afocal reducer 1/50 X.

A first afocal-1 X system has been designed and mounted on the 10 ratio zoom of the reticle branch. This experiment has shown that it was necessary to make a second change, consequently a new divergent optical element has been placed in the afocal -1 X but the performances.was still insufficient. Then a third experiment has been made using a divergent element in two parts, one of this lens had a non polished surface of which the purpose was to enlarge the field of the optical rays coming from the edge of the spot.

The system has been rejected by because the quality of STAT the spot was spoiled by the non polished surface which was in the plane of an intermediate image.

A this time we are doing a final experiment with a fourth lens.

Some others changes has been made on the reticle branch :

- the reticle illumination has been entirely redesigned.
- the objective lens of 200 mm focal lenght which is located in the afocal reducer 1/50 X has been remade.

Because of this changes and experiments the beginning of acceptance tests [redacted] will be on the 25th of March.

APP. II

MONTHLY PROGRESS REPORT

February 1970

This technical report is for the period February 16 to February 28, 1970. The report is prepared according to [redacted] STAT
[redacted] Specification number DB1001 (as modified). STAT

1. During March, the real time background (under the control of TMAT) will be updated and integrated with a driver such that test cases can be run in preparation for acceptance tests. Also, the moment the stages become operable, the read/command routines will be mated with the hardware. If this goes well, the time tic and fiducial input routines will be thoroughly unit-tested.

2. At this time it appears that [redacted] is intensively studying the STAT
correlator response. A change in the program may result from this work. If this happens, [redacted] may submit a request STAT
for change-of-scope, depending on the magnitude of the change.

3. There are no pending unresolved contractual problems.

4. [redacted] has been verbally assured that at least one stage STAT
would be working (i.e. its position can be read, and it can be commanded to new positions) by March 23, 1970.

5. No changes or agreements have been made requiring approval of the contracting officer.

6. Since returning to [redacted] has encountered extraordinary difficulty with the computer hardware (particularly the punch) and with certain vital utility routines, written [redacted] and supplied to us [redacted] under the terms of our contract. We feel that these matters must be resolved before we can effectively carry out the terms of this contract.

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APP. III

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Appendix III

Computer Program

"CRSTOK"

```
      SUBROUTINE CRSTOK  1/26/70
      COMMON XSI(4,2), XKMI(2,2,2), XMKI(2,2,2), XK1K2(2,2)
      COMMON CORR(2,2), STTC(2,2), PXSL(4,4), DXL(4), DXS(4)
      COMMON DLTAAB(2,2), XPS(4), XSS(4), DTH1(4), DTH3(4)
      COMMON XST(4), XKM(2,2), XSD(4), GAINFR(4), PI, N, IGAIN
      DIMENSION ABCD(4), TMP1(2,2), TMP2(2,2)
      EQUIVALENCE (ABCD(1),A), (ABCD(2),B), (ABCD(3),C)
      EQUIVALENCE (ABCD(4),D), (DXL(1),TMP2(1,1))
      EQUIVALENCE (DXS(1),TMP1(1,1))
      REAL MAG
      DLTAAB(1,1)= 1.0
      DLTAAB(1,2)= 0.0
      DLTAAB(2,1)= 0.0
      DLTAAB(2,2)= 1.0
      PI= 3.14159265
      ARV= ALOG(EXP(PI))
      ITAG= 0
      IGAIN= 0
    1 DO 5  J=1,4
      DO 5  K=1,4
    5 PXSL(J,K)= 0.0
      DO 100  NL=1,60
      CALL SSWTCH(1, I)
      DO 7  J=1,2
      DO 7  K=1,2
      IF (I.EQ.1) CORR(J,K)= DLTAAB(J,K)
    7 CONTINUE
      CALL OPSET(XST,XSI,N)
      CALL MONITR
   10 DO 30  I=1,2
      TRACE S1, C1, S3, C3, A, B, C, D
      SMLA=  XSI(1,I)
      MAG=   XSI(2,I)
      TH1=   XSI(3,I)
      TH2=   XSI(4,I)
      TH3=   TH1 + 2.0*TH2
      S1=    SIN(TH1)
      C1=    COS(TH1)
      S3=    SIN(TH3)
      C3=    COS(TH3)
      A1= 0.5*(SMLA + 1.0)*MAG
      A2= 0.5*(SMLA - 1.0)*MAG
      A=   A1*C1 + A2*C3
      B= -A1*S1 + A2*S3
      C=  A1*S1 + A2*S3
      D=   A1*C1 - A2*C3
      XKMI(1,1,I)= A
      XKMI(1,2,I)= B
      XKMI(2,1,I)= C
      XKMI(2,2,I)= D
      DTNT= A*D - B*C
      XMKI(1,1,I)=  D/DTNT
      XMKI(1,2,I)= -B/DTNT
      XMKI(2,1,I)= -C/DTNT
   30 XMKI(2,2,I)=  A/DTNT
   35 DO 40  J=1,2
      DO 40  K=1,2
      IF (NL.EQ.1) XKM(J,K)= XKMI(J,K,2)
      XK1K2(J,K)= 0.0
      DO 40  L=1,2
```

```
C
C
C
C
C
C     XK1K2 IS THE IDEAL VALUE OF CORR, STTC IS CROSSTALK PER-
C     TURBATION OF CORR.
C
      CALL STATIC(XK1K2,STTC)
      DO 50 J=1,2
      DO 50 K=1,2
      COR= XK1K2(J,K) + STTC(J,K) - CORR(J,K)
      CORE= CORR(J,K) + 0.3185*COR
      IF (J.EQ.K) COR= SIGN(AINT(ABS(CORE - 1.0)*50.0 + 0.5)/
     X 50.0,(CORE - 1.0)) + 1.0
      IF (J.NE.K) COR= SIGN(AINT(ABS(CORE)*100.0 + 0.5)/100.0,CORE)
      CORR(J,K)= COR
   50 CONTINUE
C
C
C     PXSL EQUALS THE PARTIAL DERIVATIVES OF XSI W.R.T. ABCD,
C     NUMBER 2 SIDE ONLY.
C
   51 IF (NL.NE.1) GO TO 90
      TRACE PXSL, ITAG
      F1= A**2 + B**2 + C**2 + D**2
      F2= 2.0*DINT
      F4= (A-D)**2 + (B+C)**2
      F5= (A+D)**2 + (B-C)**2
      F3= F4*F5
      FT= F4/F2
C
      IF (FT.GT.5.0E-7) GO TO 55
      ITAG= 1
      SA= 1.0
      XSI(1,2)= SA
      XST(1)= SA
      DO 52 K=1,4
   52 PXSL(1,K)= 0.0
      GO TO 79
C
   55 IF (ITAG.EQ.0) GO TO 60
      XSI(4,2)= (ATAN2(B+C,A-D) - XSI(3,2))/2.0
      XST(4)=   (ATAN2(B+C,A-D) - XST(3))/2.0
      ITAG= ITAG + 1
      IF (ABS(XSI(4,2)).GT.PI/2.0) XSI(4,2)= XSI(4,2) - PI
      IF (ABS(XST(4)).GT.PI/2.0) XST(4)= XST(4) - PI
C
   60 B1= F1/F2
      B2= SQRT(F3)/F2
      SA= B1 + B2
      V=  2.0*B1/F1
      W=  2.0*SA/F2
C
C
C
C
C
C
C
C
C
```

```
C
C
C
      TT= B2*F5*(A-D)/F3
      T=  B2*F4*(A+D)/F3
      UU= B2*F4*(B-C)/F3
      U=  B2*F5*(B+C)/F3
C
      PXSL(1,1)= A*V + TT + T - D*W
      PXSL(1,2)= B*V + UU + U + C*W
      PXSL(1,3)= C*V - UU + U + B*W
      PXSL(1,4)= D*V - TT + T - A*W
C
   70 EM= SQRT((F2/2.0)/SA)
      F1= 2.0*EM*SA
      F2= F2/(2.0*F1*SA)
C
      DO 72 K=1,4
      L= 5-K
      F3= ABCD(L)/F1
      IF (K.EQ.2 .OR. K.EQ.3) F3= -F3
   72 PXSL(2,K)= F3 - F2*PXSL(1,K)
C
   75 DTH1(1)= (B-C)/F5
      DTH1(4)= DTH1(1)
      DTH1(3)= (A+D)/F5
      DTH1(2)= -DTH1(3)
C
      IF (FT.GT.5.0E-7) GO TO 78
   76 DO 77 K=1,4
   77 DTH3(K)= DTH1(K)
      GO TO 79
C
   78 IF (ITAG.EQ.0) GO TO 785
      IF (ITAG.GT.2) ITAG= 0
      GO TO 76
C
  785 DTH3(4)= (B+C)/F4
      DTH3(1)= -DTH3(4)
      DTH3(2)= (A-D)/F4
      DTH3(3)= DTH3(2)
C
   79 DO 80 K=1,4
      PXSL(3,K)= DTH1(K)
   80 PXSL(4,K)= (DTH3(K) - DTH1(K))/2.0
C
   90 DO 92 J=1,2
      DO 92 K=1,2
   92 TMP1(J,K)= CORR(J,K) - DLTAAB(J,K)
      DO 93 J=1,2
      DO 93 K=1,2
      TMP2(K,J)= 0.0
      DO 93 L=1,2
   93 TMP2(K,J)=TMP2(K,J) + TMP1(J,L)*XKM(L,K)
C
C     SEE EQUIVALENCES
C
      CALL OPCOMP
C
C
C
```

```
C
C
C
C
C
C
C
      IF (XST(1).LT.  1.0) XST(1)=  1.0
      IF (XST(1).GT.  2.0) XST(1)=  2.0
      IF (XST(2).LT. 10.0) XST(2)= 10.0
      IF (XST(2).GT.200.0) XST(2)=200.0
      DO 100 L=3,4
  991 IF (XST(L).GT.-PI) GO TO 992
      XST(L)= XST(L) + 2.0*PI
      GO TO 991
  992 IF (XST(L).LE.+PI) GO TO 100
      XST(L)= XST(L) - 2.0*PI
      GO TO 992
  100 CONTINUE
      GO TO 1
      END
 $0   @-------
 END OF JOB
```

```
      SUBROUTINE STATIC (XK1K2,STTC)  2/9/70
      DIMENSION XK1K2(2,2), STTC(2,2), COEF(2,2,4), TMP1(2,2),TMP2(2,2),
     X DLTAAB(2,2)
      DATA DLTAAB(1,1),DLTAAB(2,2),DLTAAB(1,2),DLTAAB(2,1)/
     X 2*1.0, 2*0.0/
  500 FORMAT (15H  INPUT COEF(A))
  520 FORMAT (15H  INPUT COEF(B))
  540 FORMAT (15H  INPUT COEF(C))
  560 FORMAT (15H  INPUT COEF(D))
  600 FORMAT (4F15.6)
      CALL SSWITCH(1,I)
      GO TO(10,100),I
   10 WRITE(1,500)
      READ(1,600)((COEF(I,J,1),I=1,2),J=1,2)
      WRITE(1,520)
      READ(1,600)((COEF(I,J,2),I=1,2),J=1,2)
      WRITE(1,540)
      READ(1,600)((COEF(I,J,3),I=1,2),J=1,2)
      WRITE(1,560)
      READ(1,600)((COEF(I,J,4),I=1,2),J=1,2)
   20 DO 30 J=1,2
      DO 30 K=1,2
      STTC(J,K)=0.0
   30 TMP1(J,K)=XK1K2(J,K)-DLTAAB(J,K)
      DO 34 K=1,2
      DO 34 L=1,2
      STTC(1,K)=STTC(1,K)+COEF(1,L,K)*TMP1(1,L)+COEF(2,L,K)*TMP1(2,L)
   34 STTC(2,K)= STTC(2,K)+COEF(1,L,K+2)*TMP1(1,L)+COEF(2,L,K+2)
     X  *TMP1(2,L)
      DO 35 K=1,2
      DO 35 L=1,2
   35 STTC(K,L)=STTC(K,L)*TMP1(K,L)
      RETURN
  100 GO TO 20
      K= K/L
      XK= K
      L= ALOG10(XK**XK)
      END
 40  @END OF JOB
END OF JOB
```

1/30/70

```
      SUBROUTINE OPSET(XST, XSI, N)
      COMMON DUM1(64), XPS(4), DUM2(30)
      DIMENSION XSI(4,2), XST(4)
  500 FORMAT (15H   INPUT XSI(1))
  550 FORMAT (15H   INPUT XSI(2))
  600 FORMAT (4F10.6)
      CALL SSWTCH(1,I)
      GO TO (10,20),I
   10 WRITE (1,500)
      READ (1,600) (XSI(J,1),J=1,4)
      WRITE (1,550)
      READ (1,600) (XSI(J,2),J=1,4)
      PI= 3.14159265
      N= -1
      DO 15 K=1,4
      XST(K)= XSI(K,2)
   15 XPS(K)= 0.0
   20 CALL SSWTCH(2,I)
      GO TO (30,40),I
   30 WRITE (1,550)
      READ (1,600) (XSI(J,2),J=1,4)
   40 DO 50 K=1,4
      TMP1= XST(K) - XSI(K,2)
      IF (K.LT.3) GO TO 45
   44 IF (TMP1.LT.-PI) TMP1= TMP1 + 2.0*PI
      IF (TMP1.GT.+PI) TMP1= TMP1 - 2.0*PI
      IF (ABS(TMP1).GT.+PI) GO TO 44
   45 TMP2= XPS(K)
      XSI(K,2)= XSI(K,2) + .02416*TMP2 + .1305*TMP1
   50 XPS(K)= 6.981*TMP1 + .4589*TMP2
      IF (XSI(1,2).LT.1.0) XSI(1,2)= 1.0
      IF (XSI(1,2).GT.2.0) XSI(1,2)= 2.0
      IF (XSI(2,2).LT.10.) XSI(2,2)= 10.
      IF (XSI(2,2).GT.200.) XSI(2,2)= 200.
      DO 55 L= 3,4
   52 IF (XSI(L,2).GT.-PI) GO TO 53
      XSI(L,2)= XSI(L,2)+2.0*PI
      GO TO 52
   53 IF (XSI(L,2).LE.+PI) GO TO 55
      XSI(L,2)= XSI(L,2)-2.0*PI
      GO TO 53
   55 CONTINUE
      IF (XPS(1).LT.-.3333333) XPS(1)= -.3333333
      IF (XPS(1).GT.+.3333333) XPS(1)= +.3333333
      RMLT= .367*XSI(2,2)*2.094
      IF (XPS(2).LT.-RMLT) XPS(2)= -RMLT
      IF (XPS(2).GT.+RMLT) XPS(2)= +RMLT
      DO 56 L=3,4
      IF (XPS(L).LT.-2.094) XPS(L)= -2.094
      IF (XPS(L).GT.+2.094) XPS(L)= +2.094
   56 CONTINUE
      N= N + 1
   60 RETURN
      END
 ∅∅    ∅----
 END OF JOB
```

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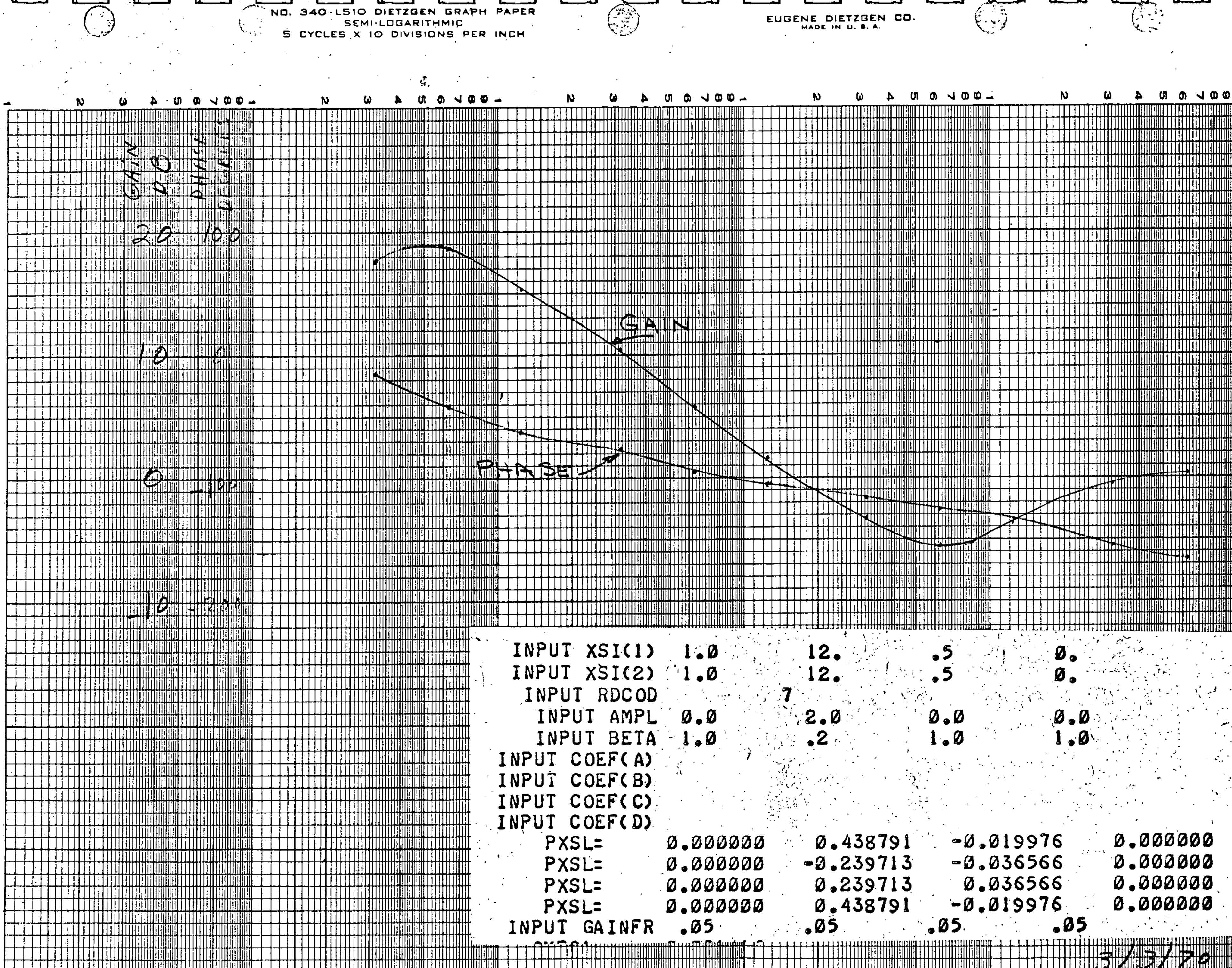
```
      SUBROUTINE OPCOMP 2/6/70
      COMMON XSI(4,2), XKMI(2,2,2), XMKI(2,2,2), XKIK2(2,2)
      COMMON CORR(2,2), STTC(2,2), PXSL(4,4), DXL(4), DXS(4)
      COMMON DLTAAB(2,2), XPS(4), XSS(4), DTH1(4), DTH3(4)
      COMMON XST(4), XKM(2,2), XSD(4), GAINFR(4), PI, N, IGAIN
      DIMENSION ABCD(4), TMP1(2,2), TMP2(2,2)
      EQUIVALENCE (ABCD(1),A), (ABCD(2),B), (ABCD(3),C)
      EQUIVALENCE (ABCD(4),D), (DXL(1),TMP2(1,1))
      EQUIVALENCE (DXS(1),TMP1(1,1))
  500 FORMAT (15H   INPUT GAINFR)
  600 FORMAT (4F10.4)
  650 FORMAT (12H       PXSL= ,4F12.6)
      IF (IGAIN.NE.0) GO TO 20
      WRITE (1,650) PXSL
      WRITE (1,500)
      READ (1,600) GAINFR
      IGAIN= 1
   20 DO 30 J=1,4
      XSI(J,2)= XSS(J)
      DO 30 K=1,4
   30 XST(J)= XST(J) + PXSL(J,K)*GAINFR(K)*DXL(K)
   40 RETURN
      END
  00    0----
END OF JOB
```

```
      SUBROUTINE MONITR 2/22/70
      COMMON XSI(4,2), XKMI(2,2,2), XMKI(2,2,2), XK1K2(2,2)
      COMMON CORR(2,2), STTC(2,2), PXSL(4,4), DXL(4), DXS(4)
      COMMON DLTAAB(2,2), XPS(4), XSS(4), DTH1(4), DTH3(4)
      COMMON XST(4), XKM(2,2), XSD(4), GAINFR(4), PI, N, IGAIN
      INTEGER RDCOD(4), RDCD
      DIMENSION ABCD(4), AMAG(4), AMP2(4), AMPL(4), BETA(4),
     1DBG(4), TMP1(2,2), TMP2(2,2), PHI(4), PSI(4), Y1(4), Y2(4),
     2Y3(4), Y4(4), Y5(4)
      EQUIVALENCE (ABCD(1),A), (ABCD(2),B), (ABCD(3),C)
      EQUIVALENCE (ABCD(4),D), (DXL(1),TMP2(1,1))
      EQUIVALENCE (DXS(1),TMP1(1,1))
      MODD(M1,M2)= M1 - (M1/M2)*M2
  500 FORMAT (7H    N= ,I4//)
  550 FORMAT (12H       XPS= ,4F12.6/)
  600 FORMAT (12H    XSI(1)= ,4F12.6/)
  650 FORMAT (12H    XSI(2)= ,4F12.6//)
  700 FORMAT (12H     XK1K2= ,4F12.6/)
  750 FORMAT (12H      CORR= ,4F12.6//)
  800 FORMAT (12H       DXL= ,4F12.6/)
  850 FORMAT (12H       XST= ,4F12.6//)
  900 FORMAT (12H      PXSL= ,4F12.6)
 1000 FORMAT (12H      XAVE= ,4F12.6)
 1050 FORMAT (12H       DBG= ,4F12.6)
 1100 FORMAT (12H       PHI= ,4F12.6)
 1110 FORMAT (12H     INAMP= ,4F12.6)
 1120 FORMAT (12H       PSI= ,4F12.6//)
 1150 FORMAT (12H     OMEGA= , F12.6)
 1200 FORMAT (15H    INPUT RDCOD)
 1250 FORMAT (15H     INPUT AMPL)
 1260 FORMAT (15H     INPUT BETA)
 1270 FORMAT (15H       INPUT NS)
 1300 FORMAT (4I10)
 1350 FORMAT (4F10.6)
 1360 FORMAT (I5)
      CALL SSWTCH(3,IR)
      IF (IGAIN.NE.0 .AND. IR.EQ.2) GO TO 10
      WRITE (1,1200)
      READ (1,1300) RDCOD
      WRITE (1,1250)
      READ (1,1350) AMPL
      WRITE (1,1260)
      READ (1,1350) BETA
      ICOD= MODD(RDCOD(1),10)
      NS= 0
      E= 2.7182818
      IF (ICOD.NE.2 .AND. ICOD.NE.3) GO TO 10
      WRITE (1,1270)
      READ (1,1360) NS
      NS= NS - 1
      N= 0
   10 DO 15 J=1,4
      IF (IGAIN.EQ.0) XSD(J)= XSI(J,2)
   15 XSS(J)= XSI(J,2)
      NM= MODD(N,60)
      J= 4
      IF (NM.EQ.1) J= 2
      IF (NM.GT.1 .AND. MODD(N,5).EQ.1) J= 3
```

```
      DO 11  K= 1,2
      DO 11  L= 1,2
      IF (K.EQ.L .AND. (CORR(K,L).LT.0.7 .OR. CORR(K,L).GT.1.4))
     1RDCD= RDCOD(1)
      IF (K.NE.L .AND. ABS(CORR(K,L)).GT.0.3) RDCD= RDCOD(1)
      IF (CORR(K,L).NE.DLTAAB(K,L) .AND. N.LE.600 .OR. ICOD.NE.0)
     1GO TO 112
   11 CONTINUE
      IF (N.LT.1) GO TO 112
      RDCD= RDCOD(1)
      LAST= LAST + 1
  112 IF (RDCD.LT.40) GO TO 50
      WRITE (1,500) N
      IF (RDCD.LT.10000) GO TO 12
      WRITE (1,600) (XSI(J,1), J=1,4)
      RDCD= RDCD - 10000
   12 IF (RDCD.LT. 4000) GO TO 14
      WRITE (1,650) (XSI(J,2), J=1,4)
      RDCD= RDCD -  4000
   14 IF (RDCD.LT. 2000) GO TO 16
      WRITE (1,550) XPS
      RDCD= RDCD -  2000
   16 IF (RDCD.LT. 1000) GO TO 18
      WRITE (1,750) CORR
      RDCD= RDCD -  1000
   18 IF (RDCD.LT.  400) GO TO 20
      WRITE (1,700) XK1K2
      RDCD= RDCD -   400
   20 IF (RDCD.LT.  200) GO TO 22
      WRITE (1,800) DXL
      RDCD= RDCD -   200
   22 IF (RDCD.LT.  100) GO TO 24
      WRITE (1,850) XST
      RDCD= RDCD -   100
   24 IF (RDCD.LT.   40) GO TO 50
      WRITE (1,900) PXSL
      RDCD= RDCD -   40
   50 IF (ICOD.NE.0) GO TO 100
      IF (LAST.GE.2) PAUSE
      RETURN
  100 IF (NS.EQ.0) N= 0
      IF (MODD(N,500).EQ.0 .AND. (ICOD.EQ.1 .OR. ICOD.EQ.3))
     1WRITE (1,500) N
      IF (N.GT.0) GO TO 110
      NS= NS + 1
      DO 105 J= 1,4
      Y1(J)= 0.0
      Y2(J)= 0.0
      Y3(J)= 0.0
      Y4(J)= 0.0
  105 Y5(J)= 0.0
      IF (NS.EQ. 1) LNTH= 6000
      IF (NS.EQ. 2) LNTH= 3000
      IF (NS.EQ. 3) LNTH= 1500
      IF (NS.EQ. 4) LNTH=  600
      IF (NS.EQ. 5) LNTH=  300
      IF (NS.EQ. 6) LNTH=  150
      IF (NS.EQ. 7) LNTH=   60
      IF (NS.EQ. 8) LNTH=   30
      IF (NS.EQ. 9) LNTH=   15
      IF (NS.EQ.10) LNTH=    6
```

```
C
C
C
C
C
C
      AL= LNTH
      OMEGA= 60.0*PI/AL
  110 AN= N
      ANGL= AN*OMEGA/30.0
      DO 120 J= 1,4
  120 XSI(J,2)= XSD(J) + AMPL(J)*SIN(ANGL) + BETA(J)*(XSS(J) -
     1XSD(J))
      IF (N.LT.300) RETURN
      DO 130 J= 1,4
      XS= XSS(J)/AL
      XI= XSI(J,2)/AL
      Y1(J)= Y1(J) + XS
      Y2(J)= Y2(J) + 2.0*XS*SIN(ANGL)
      Y3(J)= Y3(J) + 2.0*XS*COS(ANGL)
      Y4(J)= Y4(J) + 2.0*XI*SIN(ANGL)
  130 Y5(J)= Y5(J) + 2.0*XI*COS(ANGL)
      IF (N.LT.300 + LNTH) RETURN
      N= -1
      DO 140 J= 1,4
      AMP= SQRT (Y4(J)**2 + Y5(J)**2)
      AMP2(J)= AMP
      PSI(J)= ATAN2(Y5(J),Y4(J))
      IF (AMP.EQ.0.0) AMP= 1.0
      AMAG(J)= SQRT(Y2(J)**2 + Y3(J)**2)
      IF (AMAG(J).EQ.0.0) AMAG(J)= 1.0
      DBG(J)= 20.0*ALOG10(AMAG(J)/AMP)
      PHI(J)= 180.0*(ATAN2(Y3(J),Y2(J)) - PSI(J) - PI)/PI
  140 PSI(J)= 180.0*PSI(J)/PI
      WRITE (1,1150) OMEGA
      WRITE (1,650) XSS
      WRITE (1,1000) Y1
      WRITE (1,1050) DBG
      WRITE (1,1100) PHI
      WRITE (1,1110) AMP2
      WRITE (1,1120) PSI
      IF (NS.GE.11) PAUSE
      RETURN
      END
$0---@----
END OF JOB
```

APP. IVa



INPUT XSI(1)	1.Ø	12.	.5	Ø.
INPUT XSI(2)	1.Ø	12.	.5	Ø.
INPUT RDCOD	7			
INPUT AMPL	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø
INPUT BETA	1.Ø	.2	1.Ø	1.Ø
INPUT COEF(A)				
INPUT COEF(B)				
INPUT COEF(C)				
INPUT COEF(D)				
PXSL=	Ø.ØØØØØØ	Ø.438791	-Ø.Ø19976	Ø.ØØØØØØ
PXSL=	Ø.ØØØØØØ	-Ø.239713	-Ø.Ø36566	Ø.ØØØØØØ
PXSL=	Ø.ØØØØØØ	Ø.239713	Ø.Ø36566	Ø.ØØØØØØ
PXSL=	Ø.ØØØØØØ	Ø.438791	-Ø.Ø19976	Ø.ØØØØØØ
INPUT GAINFR	.Ø5	.Ø5	.Ø5	.Ø5

FIG 1.

W = ANGULAR FREQUENCY = 2πf

App. IVa Sine-Wave Tests

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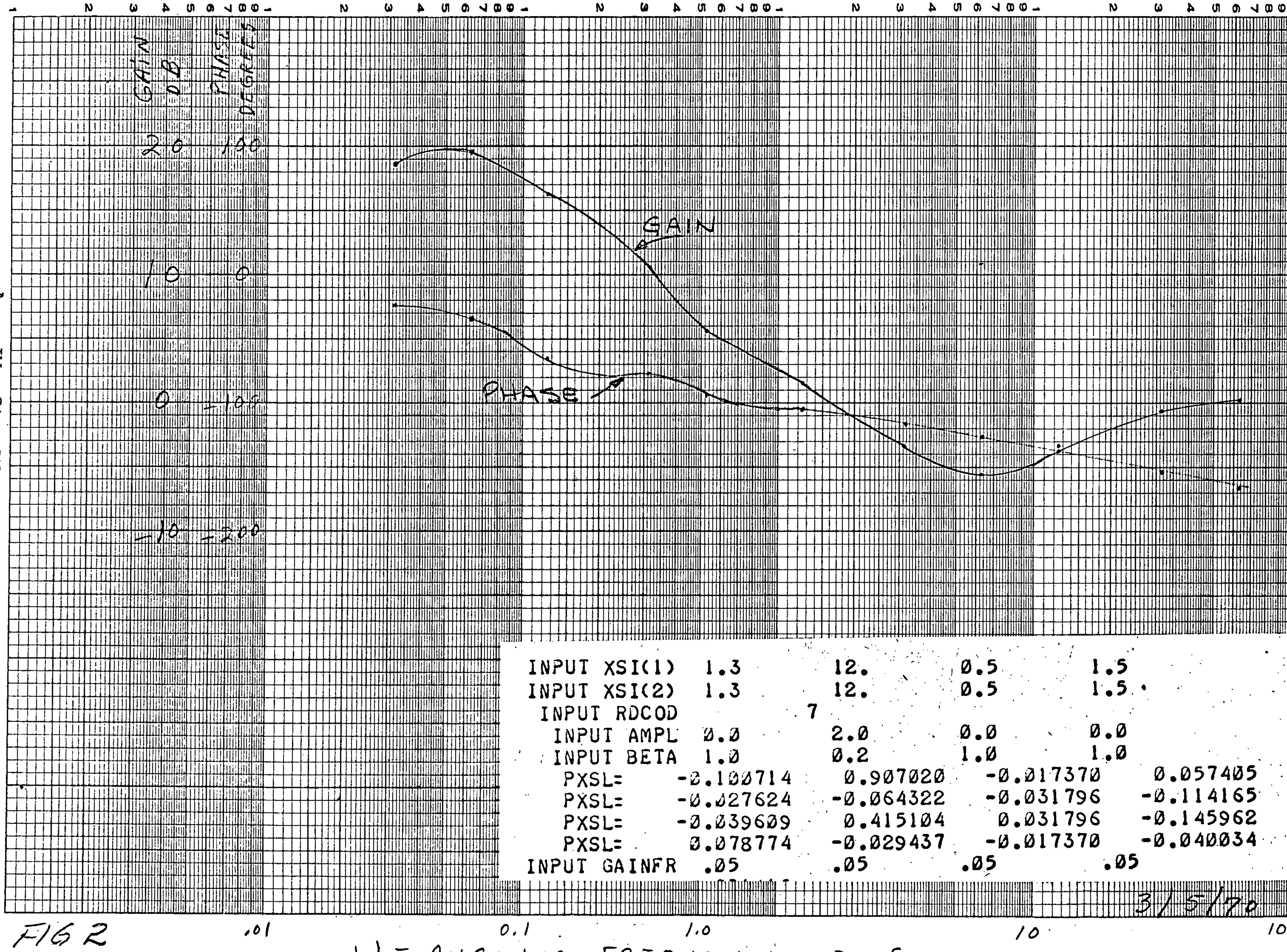

INPUT XSI(1)	1.3	12.	0.5	1.5
INPUT XSI(2)	1.3	12.	0.5	1.5
INPUT RDCOD		7		
INPUT AMPL	0.0	2.0	0.0	0.0
INPUT BETA	1.0	0.2	1.0	1.0
PXSL=	-0.100714	0.907020	-0.017370	0.057405
PXSL=	-0.027624	-0.064322	-0.031796	-0.114165
PXSL=	-0.039609	0.415104	0.031796	-0.145962
PXSL=	0.078774	-0.029437	-0.017370	-0.040034
INPUT GAINFR	.05	.05	.05	.05

FIG 2

App. IVa Sine-Wave Tests

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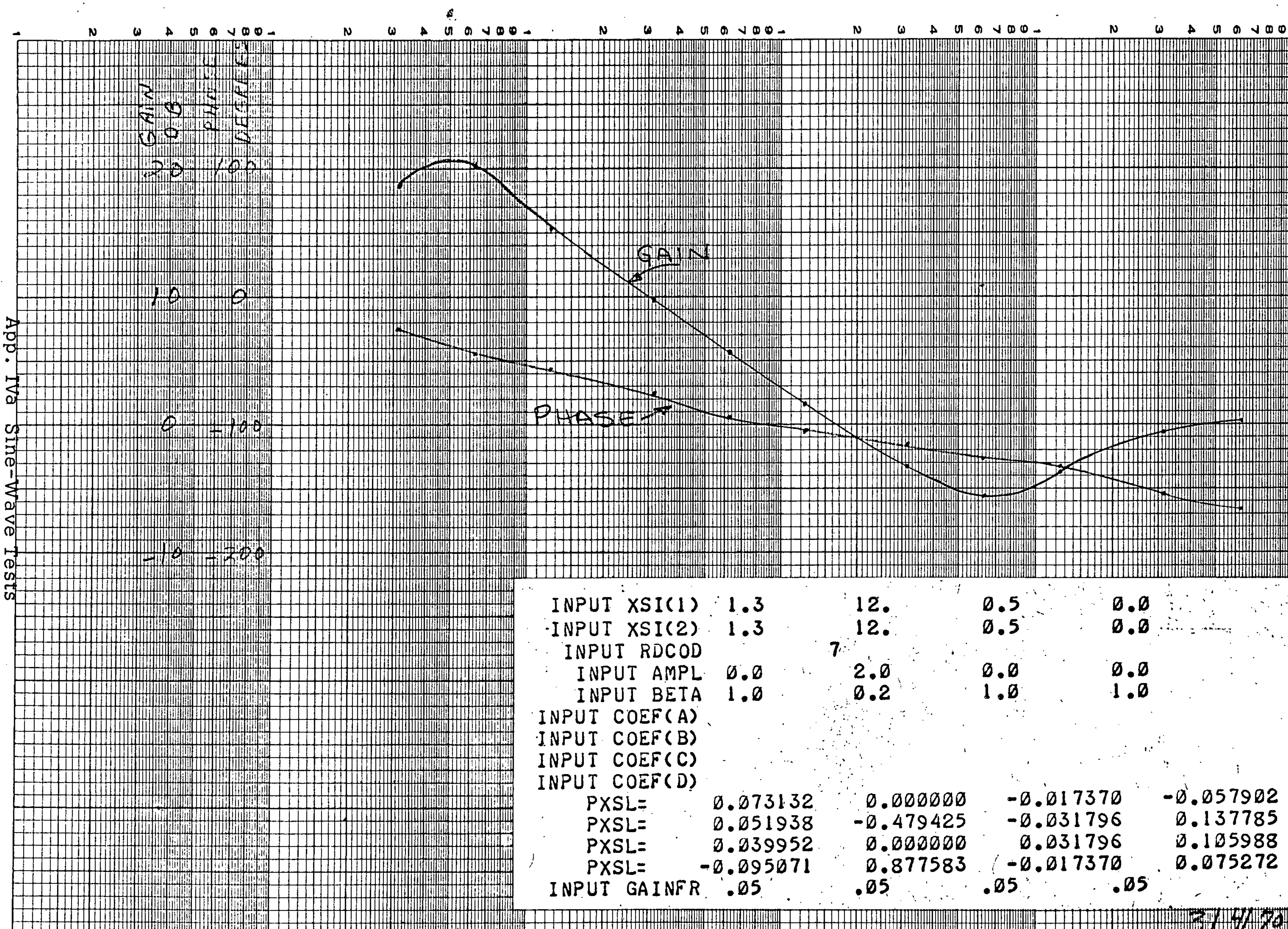
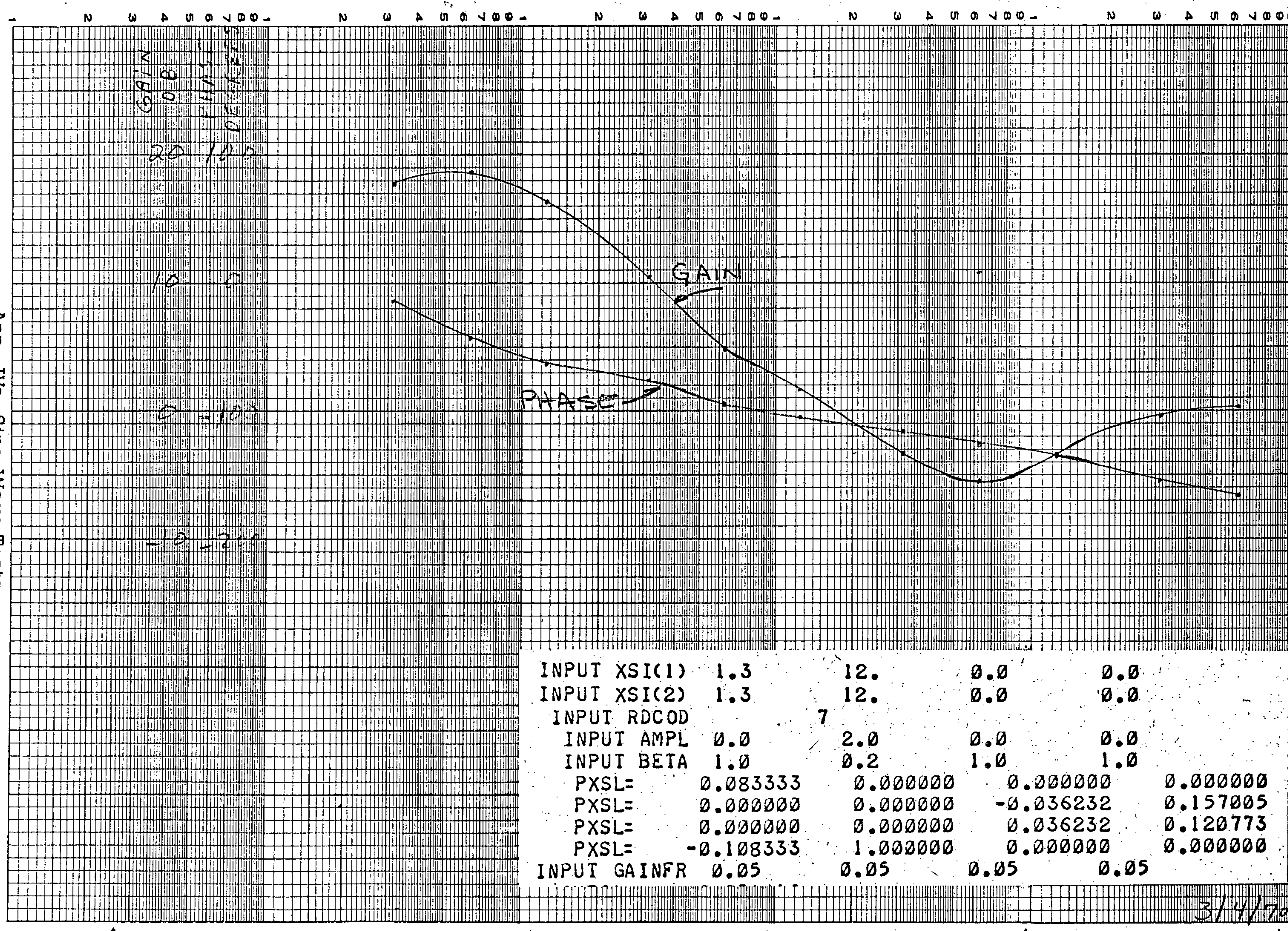


INPUT XSI(1)	1.3	12.	0.5	0.0
INPUT XSI(2)	1.3	12.	0.5	0.0
INPUT RDCOD		7		
INPUT AMPL	0.0	2.0	0.0	0.0
INPUT BETA	1.0	0.2	1.0	1.0
INPUT COEF(A)				
INPUT COEF(B)				
INPUT COEF(C)				
INPUT COEF(D)				
PXSL=	0.073132	0.000000	-0.017370	-0.057902
PXSL=	0.051938	-0.479425	-0.031796	0.137785
PXSL=	0.039952	0.000000	0.031796	0.105988
PXSL=	-0.095071	0.877583	-0.017370	0.075272
INPUT GAINFR	.05	.05	.05	.05

3/4/70

FIG 3

App. IVa Sine-Wave Tests

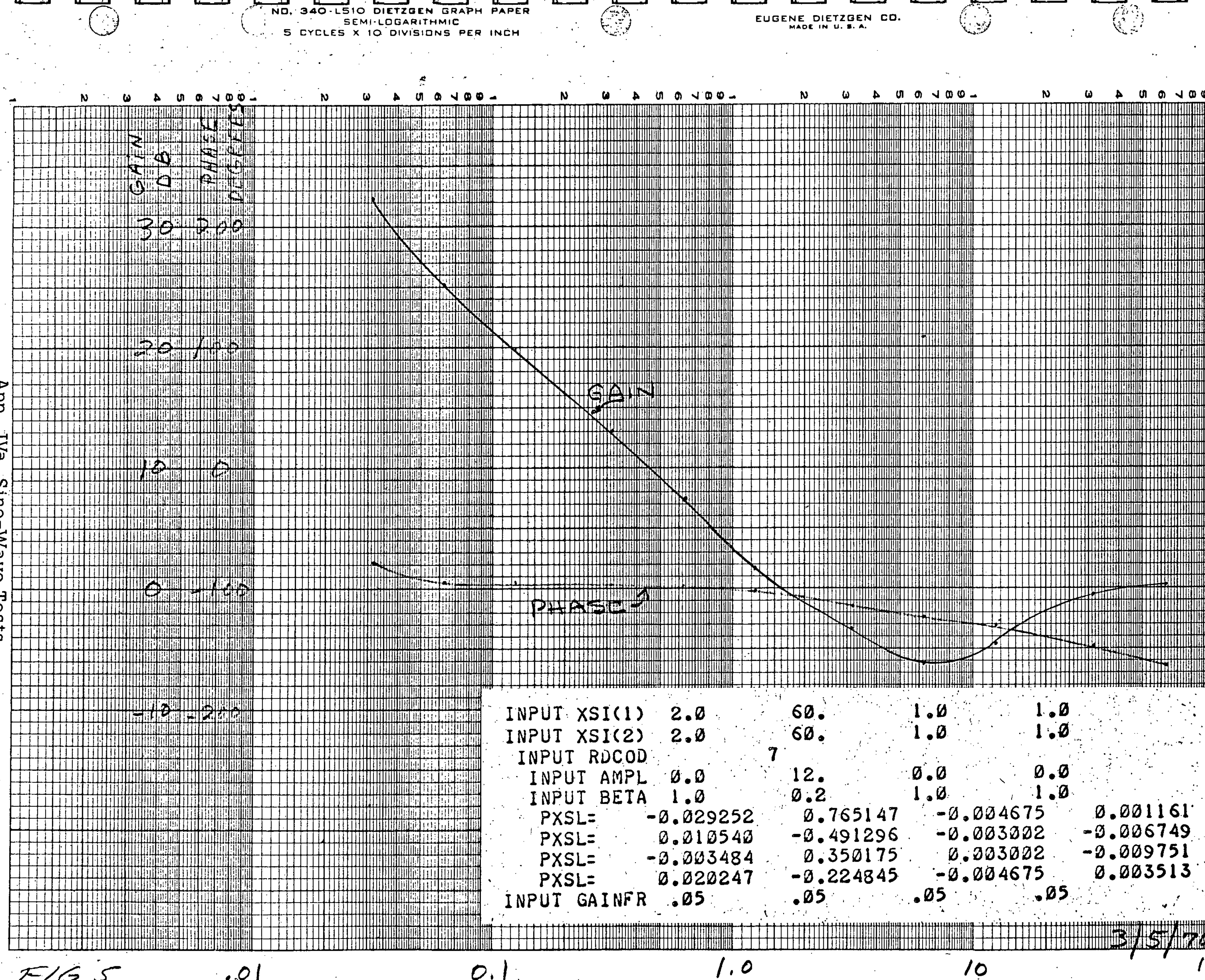


INPUT XSI(1)	1.3	12.	0.0	0.0
INPUT XSI(2)	1.3	12.	0.0	0.0
INPUT RDCOD		7		
INPUT AMPL	0.0	2.0	0.0	0.0
INPUT BETA	1.0	0.2	1.0	1.0
PXSL=	0.083333	0.000000	0.000000	0.000000
PXSL=	0.000000	0.000000	-0.036232	0.157005
PXSL=	0.000000	0.000000	0.036232	0.120773
PXSL=	-0.108333	1.000000	0.000000	0.000000
INPUT GAINFR	0.05	0.05	0.05	0.05

FIG 4

W = ANGULAR FREQUENCY = $2\pi f$

App. IVa Sine-Wave Tests



INPUT XSI(1)	2.0	60.	1.0	1.0
INPUT XSI(2)	2.0	60.	1.0	1.0
INPUT RDCOD		7		
INPUT AMPL	0.0	12.	0.0	0.0
INPUT BETA	1.0	0.2	1.0	1.0
PXSL=	-0.029252	0.765147	-0.004675	0.001161
PXSL=	0.010540	-0.491296	-0.003002	-0.006749
PXSL=	-0.003484	0.350175	0.003002	-0.009751
PXSL=	0.020247	-0.224845	-0.004675	0.003513
INPUT GAINFR	.05	.05	.05	.05

FIG 5

App. IVa Sine-Wave Tests

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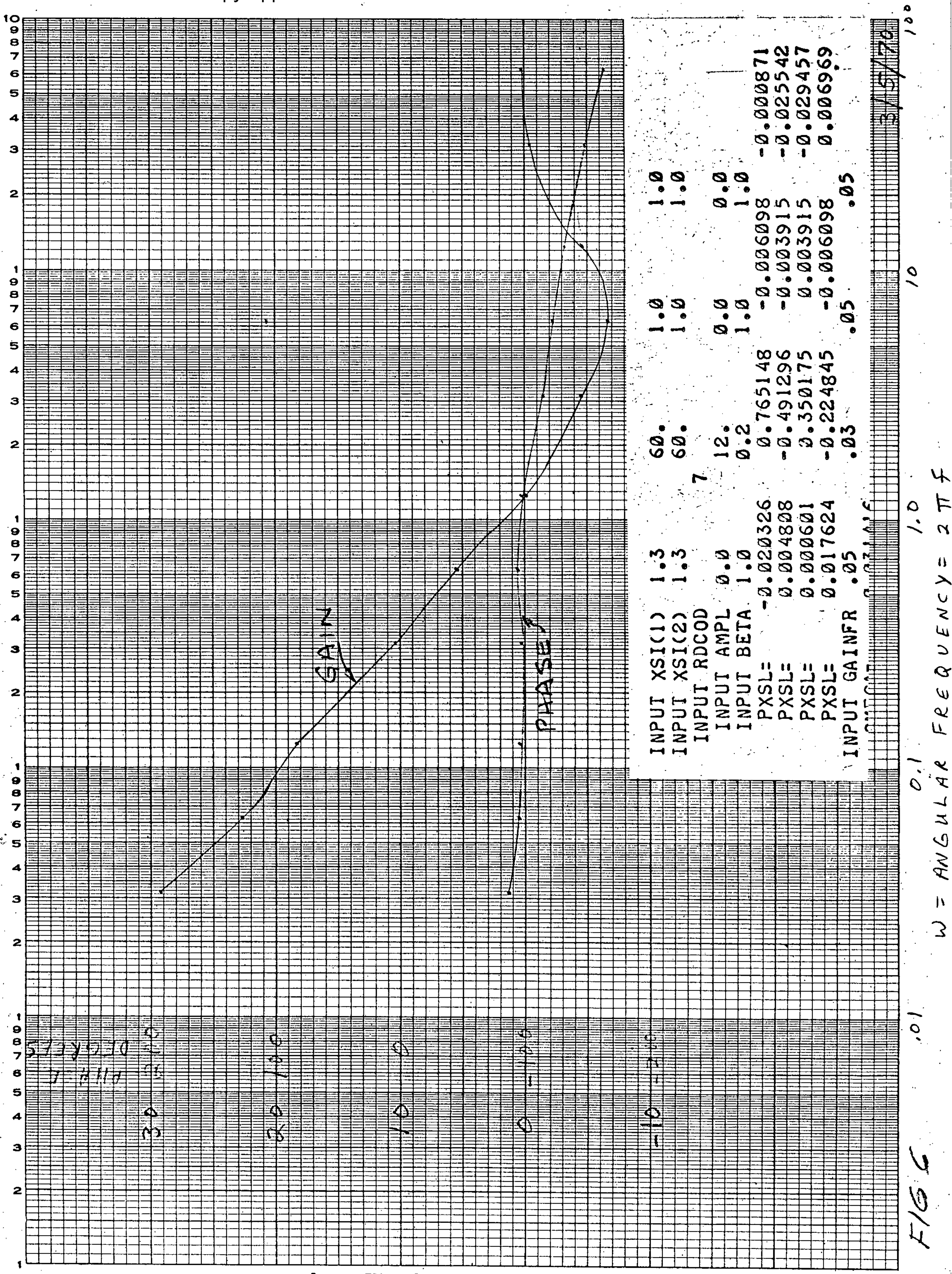
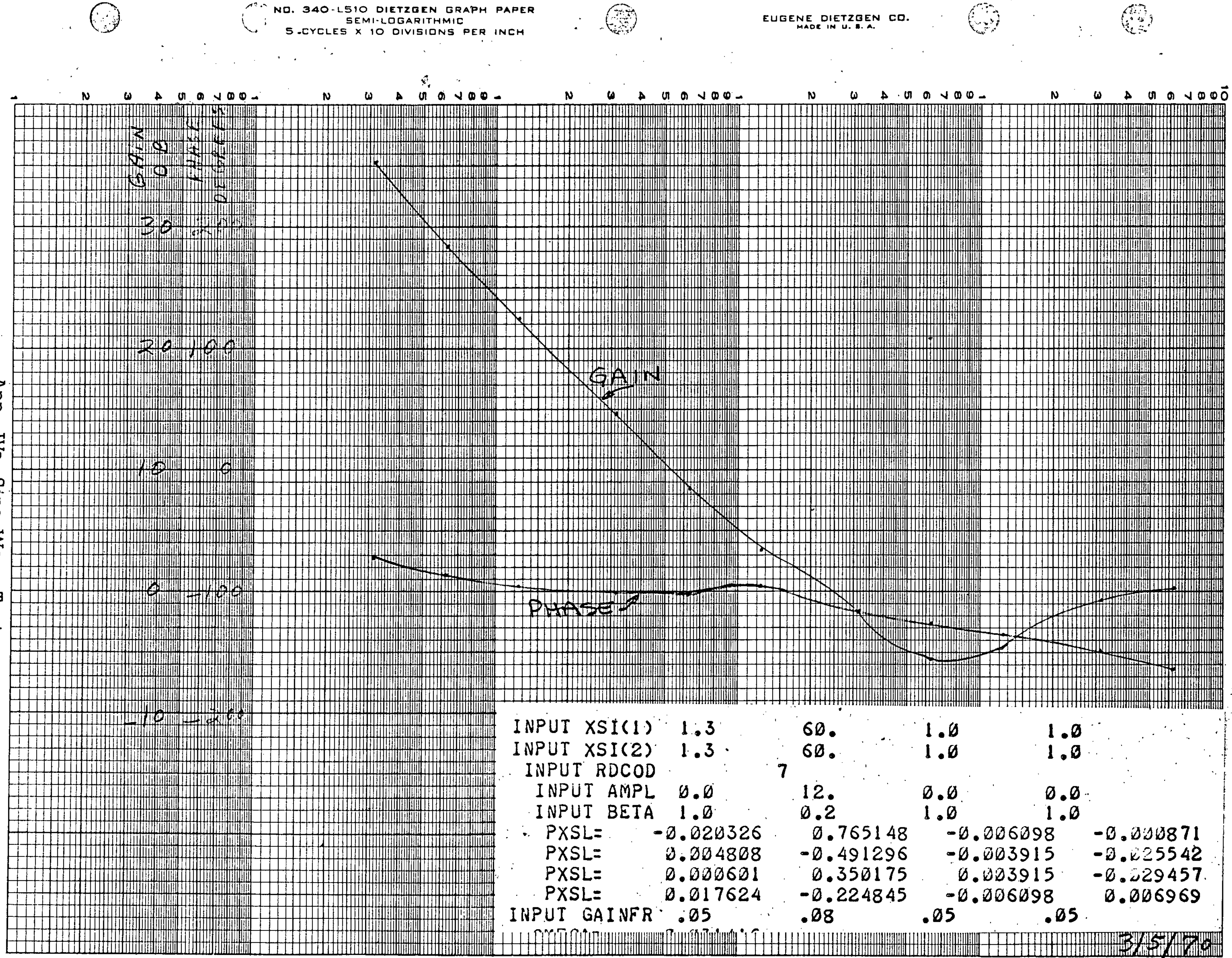


App. IVa Sine-Wave Tests

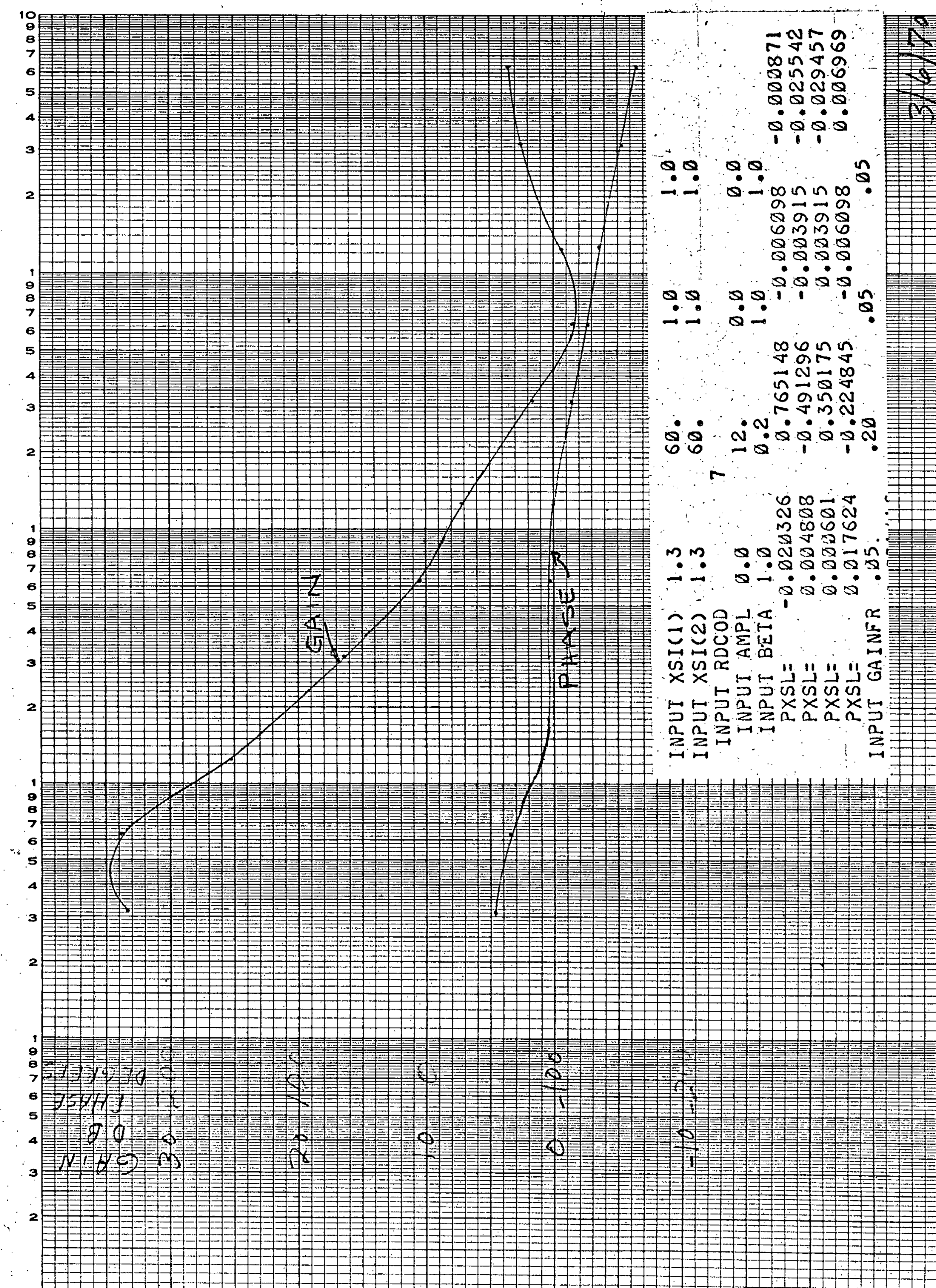


INPUT XSI(1)	1.3	60.	1.0	1.0
INPUT XSI(2)	1.3	60.	1.0	1.0
INPUT RDCOD		7		
INPUT AMPL	0.0	12.	0.0	0.0
INPUT BETA	1.0	0.2	1.0	1.0
PXSL=	-0.020326	0.765148	-0.006098	-0.000871
PXSL=	0.004808	-0.491296	-0.003915	-0.025542
PXSL=	0.000601	0.350175	0.003915	-0.029457
PXSL=	0.017624	-0.224845	-0.006098	0.006969
INPUT GAINFR	.05	.08	.05	.05

FIG 7

W = ANGULAR FREQUENCY = 2πf

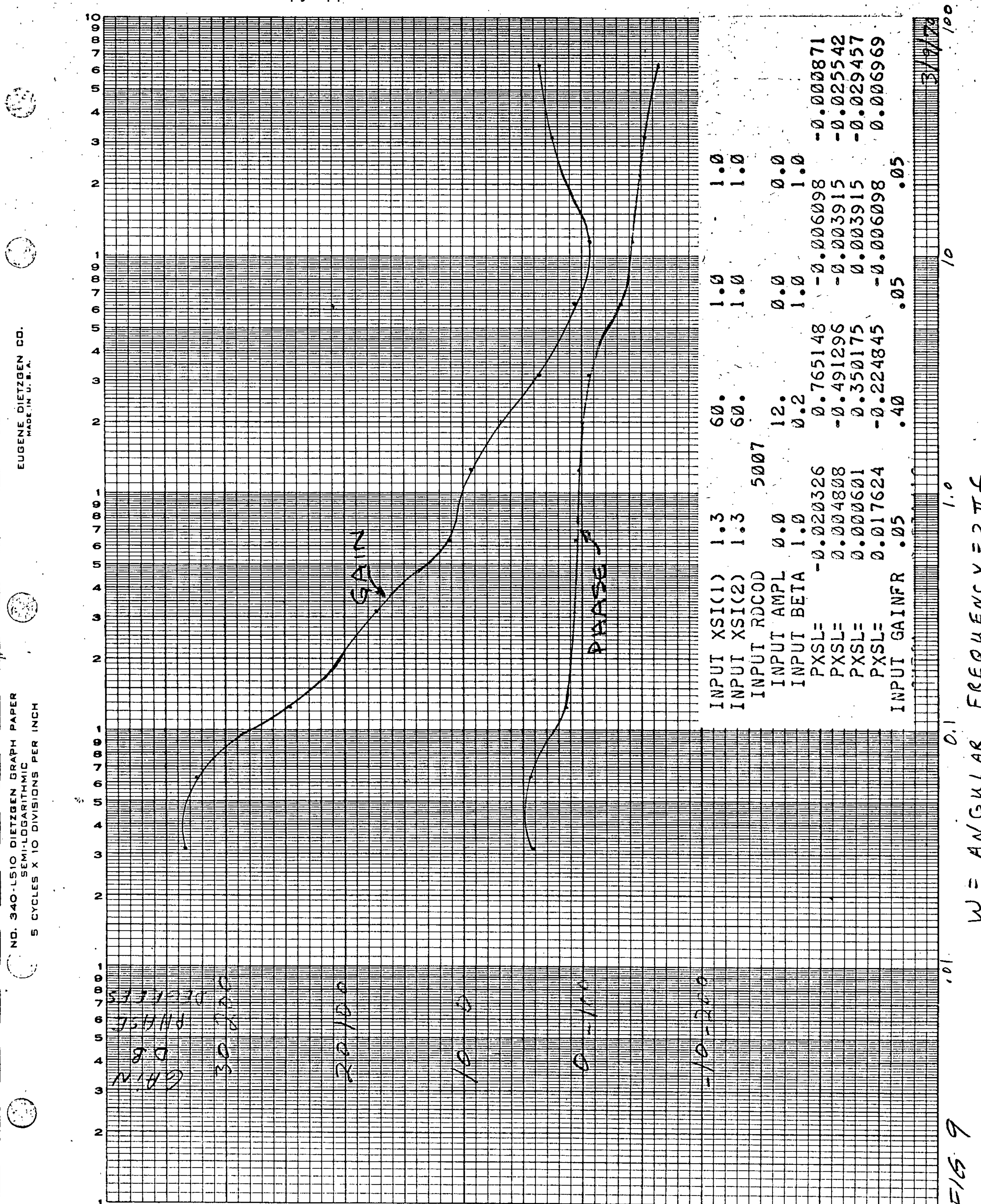
App. IVa Sine-Wave Tests



W = ANGULAR FREQUENCY = 2πf

FIG 8

App. IVa Sine-Wave Tests



App. IVa Sine-Wave Tests

APP. IVb

Appendix IVb

TRANSIENT PULL-IN TESTS

	Anamorph Ratio	Magni-fication	Image Rotation	Anamorph Rotation
XSI(1)	1.3	40.	1.0	1.0
XSI(2)	1.24	32.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.322	40.084	1.009	0.962
N	342			
XSI(1)	1.3	40.	1.0	1.0
XSI(2)	1.24	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.313	40.461	1.009	0.972
N	138			
XSI(1)	1.3	80.	1.0	1.0
XSI(2)	1.24	64.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.322	80.168	1.009	0.962
N	342			
XSI(1)	1.3	80.	1.0	1.0
XSI(2)	1.24	96.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.313	80.923	1.009	0.972
N	138			

	Anamorph Ratio	Magni-fication	Image Rotation	Anamorph Rotation
XSI(1)	1.3	120.	1.0	1.0
XSI(2)	1.24	96.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.322	120.254	1.009	0.962
N	342			
XSI(1)	1.3	120.	1.0	1.0
XSI(2)	1.24	144.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.313	121.365	1.009	0.972
N	138			
XSI(1)	1.8	60.	1.0	1.0
XSI(2)	1.96	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.769	59.937	1.014	1.015
N	86			
XSI(1)	1.3	160.	1.0	1.0
XSI(2)	1.24	192.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.313	161.846	1.009	0.972
N	138			
XSI(1)	1.3	60.	1.0	1.0
XSI(2)	1.24	48.	0.8	0.8
GAINFR	.05	.35	.35	.35
XSI(2)	1.301	58.575	0.990	1.014
N	264			

	Anamorph Ratio	Magni-fication	Image Rotation	Anamorph Rotation
XSI(1)	1.3	60.	1.0	1.0
XSI(2)	1.24	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.322	60.127	1.009	0.962
N	342			
XSI(1)	1.3	60.	1.0	1.0
XSI(2)	0.36	48.	0.8	0.8
GAINFR	.05	.35.	.35	.35
XSI(2)	1.317	60.266	1.007	0.964
N	114			
XSI(1)	1.3	60.	1.0	1.0
XSI(2)	1.36	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.321	58.474	1.002	1.033
N	125			
XSI(1)	1.5	60.	1.0	1.0
XSI(2)	1.4	48.	0.8	0.8
GAINFR	.05	.35	.35	.35
XSI(2)	1.505	58.518	0.993	1.003
N	127			
XSI(1)	1.5	60.	1.0	1.0
XSI(2)	1.4	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.442	60.785	1.004	1.015
N	143			

	Anamorph Ratio	Magni-fication	Image Rotation	Anamorph Rotation
XSI(1)	1.5	60.	1.0	1.0
XSI(2)	1.6	48.	0.8	0.8
GAINFR	.05	.35	.35	.35
XSI(2)	1.475	59.678	1.014	1.030
N	120			
XSI(1)	1.5	60.	1.0	1.0
XSI(2)	1.6	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.502	61.276	1.011	0.994
N	149			
XSI(1)	1.8	60.	1.0	1.0
XSI(2)	1.64	48.	0.8	0.8
GAINFR	.05	.35	.35	.35
XSI(2)	1.787	61.525	0.998	0.986
N	86			
XSI(1)	1.8	60.	1.0	1.0
XSI(2)	1.64	48.	0.8	0.8
GAINFR	.10	.35	.35	.35
XSI(2)	1.773	59.819	1.012	1.012
N	95			
XSI(1)	1.8	60.	1.0	1.0
XSI(2)	1.96	48.	0.8	0.8
GAINFR	.05	.35	.35	.35
XSI(2)	1.823	60.365	1.007	0.981
N	87			

	Anamorph Ratio	Magni- fication	Image Rotation	Anamorph Rotation
XSI(1)	1.3	160.	1.0	1.0
XSI(2)	1.24	128.	0.8	0.8
GAINFR	.10	.35	.35	.35
Out of correlation		N = 239 - 246		
XSI(2)	1.278	157.496	0.999	0.962
N	318			