New Folder Name Interferometer Handbook

BATCH
START

Intro

STAPLE
OR
DIVIDER

FROM: JEFF HARMAN

TO: OWNERS OF "INTERFEROMETER LOCKING SERVO HANDBOOK,"
"BLUE BOOK"

SUBJECT: UPDATES, DEC 2, 1987

ENCLOSED ARE PAGES REFLECTING THE STATE OF THE INTERFEROMETER TODAY. THESE SHOULD BE ADDED TO THE APPROPRIATE SECTIONS. IN THOSE CASES WHERE THE UPDATES OBSOLETE THE EXISTING SECTIONS, MARK THOSE PAGES OBSOLETE, BUT KEEP THEM FOR [illegible]

IT IS SUGGESTED THAT THE MOST CURRENT PAGES BE KEPT AT THE FRONT OF EACH SECTION.

FUTURE UPDATES WILL BE PROVIDED MONTHLY.

J. HARMAN (4 COPIES)

R. DREVER

W. ALTHOUSE

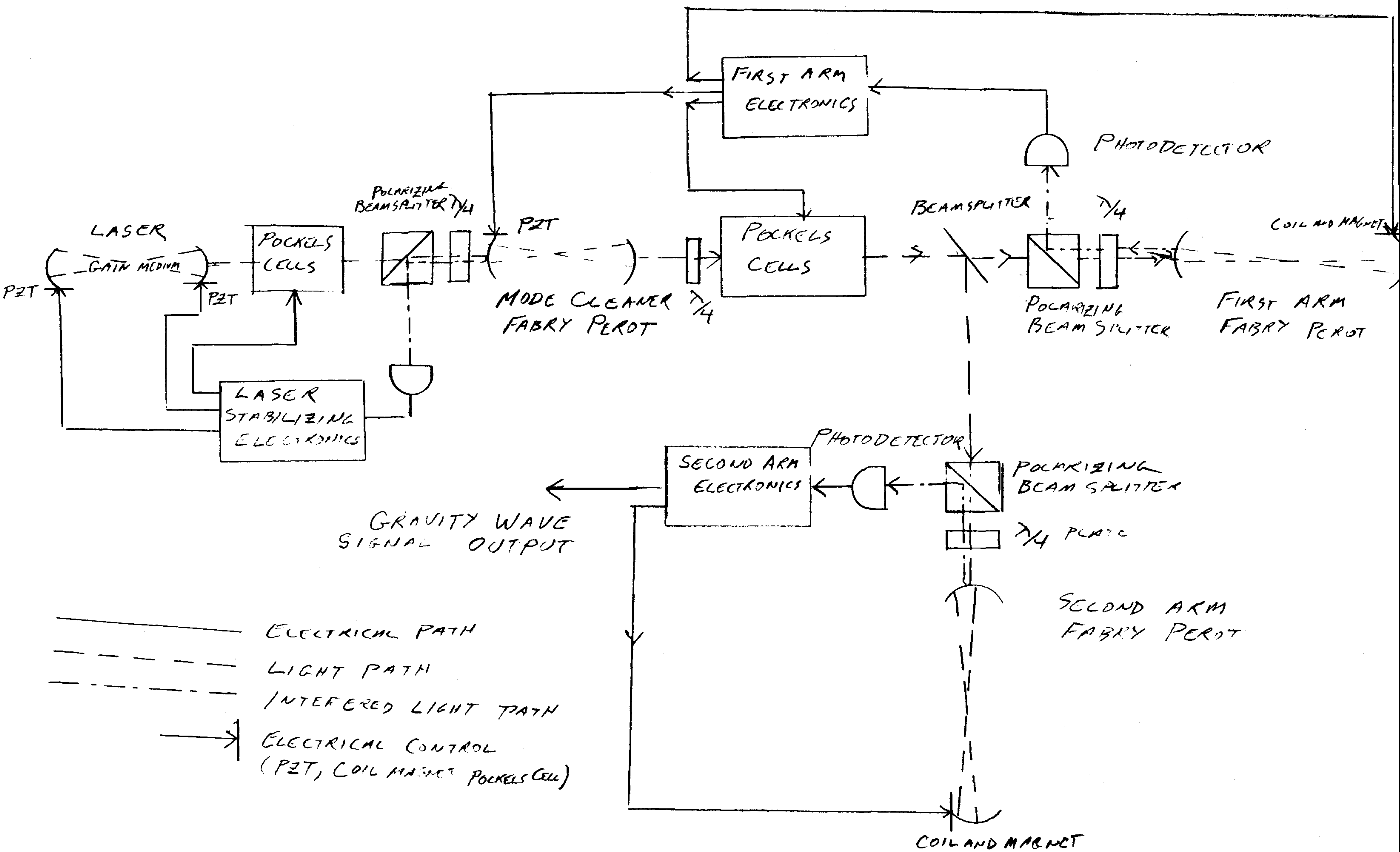
F. RAAB

M. GURSEL

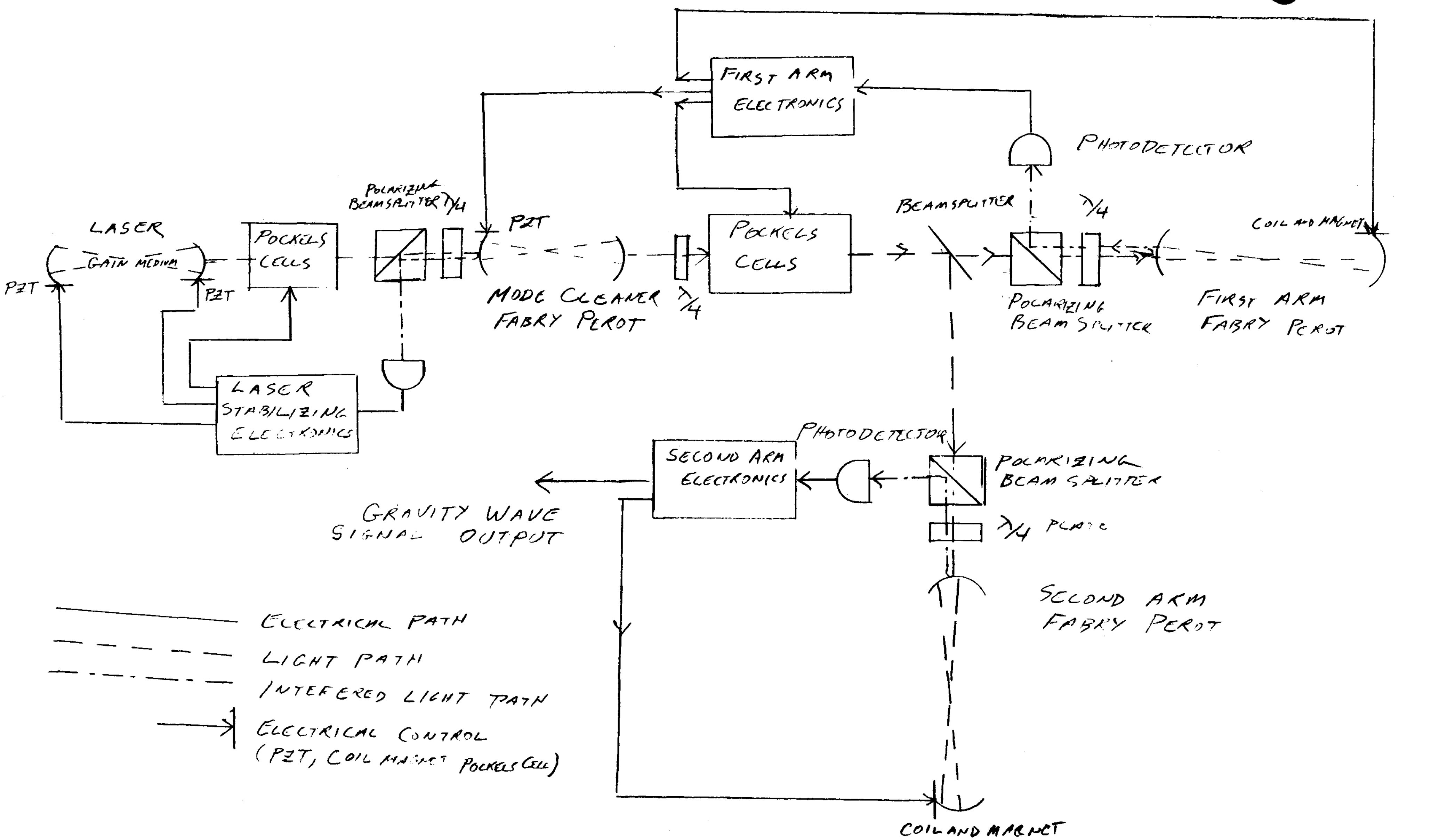
M. ZUCKER

A. ABRAMOVICI

INTRODUCTION ADDITIONS:



GRAVITY WAVE INTERFEROMETER OVERALL SYSTEM DIAGRAM



GRAVITY WAVE INTERFEROMETER OVERALL SYSTEM DIAGRAM

J. Hanna

INTRODUCTION

This handbook is intended to be a collection of circuit diagrams and other relevant information about the locking servos of the 40 meter prototype Gravitational Wave Detector at Caltech.

The information contained in this handbook reflects the state of the servos as of July 1989. The handbook should be updated continuously; Otherwise it will be obsolete very soon.

In order to update a circuit diagram in the hand book; please make a copy of the old diagram and mark your changes on the copy. Then put the upgraded copy in front of the old diagram in the hand book. A short explanation of the changes on the diagram is also very desirable.

Thank you very much for your cooperation.

[illegible]

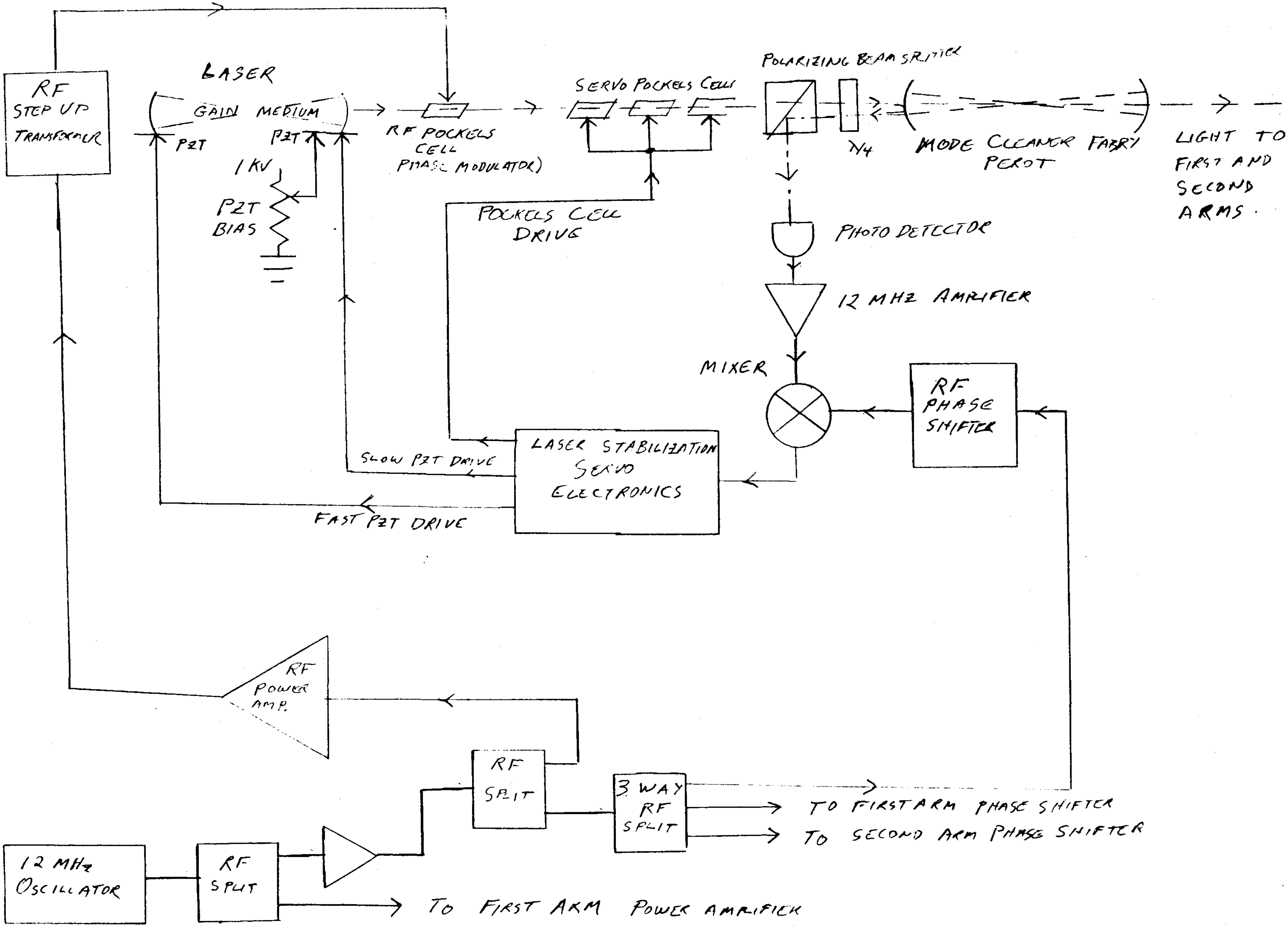
J[illegible] 1989

BATCH START

Mode Cleaner

STAPLE OR DIVIDER

MODE CLEANER SECTION ADDITIONS



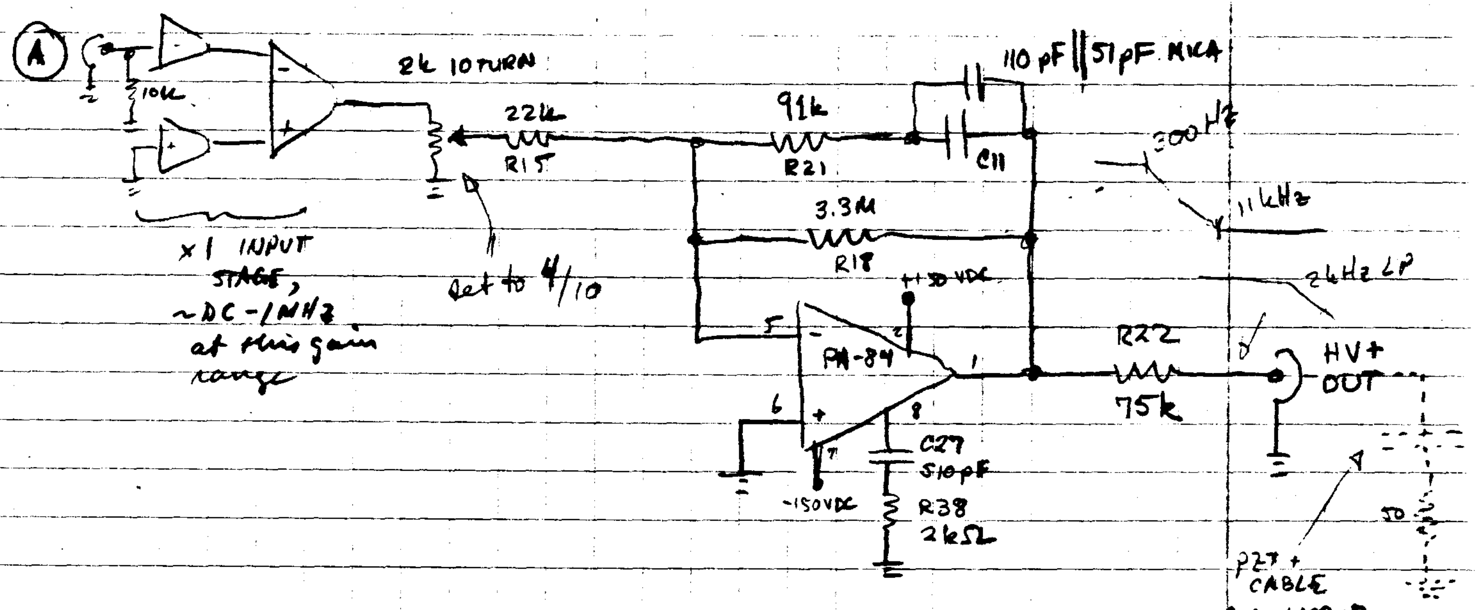
LASER STABILIZATION (MODE CLEANER) SERVO

10/25/89

Temporarily setting aside the mystery of the loop gain measurement discrepancy, decided to work on improving laser stabilization loop some more.

JH and BT improved on loop gain by improving the PZT drive amplifier. Previously HV #1 had been used, range x1, vernier + 2/10, ⇒ D.C. Gain = 6dB effective single pole (due to $Z_{out} = 160 k\Omega$ / $Z_{PZT} \approx 800 pF$) @ 1 kHz, extra phase shift at 100kHz of about 20° due to strays in amplifier circuit (5pF ∥ 330k ⇒ 100kHz due to strays across FB loop!)

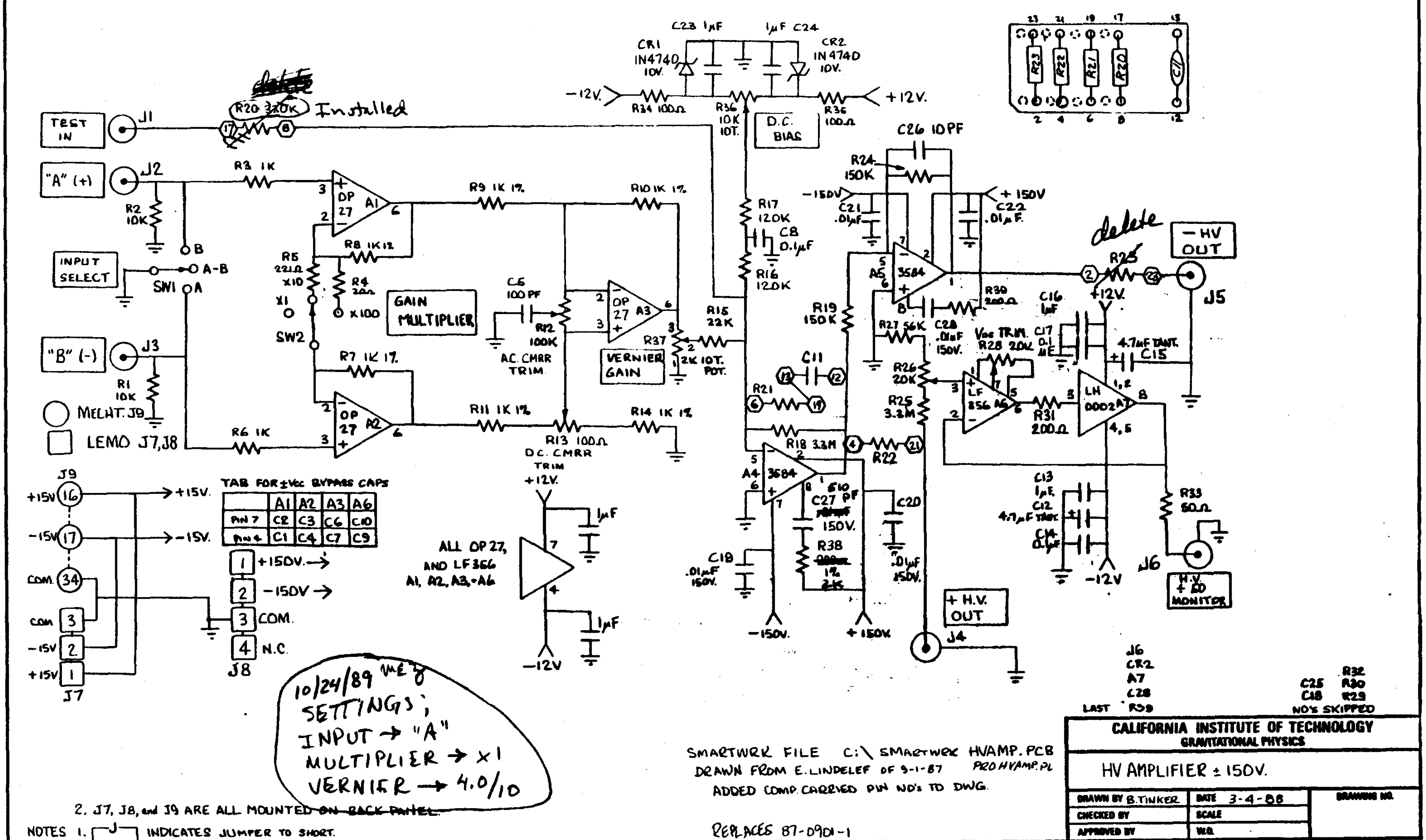
Installed improved circuit (abbreviated diagram below, complete diagram + tfer-function to follow)



HV #III
AS CONFIGURED 10/24/89 FOR SUCCESSFUL LOCKING IN LASER STABILIZATION SERVO LOOP

NB) ÷50 mon. still drives line driver + "Vector" HV amp exactly as before.

HV # III INSTALLED 10/24/89 TO DRIVE FAST PZT MIRROR IN LASER LOOP



BISHOP GRAPHICS/ACCUPRESS REORDER NO. A38381

88-0304-1

R20 = 330K
C11 = ~~51pF~~ → 150 pF 10/24/89 MEZ
R21 = 91K
R22 = 75K
~~R20~~ R23 } not used
A5 (3584) REMOVED.

MODIFIED 10-20-89 B.T.

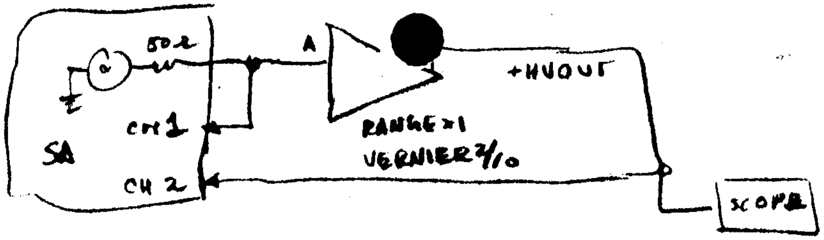
	WAS	IS
C27	.01µF	510pF
R38	200Ω	2K 1%

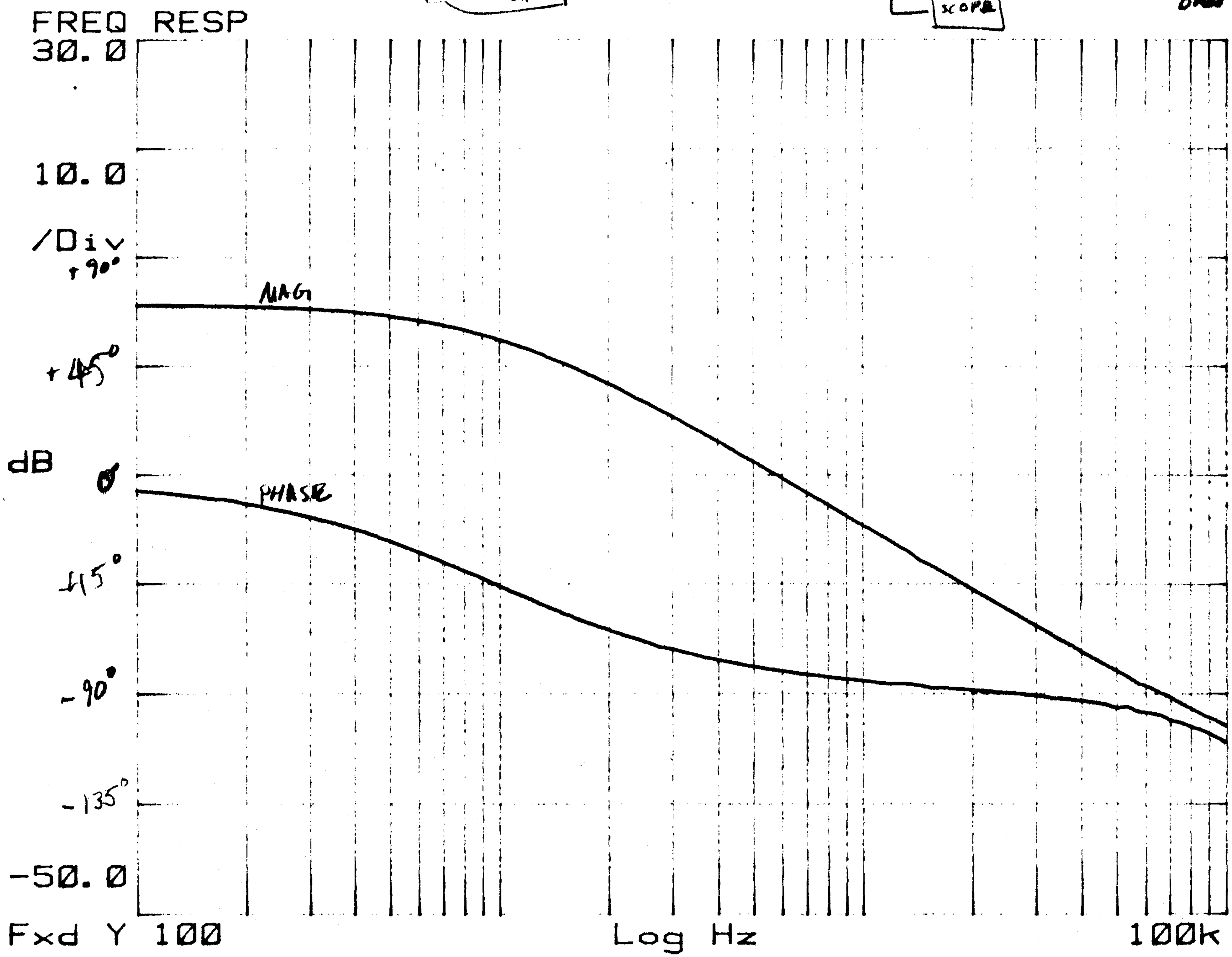
MOD. 1 S/N. 3.

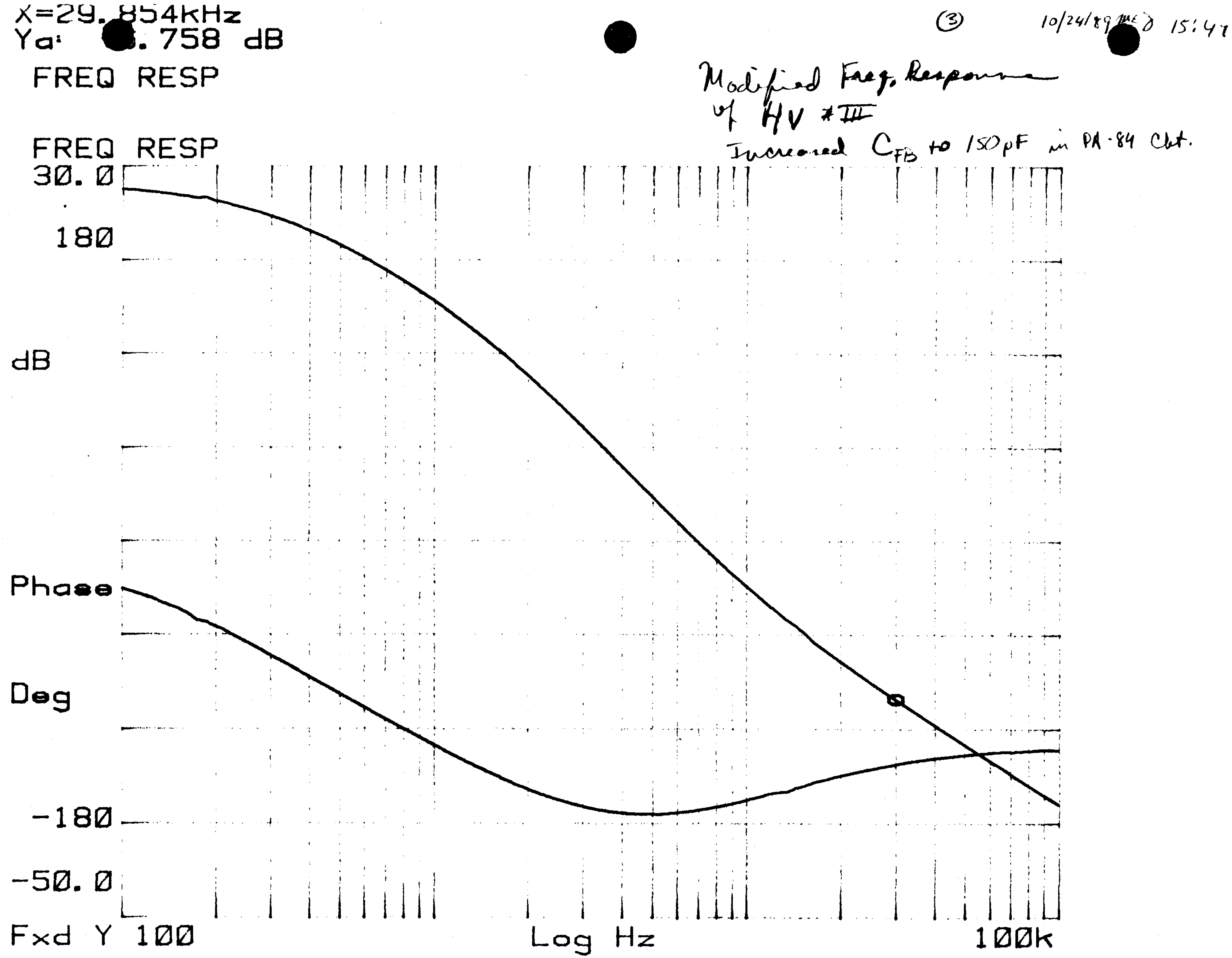
10/24/89 14:30

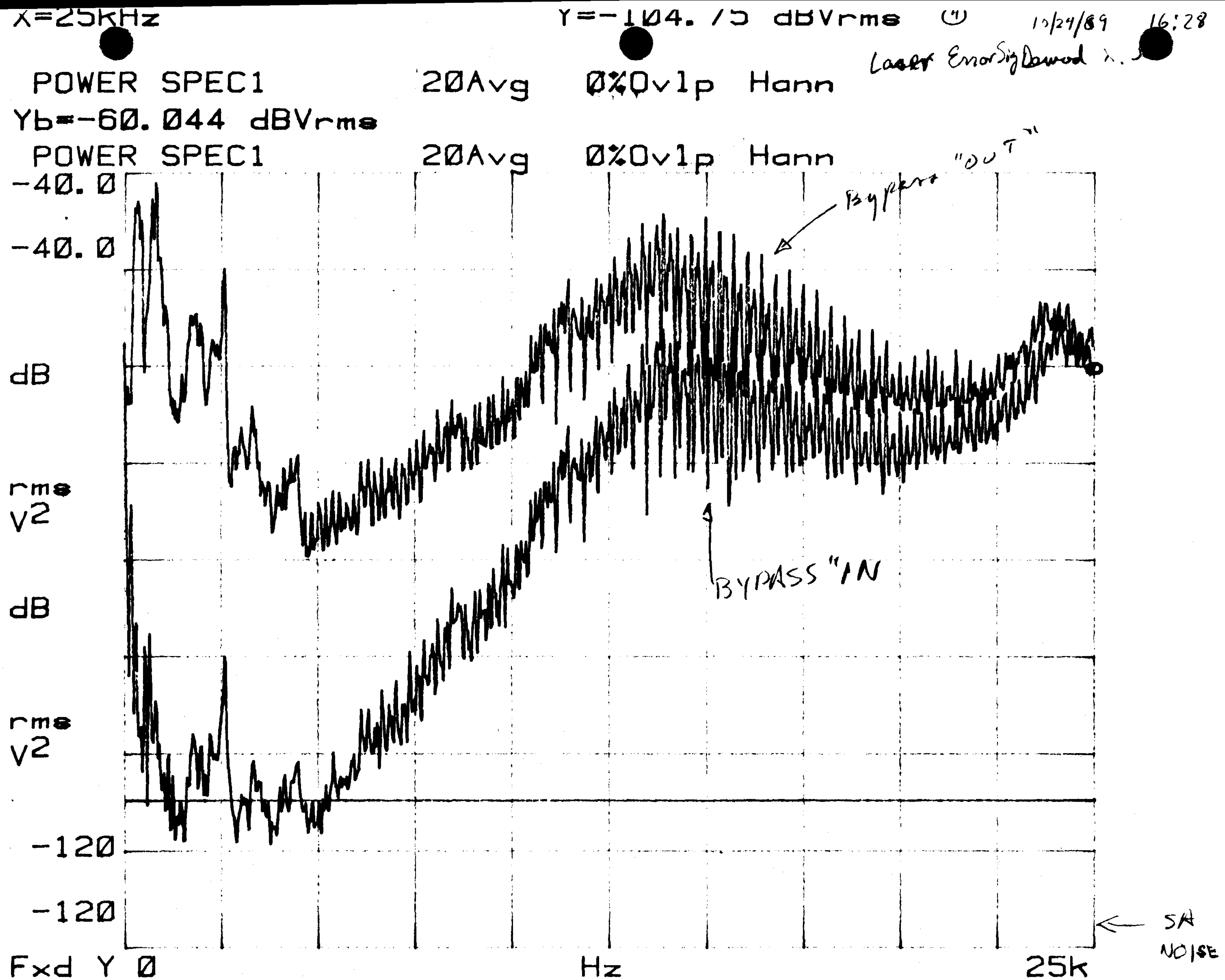
① HU #1

(NOTE: ÷500 OUTPUT IS NOT TO BE TRUSTED! BAD FREQUENCY RESPONSE!!)





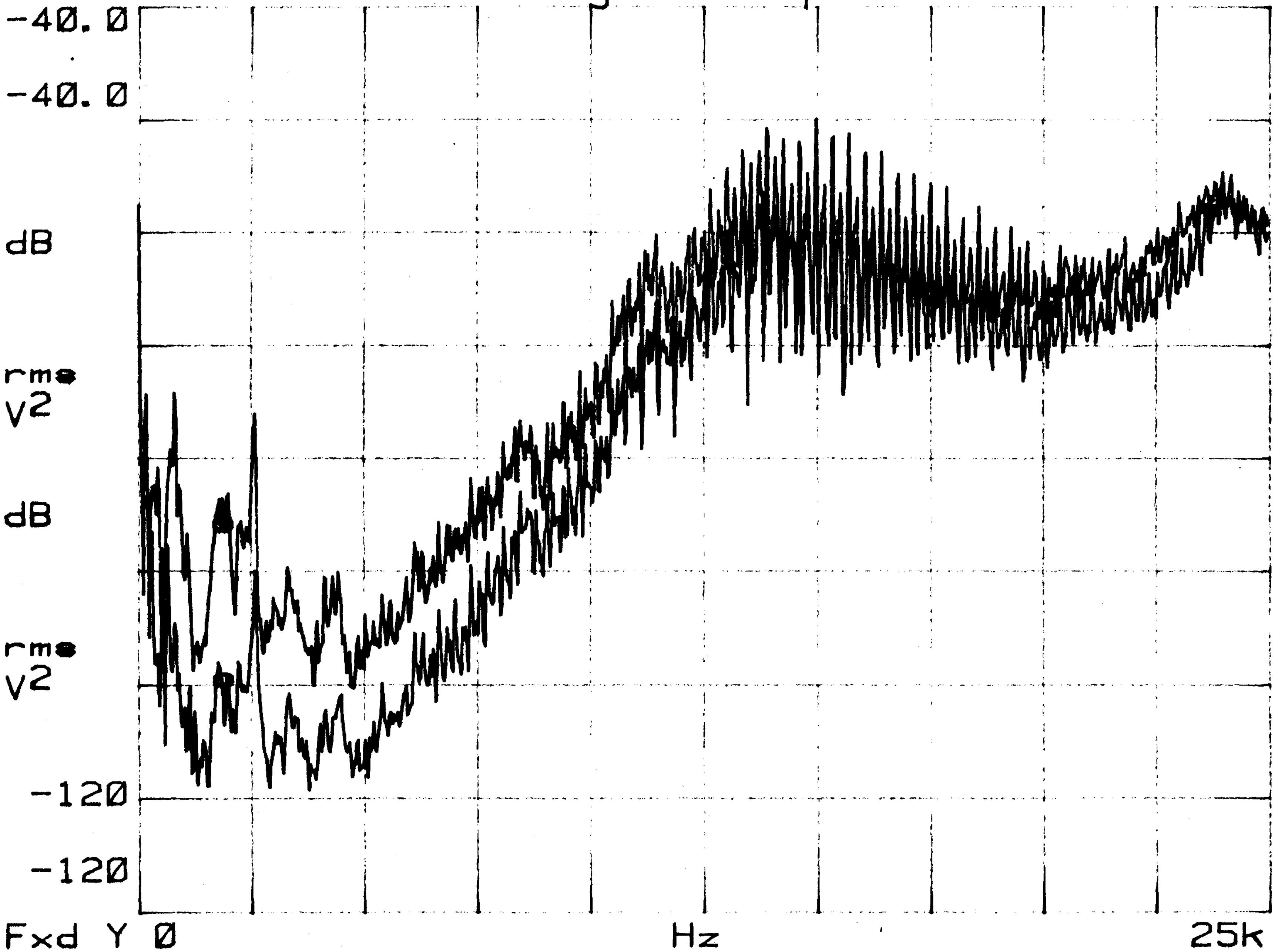

X=29.854kHz
Ya: .758 dB
FREQ RESP
FREQ RESP
30.0
180
dB
Phase
Deg
-180
-50.0
Fxd Y 100
Log Hz
100k
③
10/24/89
15:47
Modified Freq. Response
of HV #III
Increased C_FB to 150pF in PA-84 Ckt.


X=25kHz
Y=-104.75 dBVrms
10/24/89
16:28
POWER SPEC1 20Avg 0%Ovlp Hann
Yb=-60.044 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann
-40.0
-40.0
dB
rms
V2
dB
rms
V2
-120
-120
Fxd Y 0
Hz
25k
Bypass "OUT"
BYPASS "IN
SA
NOISE

(5) 10/24/84 17:50

Demod Mon. #1
Black; Old PZT Drive
Blue; New PZT Drive

X=1.844kHz
Ya= [illegible].819 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann
Yb=-99.484 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann



X=1.8437kHz Y=-125.5 dBVrms

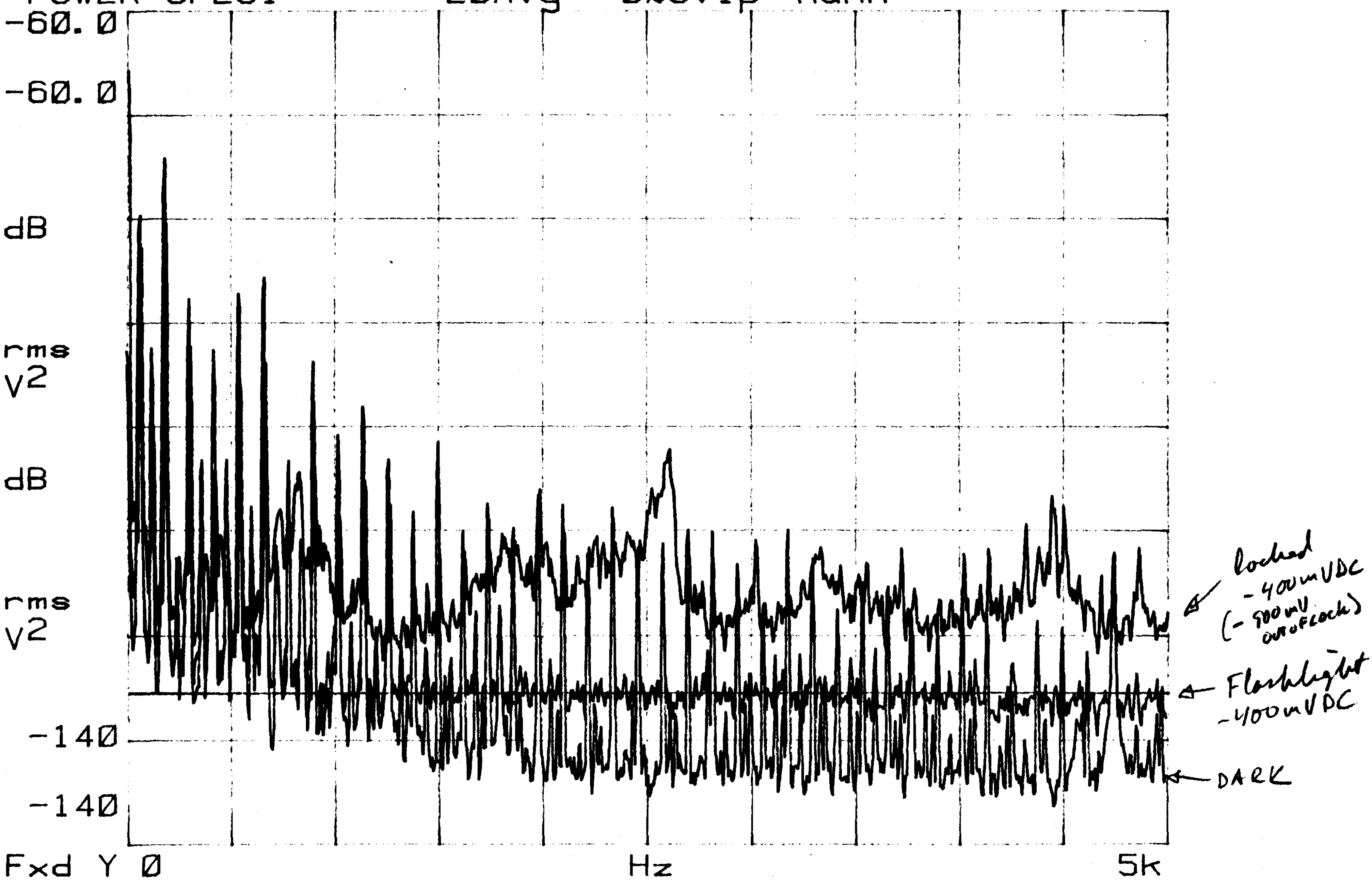
(6) 10/24/87 17:40

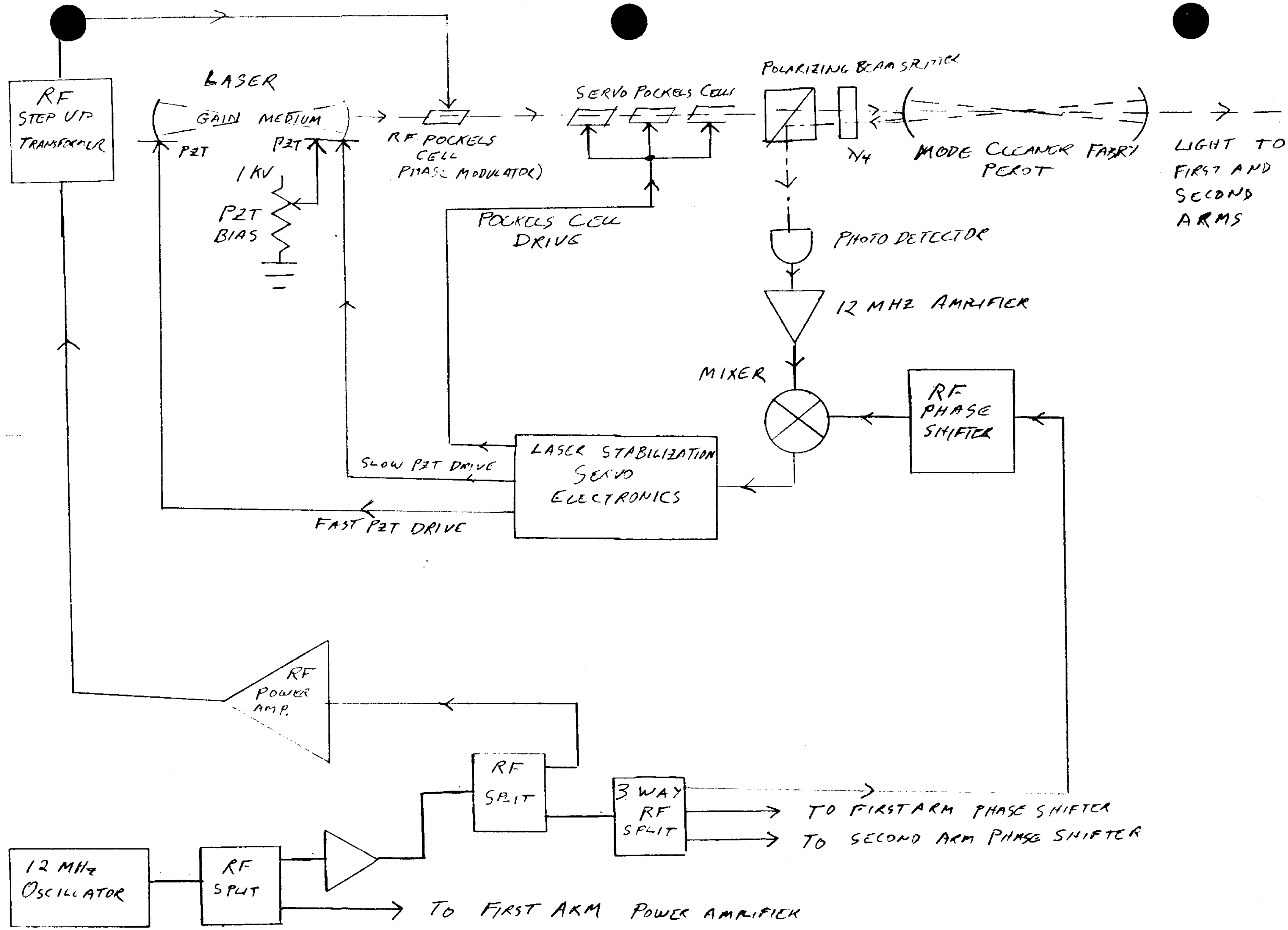
Demod X10 Mon on Laser Servo w/ new PZT Drive Circuit

POWER SPEC1 20Avg 0%Ovlp Hann

Yb=-125.87 dBVrms

POWER SPEC1 20Avg 0%Ovlp Hann





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10/25/89

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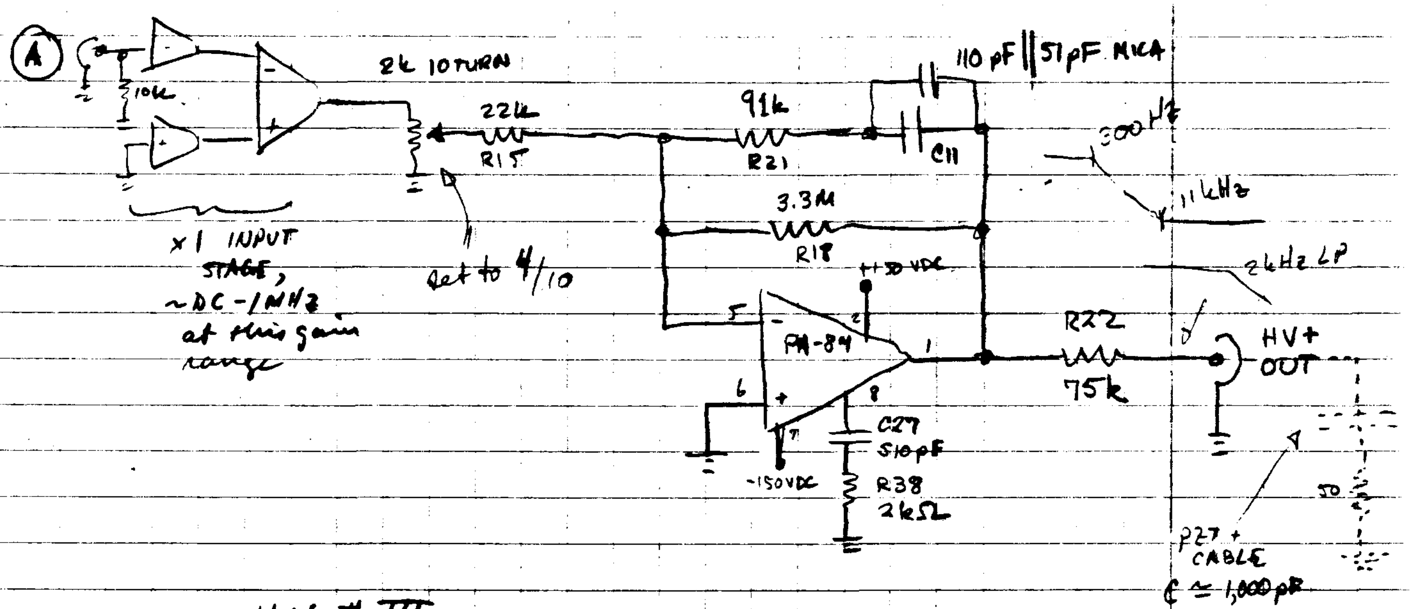

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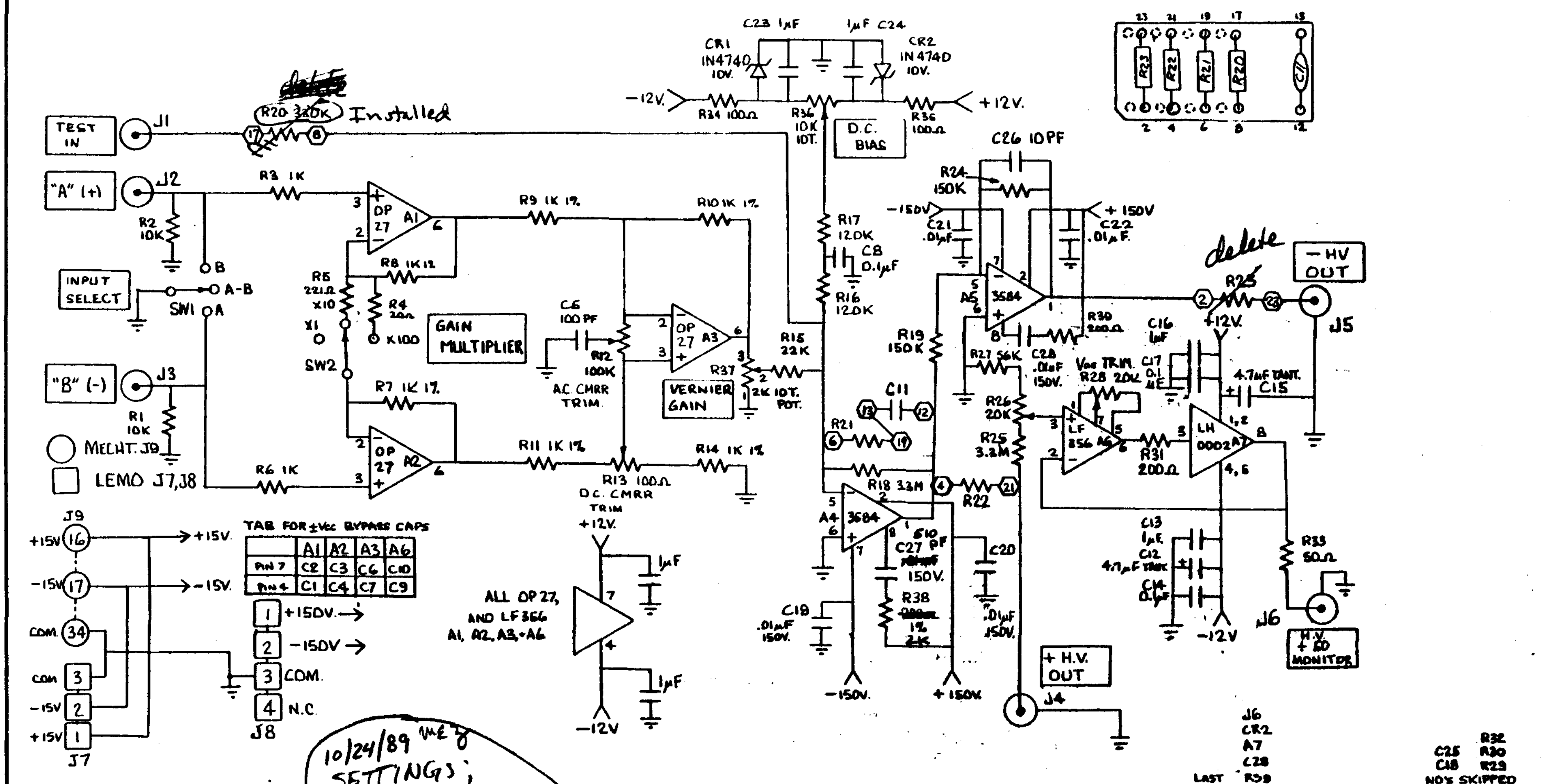

	A1	A2	A3	A6
PIN 7	C2	C3	C6	C10
PIN 4	C1	C4	C7	C9

10/24/89 ME
SETTINGS;
INPUT → "A"
MULTIPLIER → x1
VERNIER → 4.0/10

LAST: J6, CR2, A7, C28, R39

NO'S SKIPPED: C25, C18, R32, R30, R29

SMARTWRK FILE C:\SMARTWRK HVAMP.PCB PRO HVAMP.PL
DRAWN FROM E. LINDELEF OF 9-1-87
ADDED COMP CARRIED PIN NO's TO DWG.

NOTES 1. ⌐J¬ INDICATES JUMPER TO SHORT.
2. J7, J8, and J9 ARE ALL MOUNTED ~~ON BACK PANEL.~~

REPLACES 87-0901-1

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

HV AMPLIFIER ± 150V.

DRAWN BY B. TINKER	DATE 3-4-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

BISHOP GRAPHICS/ACCUPRESS REORDER NO. A38381

88-0304-1

R20 = 330K
C11 = ~~51pF~~ → 150 pF 10/24/89 ME
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~~R20~~ R23 } not used
A5 (3584) REMOVED

MODIFIED 10-20-89 B.T.

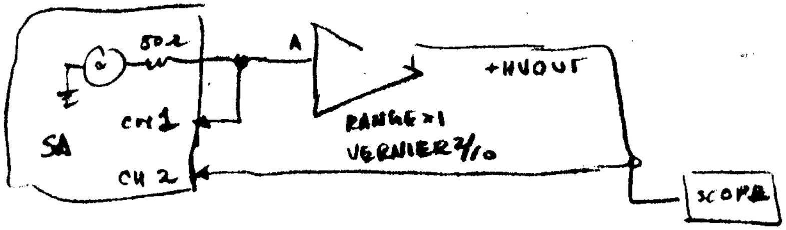
	WAS	IS
C27	.01μF	510pF
R38	200Ω	2K 1%

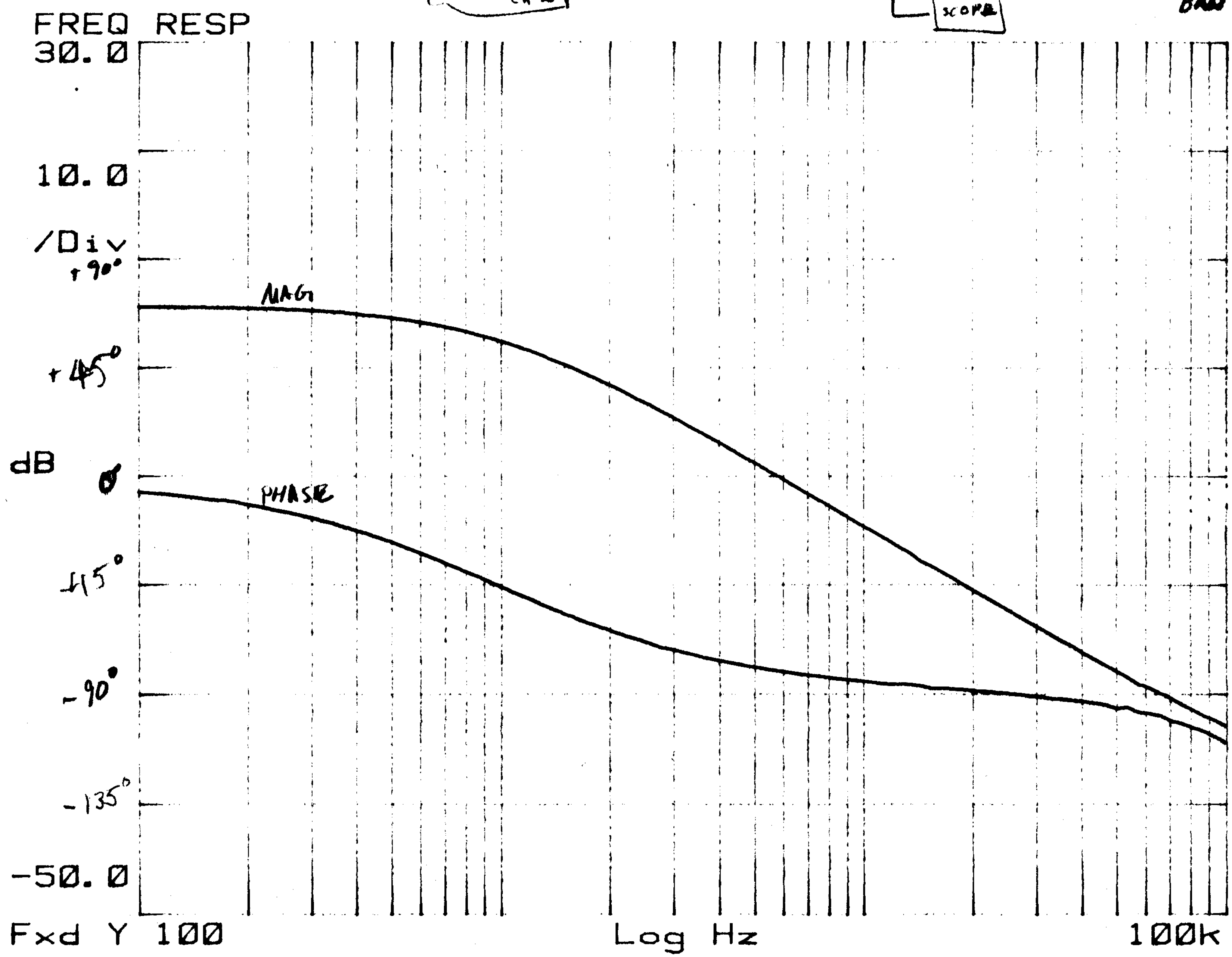
MOD. 1 S/N. 3

① 10/24/89 14:30

HU #1 in after P'k

(NOTE: ÷ 500 OUTPUT IS NOT TO BE TRUSTED! BAD FREQUENCY RESPONSE!!)



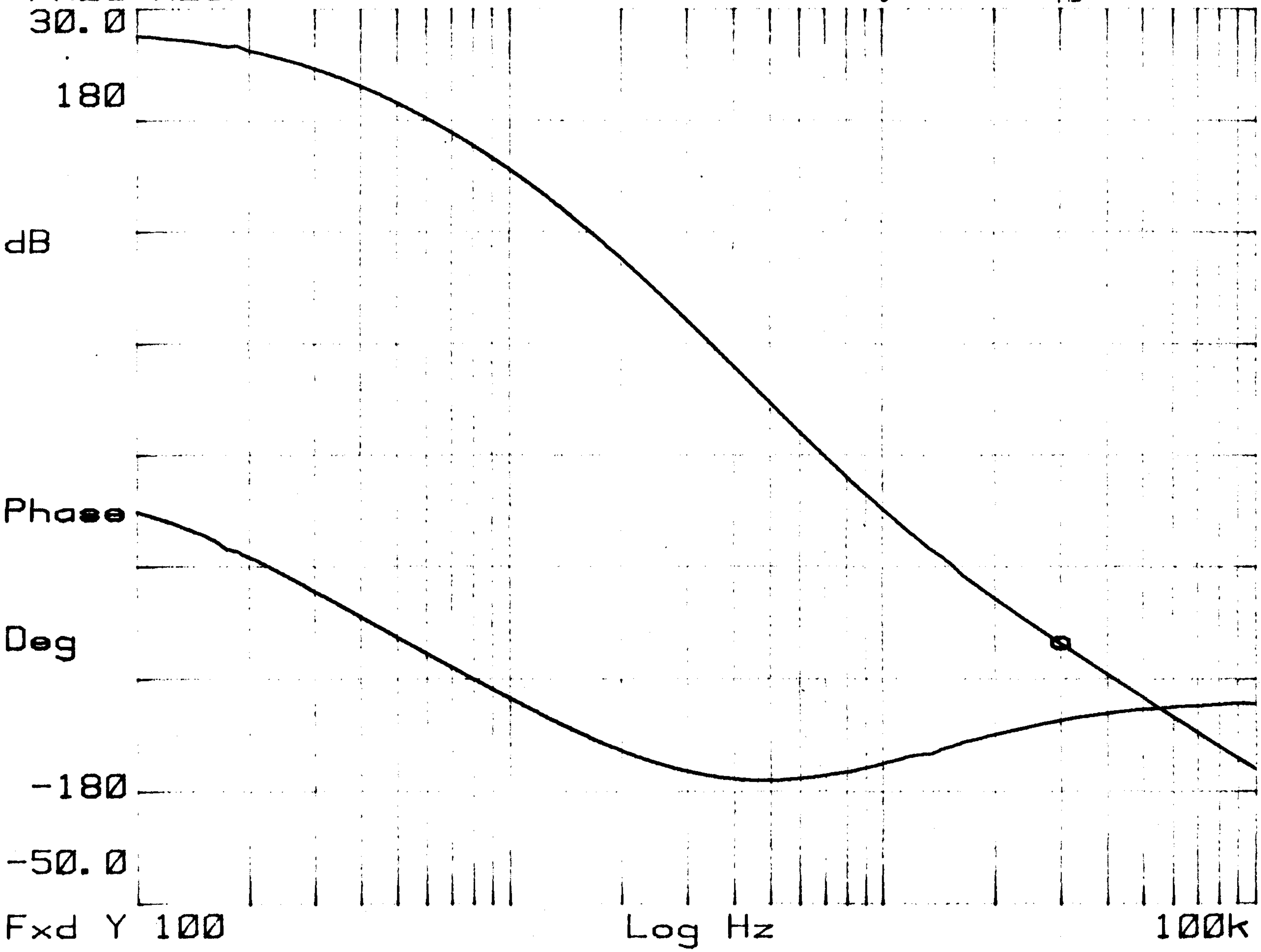


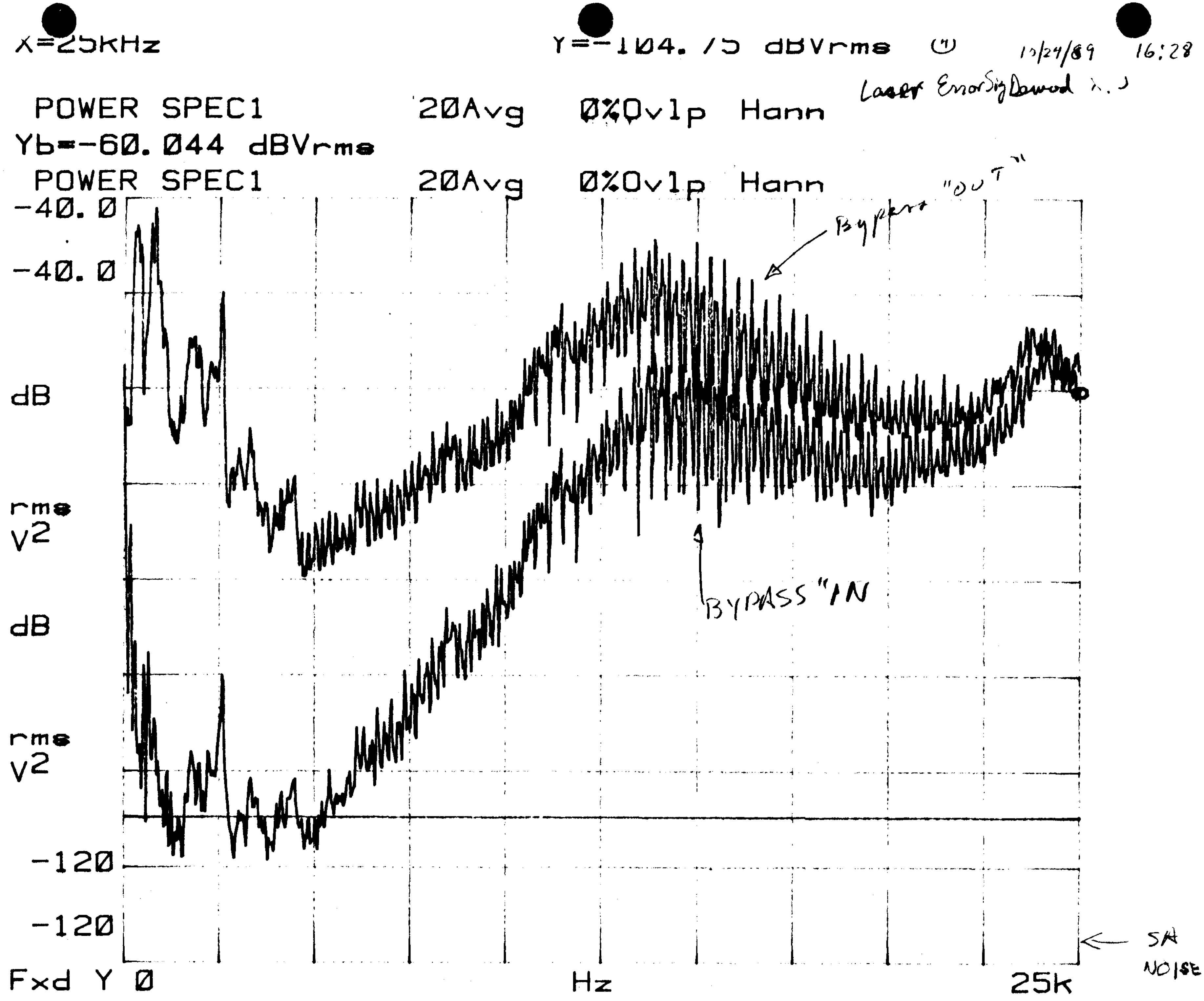
X=29.854kHz
Ya: 5.758 dB
FREQ RESP

(3) 10/24/89 MEJ 15:47

Modified Freq. Response of HV #III
Increased C_{FB} to 150pF in PA-84 Ckt.

FREQ RESP



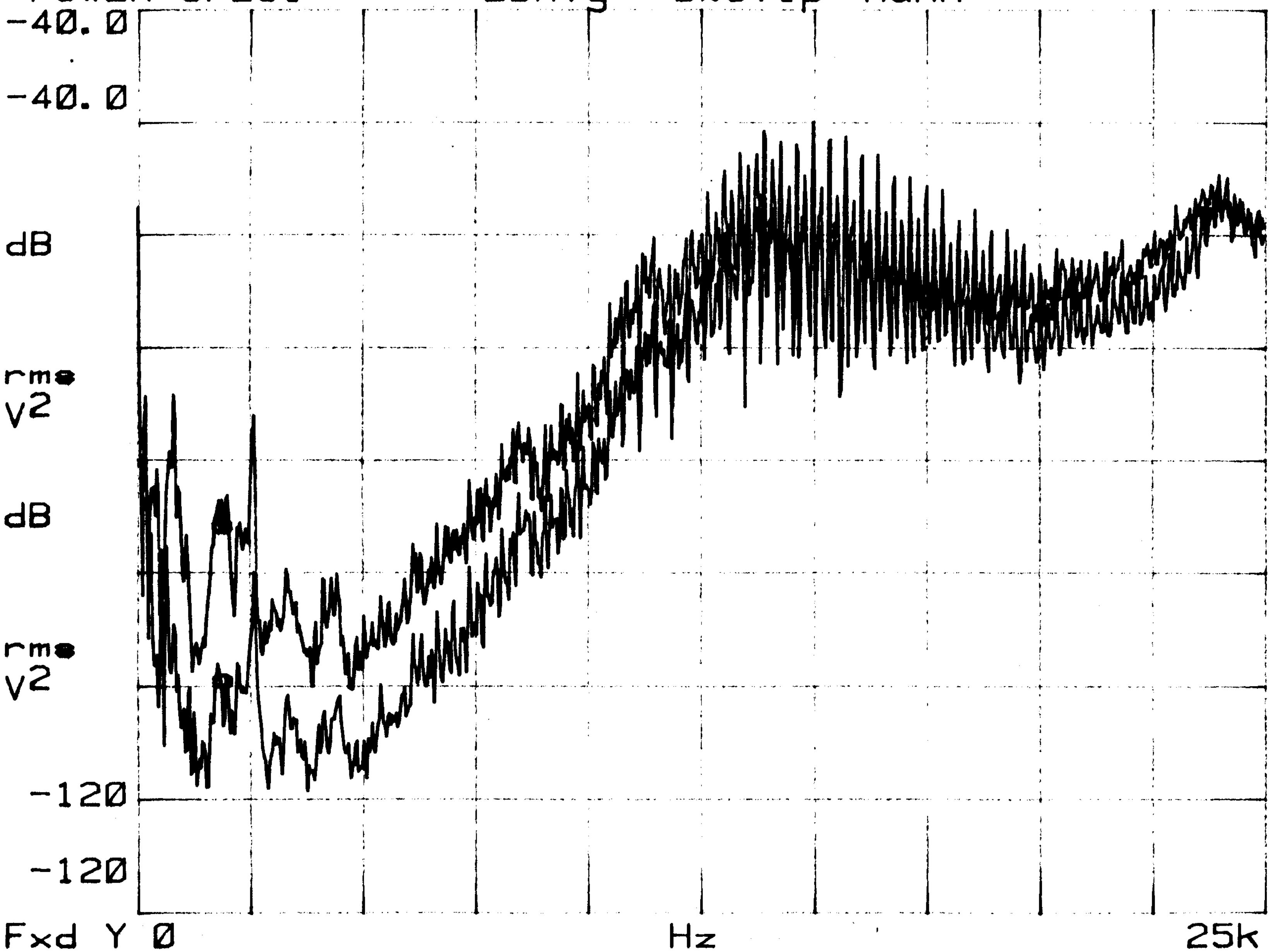

X=25kHz
Y=-104.75 dBVrms
10/24/89 16:28
Laser
POWER SPEC1 20Avg 0%Ovlp Hann
Yb=-60.044 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann
-40.0
-40.0
dB
rms
V2
dB
rms
V2
-120
-120
Fxd Y 0
Hz
25k
Bypass "OUT"
BYPASS "IN"
SA NOISE

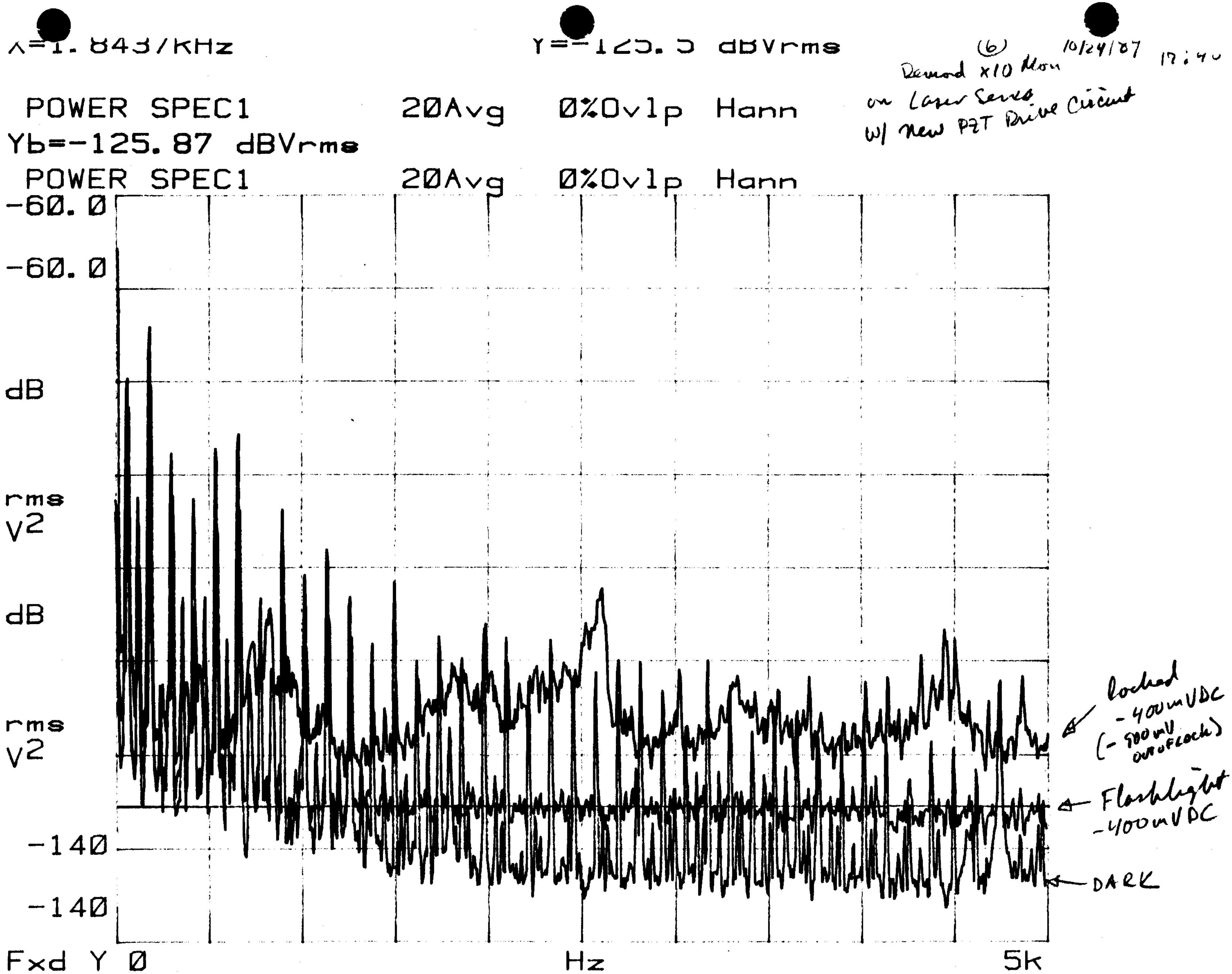
(5)

10/24/84 17:30

Removed Mon. 81
Black; Old PZT Drive
Blue; New PZT Drive

X=1.844kHz
Ya= 5.819 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann
Yb=-99.484 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann

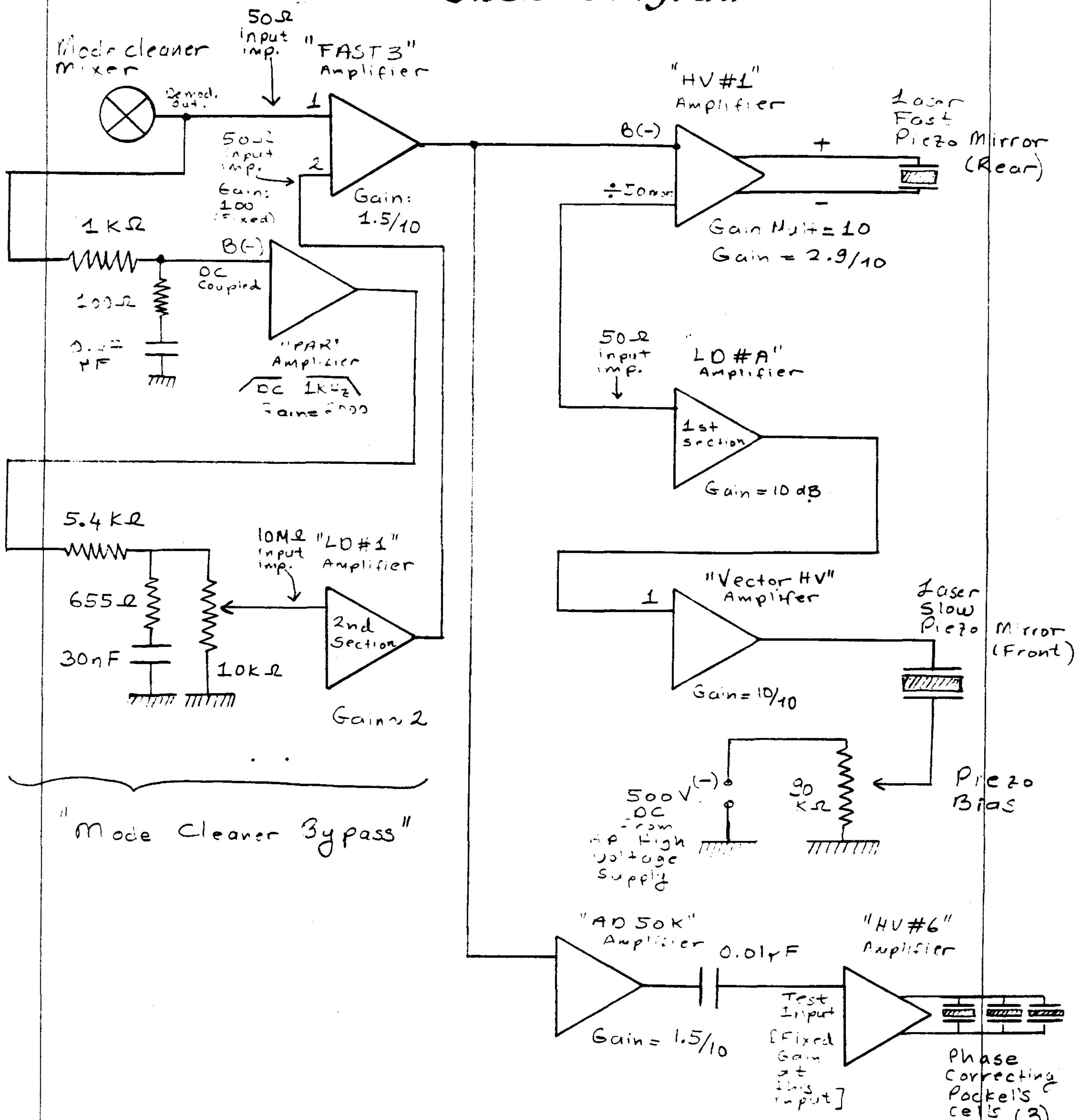



X=1.8437kHz
Y=-125.5 dBVrms
(6)
10/24/07
17:40
Demod x10 Mon
on Laser Servo
w/ new PZT Drive Circuit
POWER SPEC1 20Avg 0%Ovlp Hann
Yb=-125.87 dBVrms
POWER SPEC1 20Avg 0%Ovlp Hann
-60.0
-60.0
dB
rms
V2
dB
rms
V2
-140
-140
Fxd Y 0
Hz
5k
locked -400mVDC (-900mV out of lock)
Flashlight -400mVDC
DARK

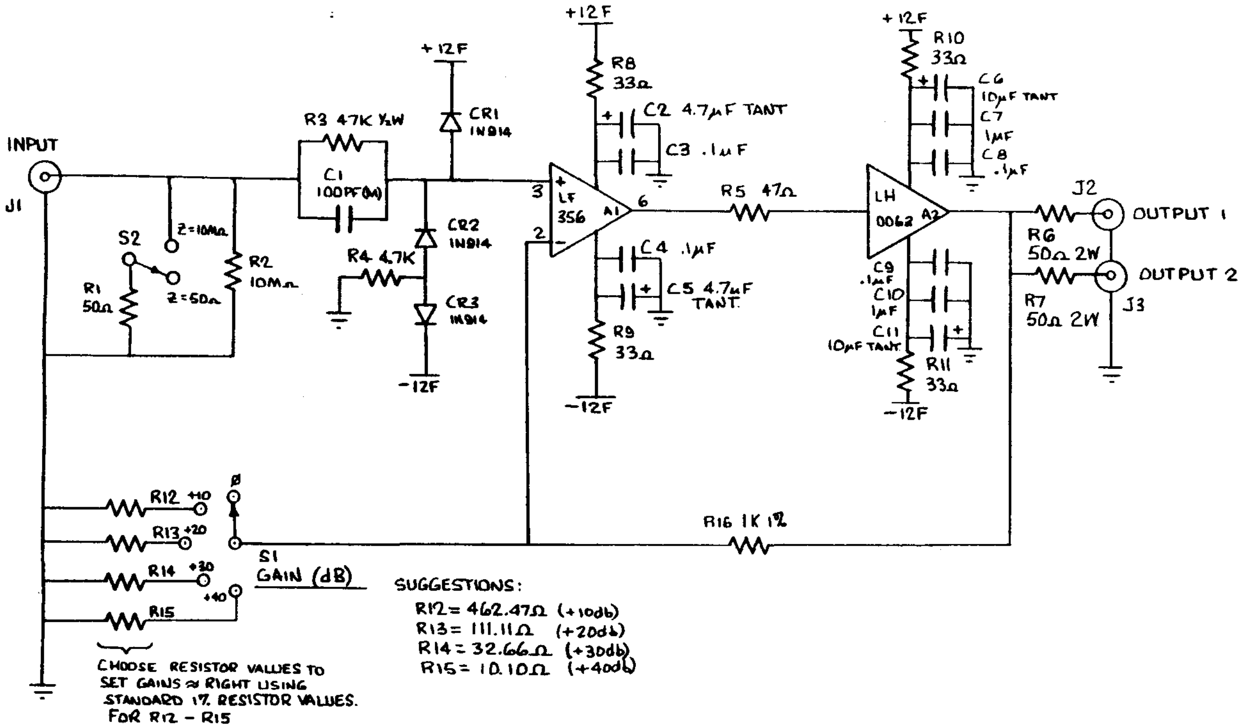
OBSOLETE 12/89

Mode Cleaner Servo Loop

Block Diagram



July 21, 1989



SUGGESTIONS:
R12 = 462.47Ω (+10db)
R13 = 111.11Ω (+20db)
R14 = 32.66Ω (+30db)
R15 = 10.10Ω (+40db)

A2
CR3
S2
J3
R16
LAST C

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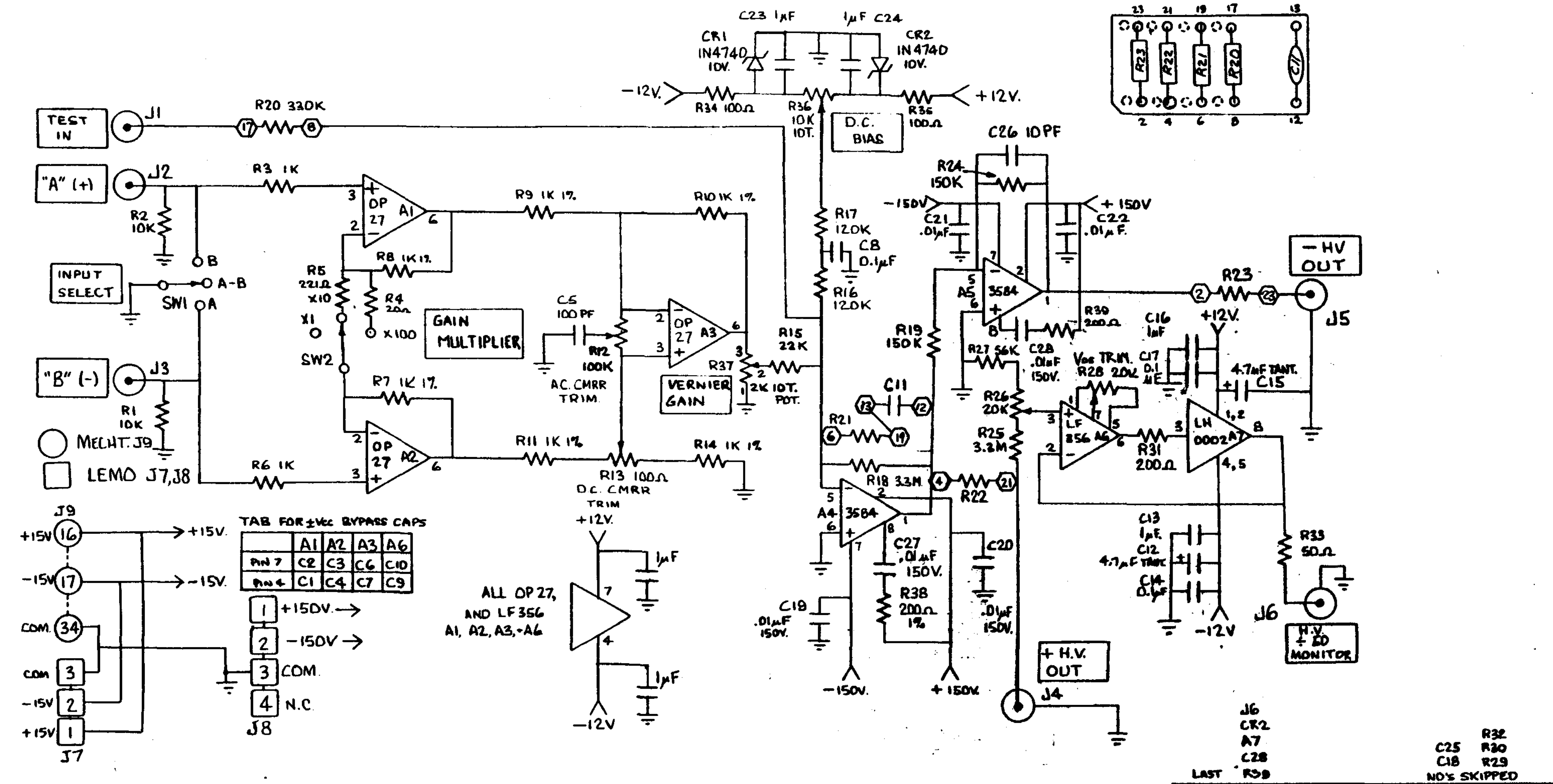
LINE DRIVER

DRAWN BY B.T.	DATE 6-13-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

88-0613-1



	A1	A2	A3	A6
PIN 7	C2	C3	C6	C10
PIN 4	C1	C4	C7	C9

SMARTWRK FILE C:\ SMARTWRK HVAMP.PCB

DRAWN FROM E. LINDELEF OF 9-1-87 PRO HVAMP.PL

ADDED COMP. CARRIED PIN NO's TO DWG.

2. J7, J8, and J9 ARE ALL MOUNTED ON BACK PANEL.

NOTES 1. ⌐J¬ INDICATES JUMPER TO SHORT.

REPLACES 87-0901-1

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

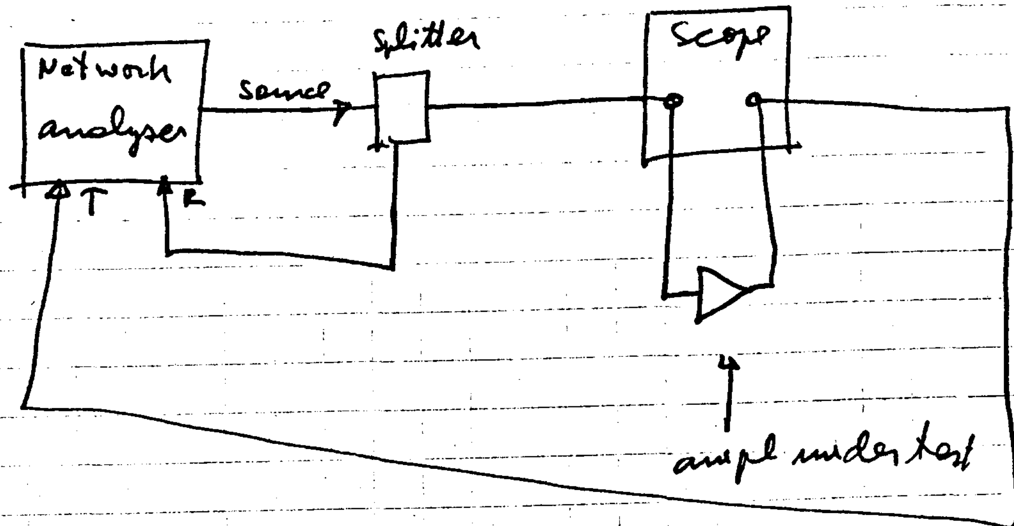
HV AMPLIFIER ± 150V.

DRAWN BY B. TINKER	DATE 3-4-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

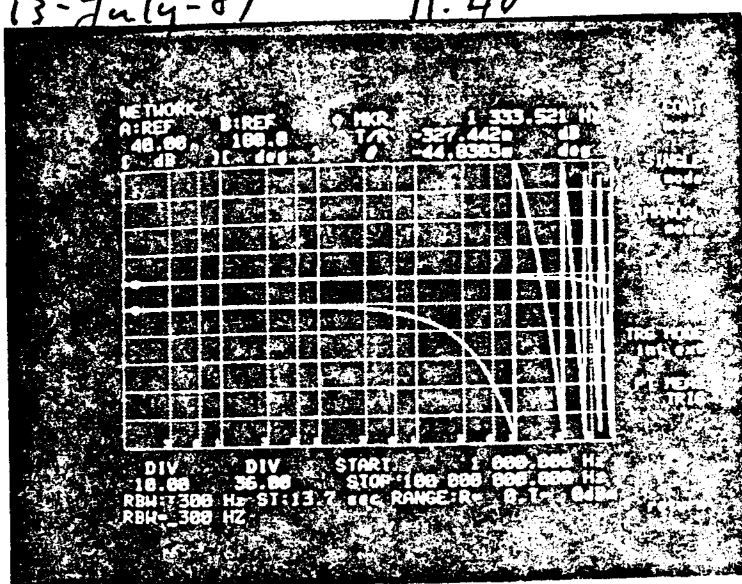
88-0304-1

13-July-89

Since ~30' of cables were used to connect the amplifier under test (see diagram below), we took the response of the cables themselves (trace at 11:40)



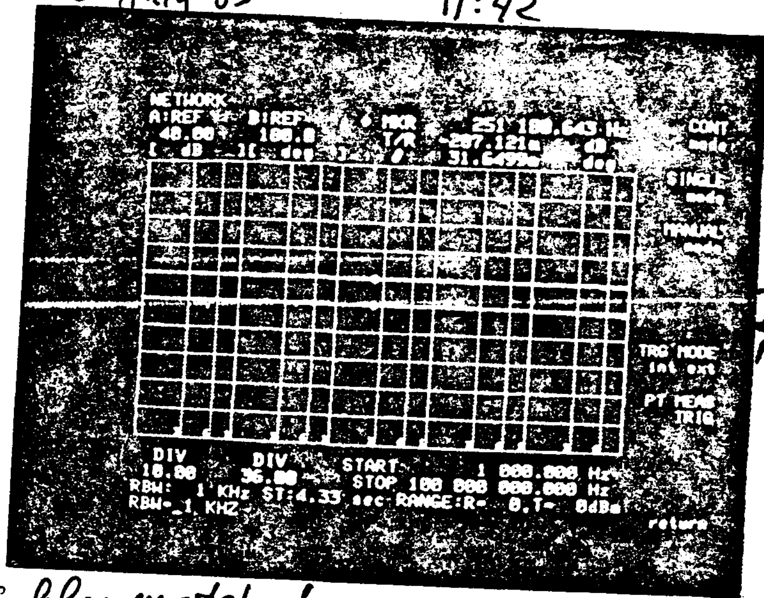
13-July-89 11:40



TR. FUNCTION OF CABLES – they are badly imbalanced

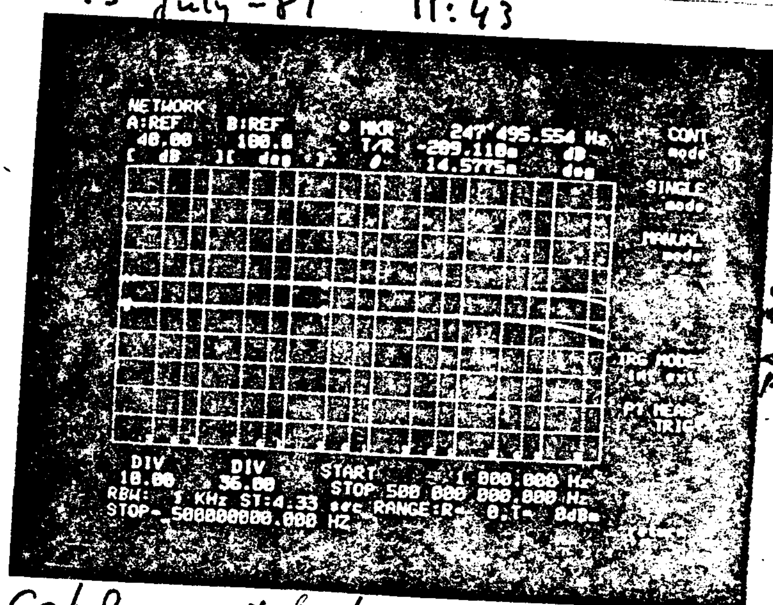
- It turns out that at 250 kHz the cables alone show a phase shift of 5°.
- Therefore, the ~3' cable from splitter to R input was replaced with a long cable, matched to the one in the test path. See traces overleaf

13-July-89 11:42



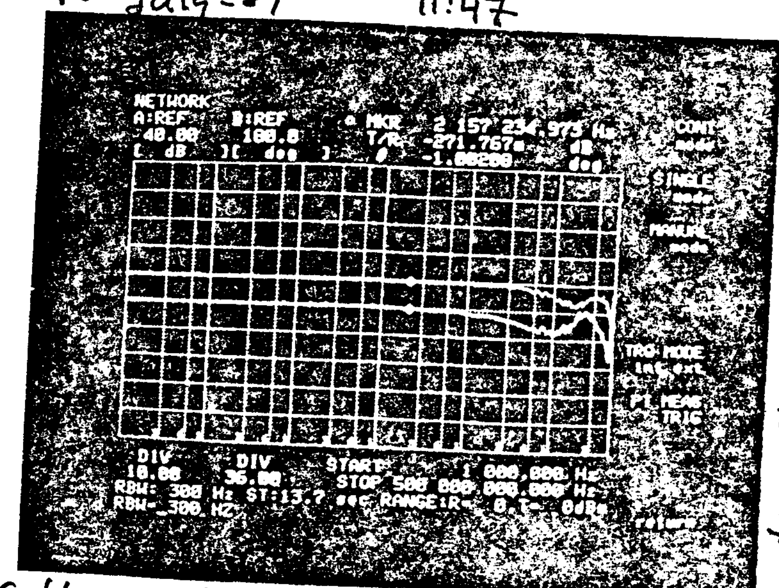
Cables matched

13-July-89 11:43



Cables matched

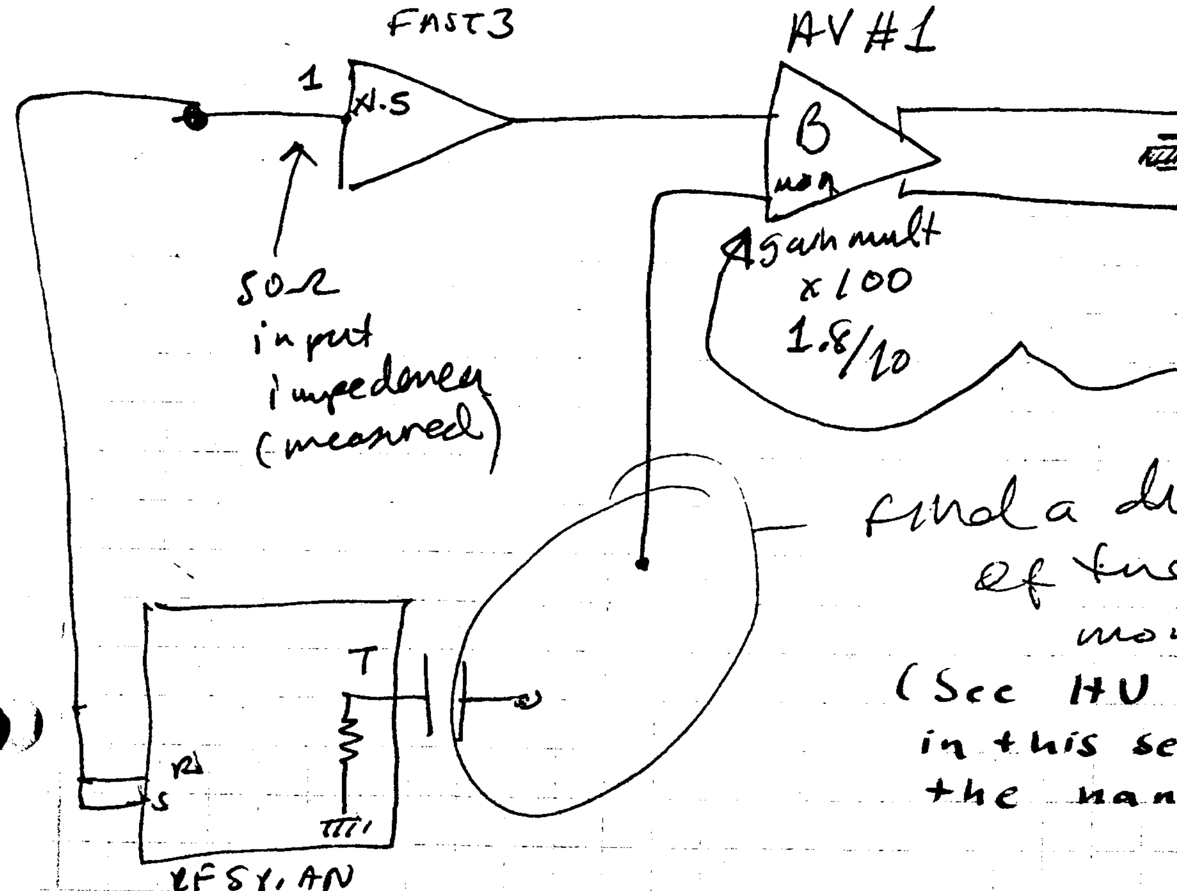
13-July-89 11:47



to scope

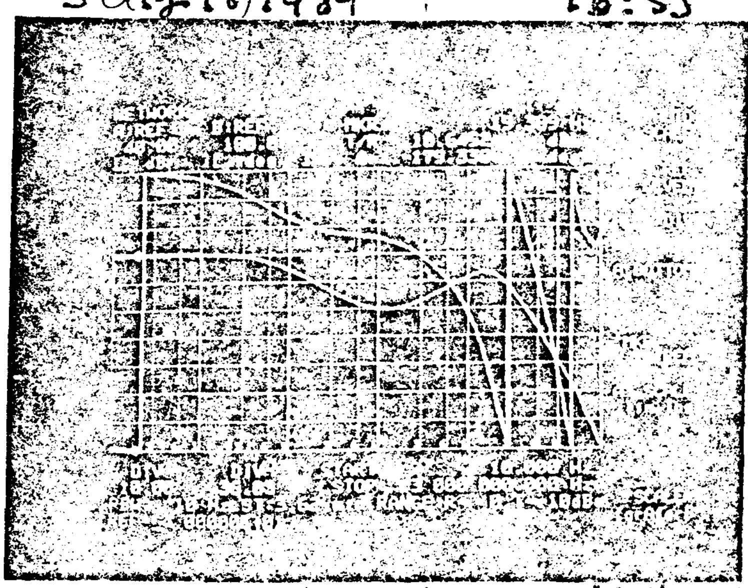
Cables matched, going through T's connected

Fast Piezo branch of mode cleaner loops (Transfer Function)



find a diagram of the monitor!
(See HV amp schematic in this section of the handbook)

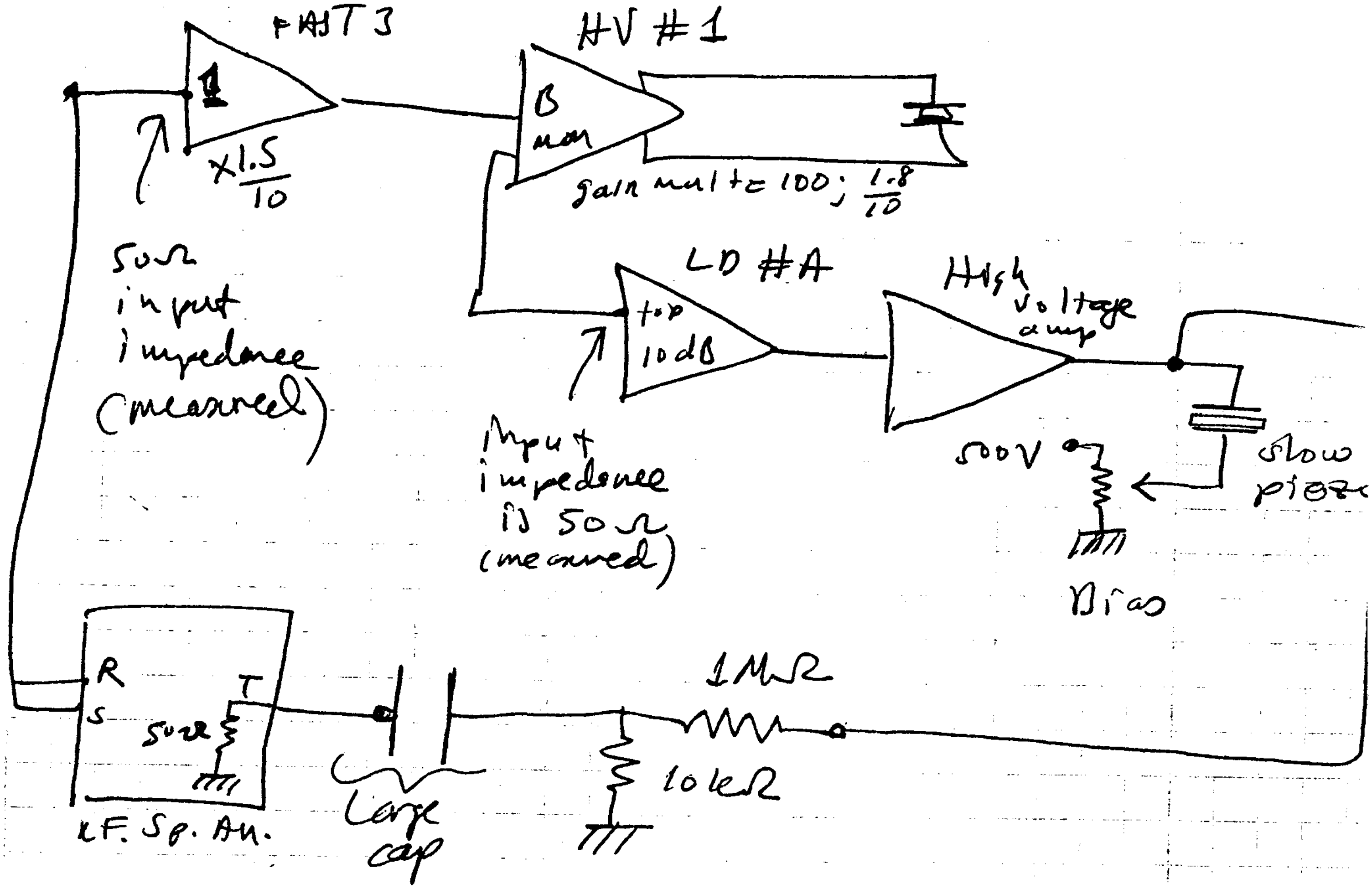
July 18, 1989 15:55



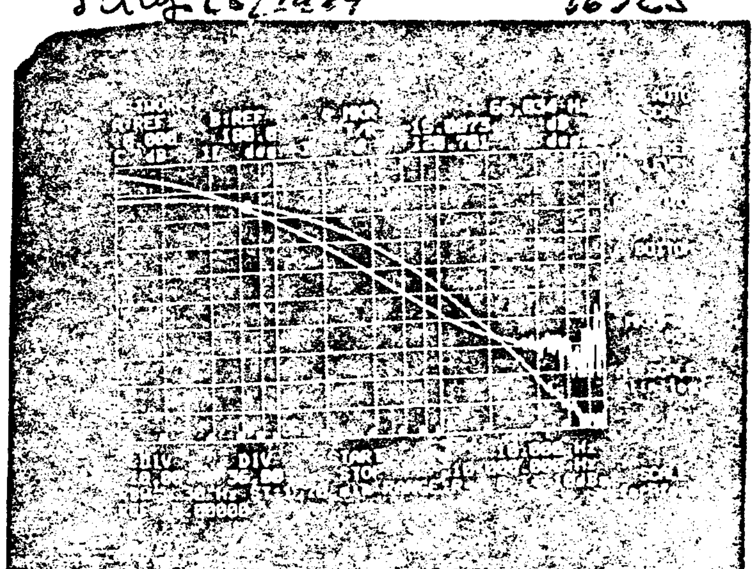
MOCLFA 7/18

Fast piezo branch of mode cleaner Loop

Mode cleaner slow piezo branch ~~piezo~~ transfer function:

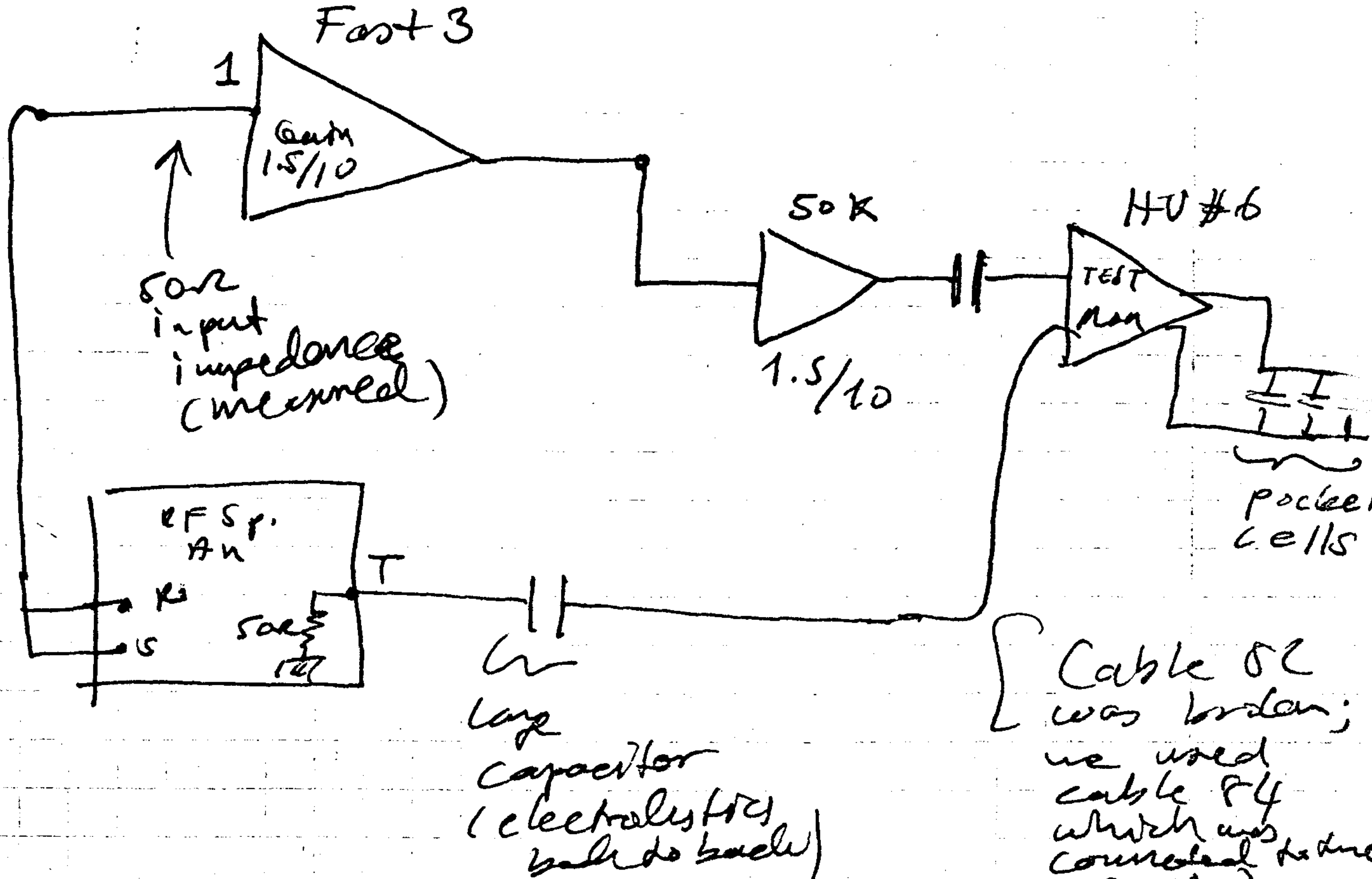


July 18, 1999 16:25



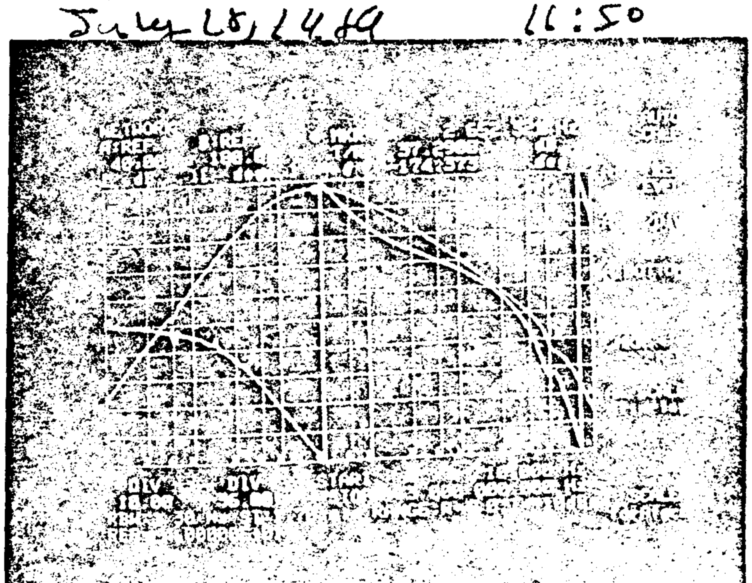
Mode cleaner slow piezo branch transfer function.

Mode cleaner phase correcting pockel's cells branch transfer function:



[Cable 82 was broken; we used cable 84 which was connected to the ...)

July 28, 1989 11:50

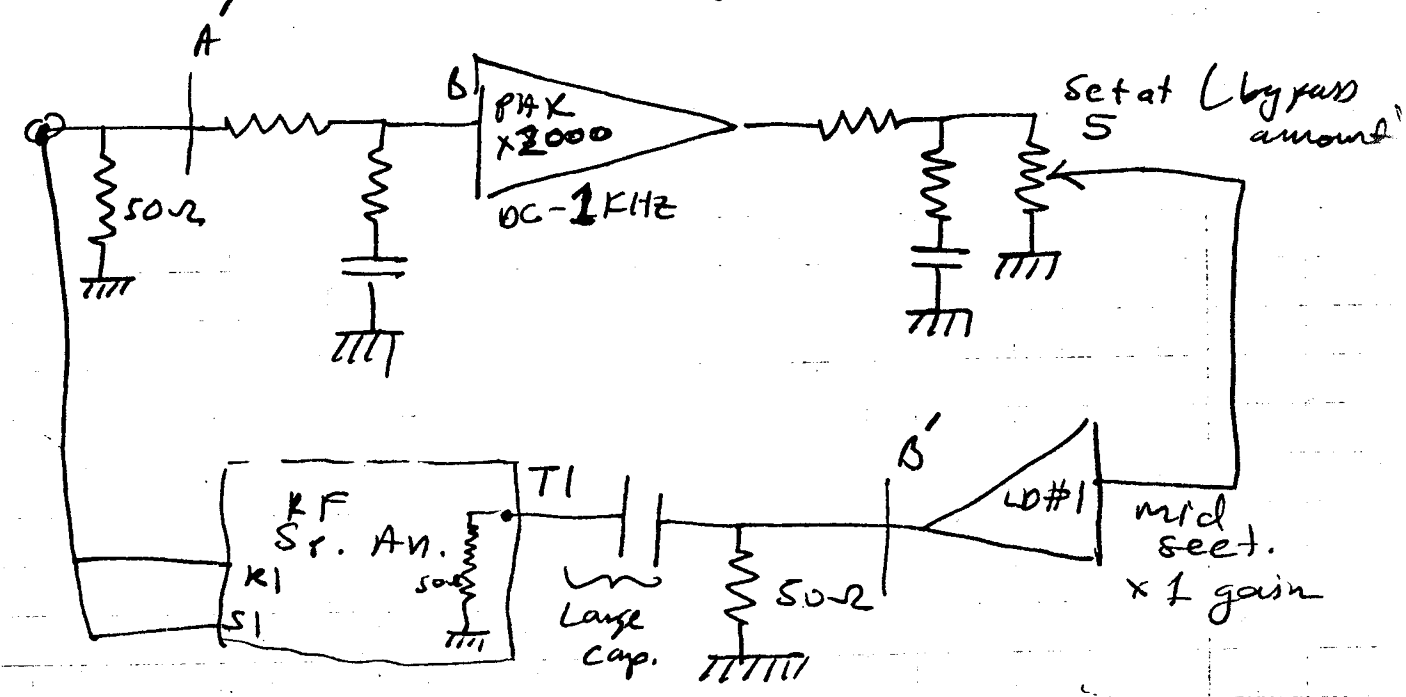


MDCLPC 7/8

Mode cleaner phase correcting pockel's cell branch tr. function.

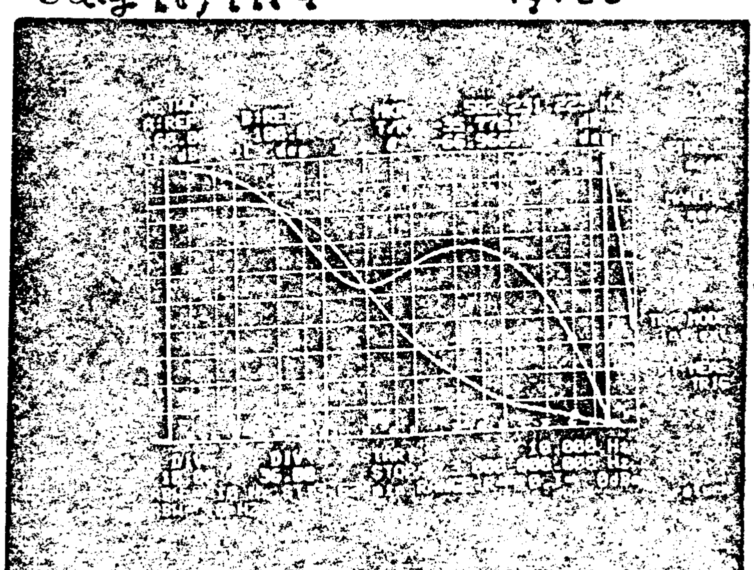
July 18, 1989
YG

Mode cleaner loop servo branch transfer functions:



A' to B' : Mode cleaner bypass circuit.

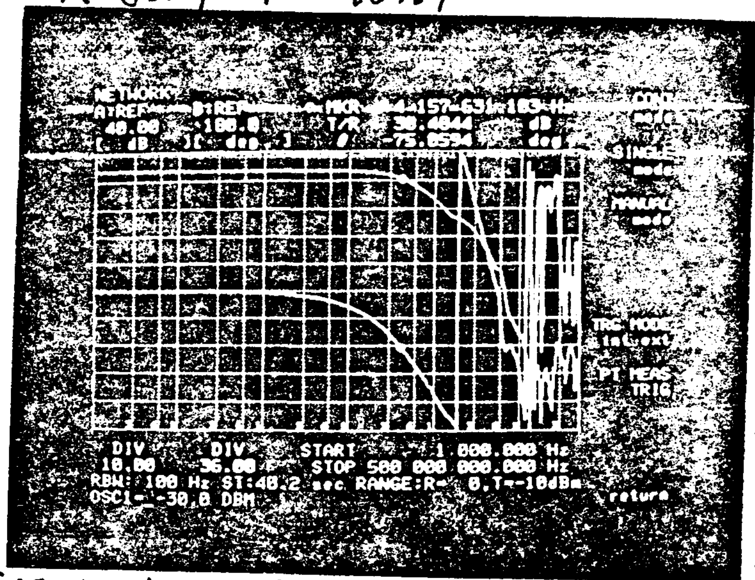
July 18, 1989 14:30



MDCLBP718

Mode cleaner bypass tr. funct.

14-July 89   10:59

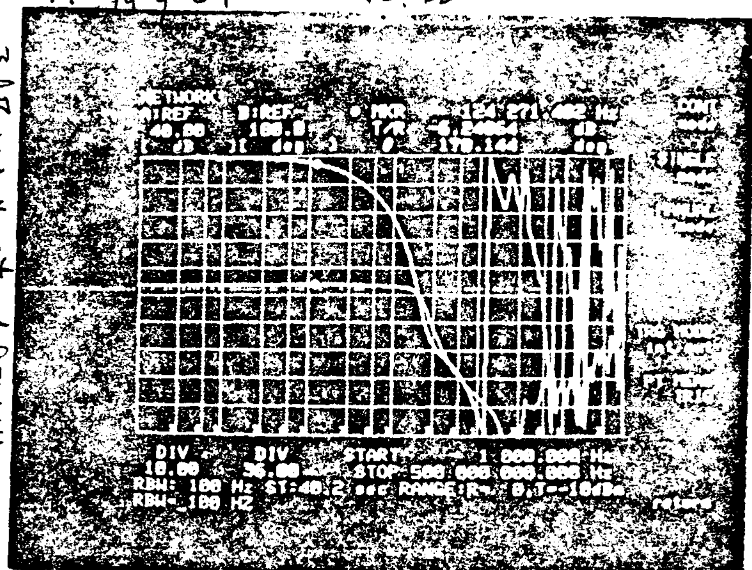


FAST3, Var. in (max)   10°: 461.6 kHz

FAST 3 711V ←

17 July 89   13:35

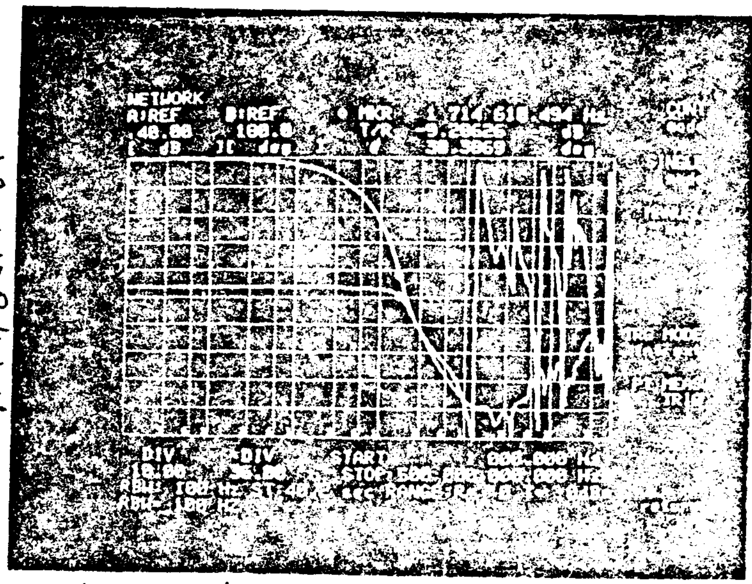
3dB point at: 1.955 MHz



LDA MID ØDB

Line driver A, mid, 0dB, 50Ω out.

10° : 128.4 kHz



LDA LOW

Line driver A lower, 50Ω out, 0dB

17 July-89   13:30

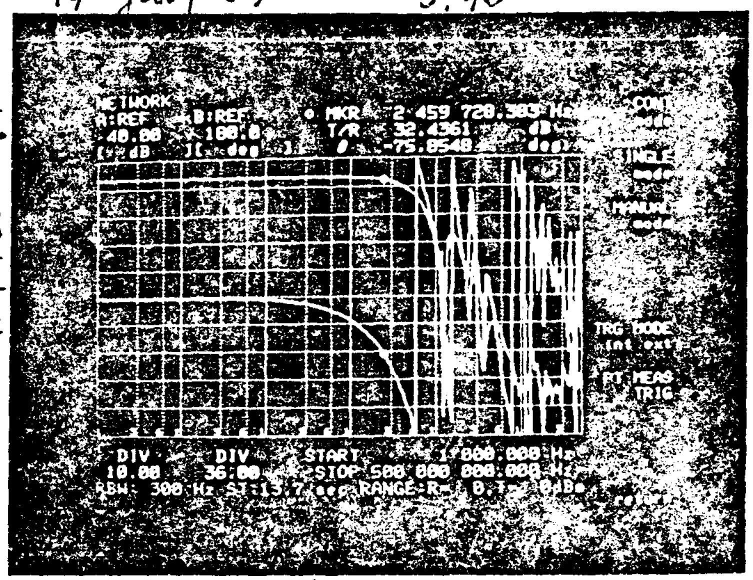
10° at: 124 kHz

LDA UP 0DB

Line driver A, upper, 0 dB, 50Ω at outp.

17 July 1989

17 July 89 9:40



10°: 321 kHz

AXES: 100 MHz 40dB

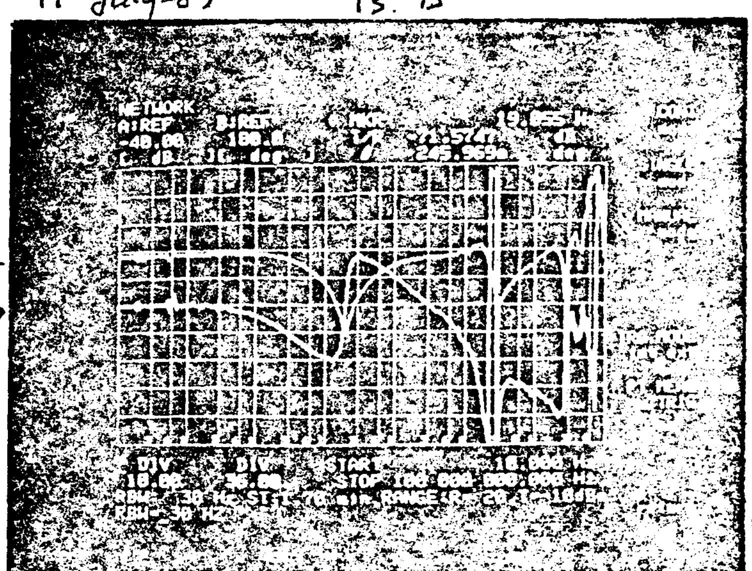
FAST 1 V

FAST 1   50 Ω out, V inp, full gain (33.5 dB)

17 July-89 13:43

e

φ



CROST 1

←

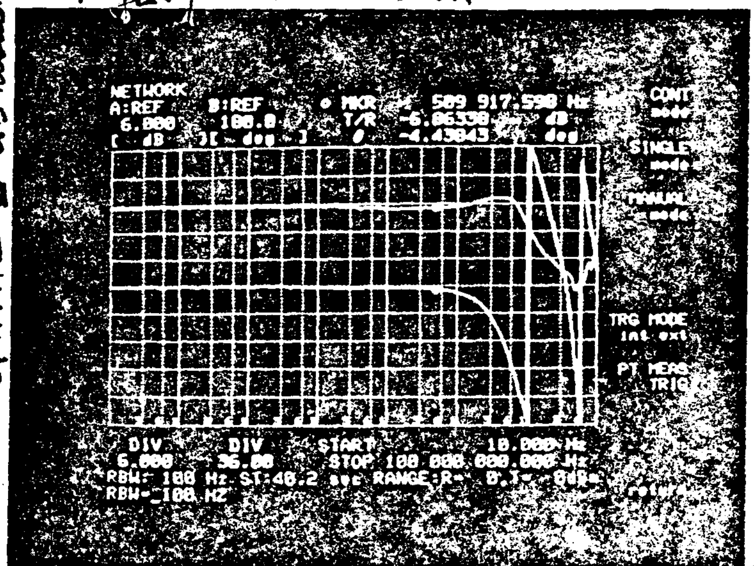
Crosstalk between n.J. in and Lower out on LD#A

14-July-89

More transfer functions taken

14-July-89 10:17

GAIN = 10 dB nominal



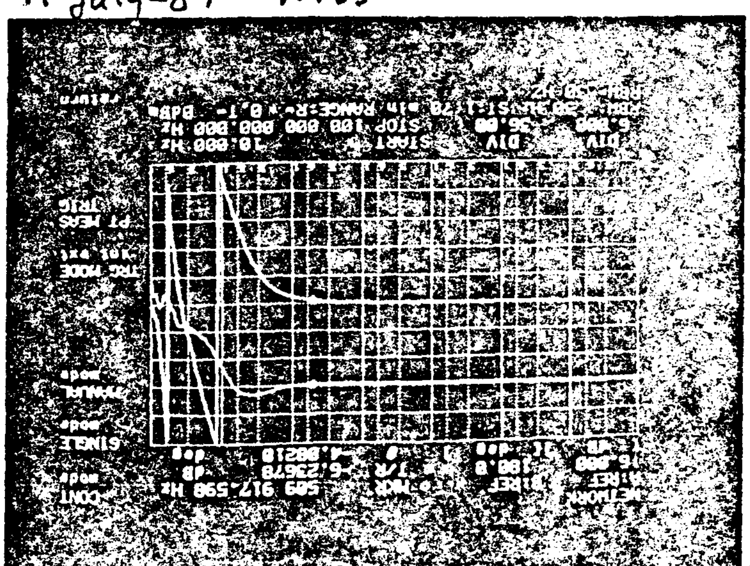
LD1 MID

←

LINE DRIVER 1, Middle, 50Ω in, out

14-July-89 10:25

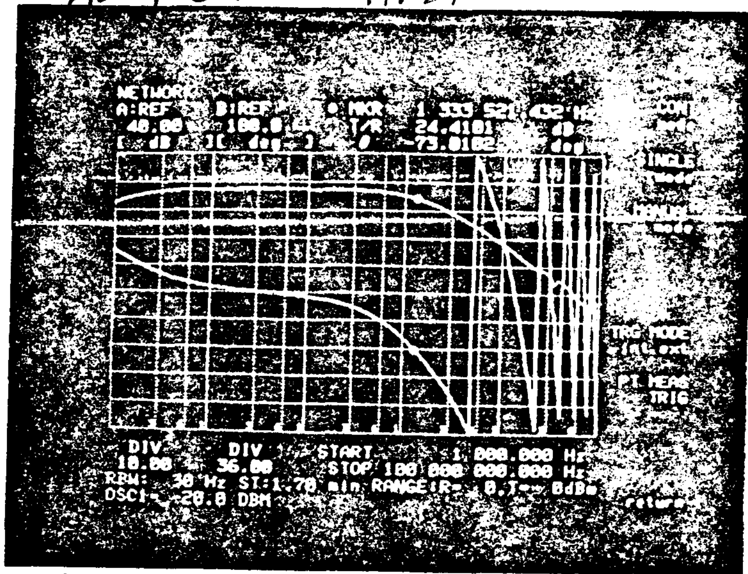
GAIN = 0 dB nominal



LD1 low

Line driver 1, Lower, 50Ω in out

13-July-89 11:21



AXES: 100 MHz 40dB

← unmatched cables

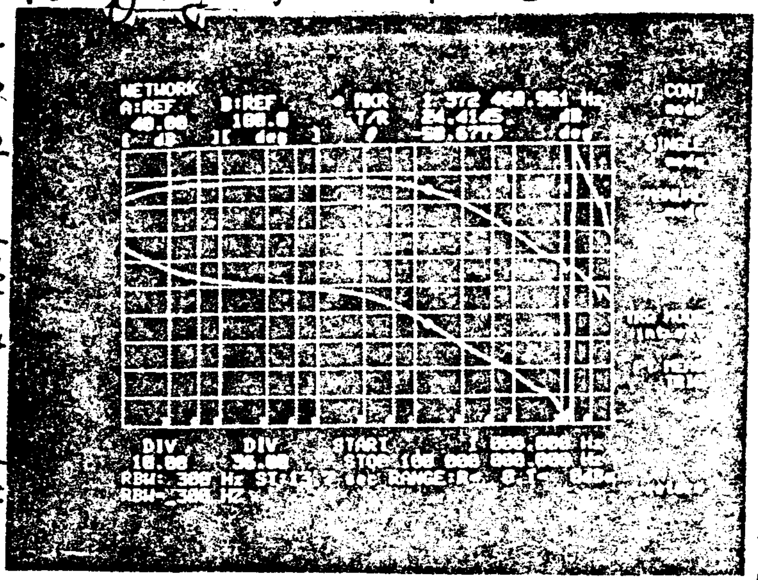
←

50K-713

50K 50Ω in and out

13-July 89 12:02

10° phase shift at 230 KHz



~~50K-713~~

← matched cables

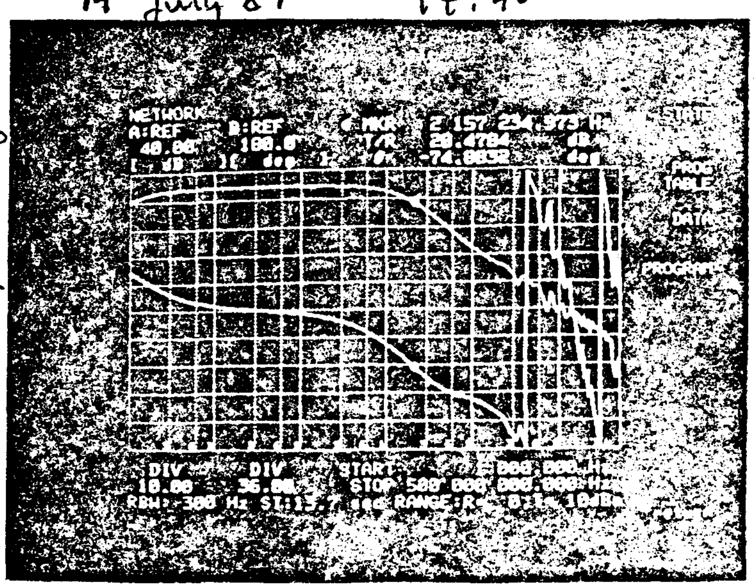
←

~~50K in and out~~

50K 50Ω in and out

14-July 89 17:40

10°: 203 KHz



←

50K 713

50K 50Ω ~~and~~ out

CALIFORNIA INSTITUTE OF TECHNOLOGY

GRAVITATIONAL PHYSICS 130-33

November 16, 1988

Jeff Livas
MIT Gravitational Physics Group

Howdy, Jeff—

I've finally come up with the much-promised description and evaluation of our current (reasonably successful) fast piezo laser stabilization servo. The numbers are very crude but give all the qualitative features we actually observe in their respective places. Some of the numbers I quoted to you on the phone weren't quite right; one that I remember misquoting is the responsivity of our "slow" pzt stack. It is really more like 40 Å /volt.

The procedure I use for working out the crossover points between the various parallel signal paths in these "bypass topology" loops is to break them apart into subunits at those points where they share a common input or output. In this example, I've taken the output of the "Fast # 3" video preamplifier as one common signal path, and the laser output frequency (after all the contributions from fast and slow piezos and the phase-correcting Pockels cells have been added together) as another. The various electronic transfer functions of the parallel subunits are computed, multiplied by the electro-optic transfer functions of their respective actuators, and added together. It's easiest to just do this graphically on a log-log plot, since your input data is rarely more accurate than your pencil and (for a good robust design) the major stability criteria should be extremely insensitive to small changes in gain.

You should be warned of a few glitches that we'd rather not have. Since our PA-85 amp blew up we've been using the "HV # 6" in its place for the pockels cells. It unfortunately is not fast enough

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and has this weird wrinkle around 100 kHz where the inverting half poops out. With the PA-85 in place we got a unity–gain frequency of about 1 MHz rather than 350 kHz and no wrinkle. Also, you will note that the slow pzt/fast pzt crossover violates the canonical rule of "no crossovers at greater than 6 db/octave relative slope." We just barely get away with this one because this crossover is not far enough away from the "extra" pole to have the full effect of its phase shift. This is a marginal situation which we hope to correct in the next version.

In our conversation you asked about dealing with the resonance of the PZ80 piezo mirror at 5 kHz and I'm afraid I wasn't too clear about my recommendation. Just in case, let me state the problem more formally; one wants to attenuate the signal reaching the nasty element (the PZ80) by a large factor to prevent its resonant behavior from dominating over the righteous and properly–phased feedback going to, say, your fast piezo at that resonant frequency f_r. At the same time, the crossover rule prohibits you from adding too much phase shift at some lower frequency $f_{\text{crossover}}$. The optimization therefore is for maximum attenuation in the stop band with minimum phase shift in the passband, and the solution we tend to use is a Butterworth filter with the 3dB point chosen at the geometric mean $f_{3\text{dB}} = (f_r f_{\text{crossover}})^{1/2}$ with whatever number of poles it takes to control the resonance.

Give me a ring if you have a chance to look at this stuff and we can discuss it. Happy frequency stabilization !!

Closing the loop,

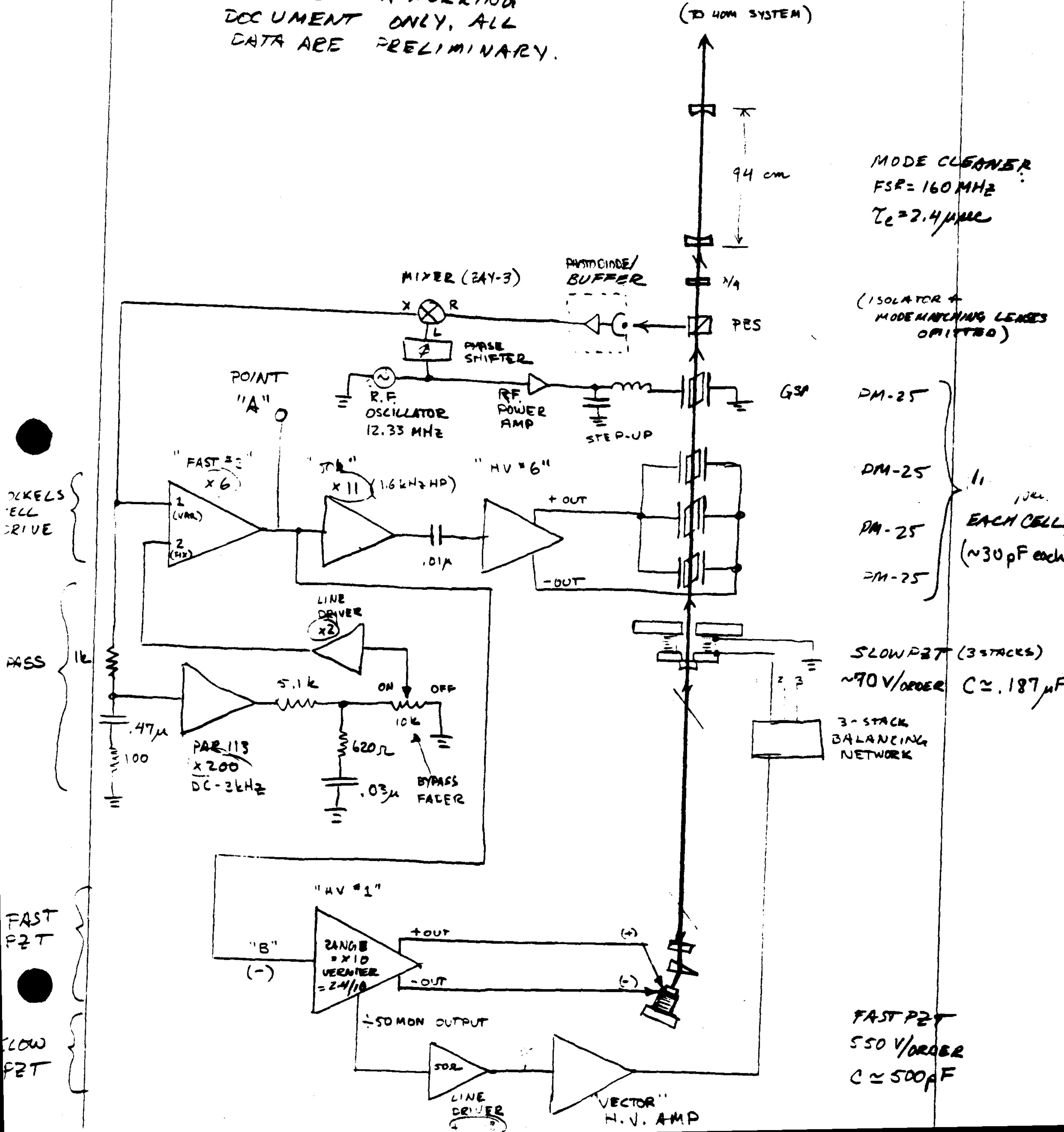
M. E. Zucker

cc: Alex Abramovici
Bob Spero
Jeff Harman

11/14/88 MEC

MODE CLEANER SERVO BLOCK DIAGRAM

NOTE: THIS IS A WORKING DOCUMENT ONLY. ALL DATA ARE PRELIMINARY.



11/14/88 MEZ

MODE CLEANER SERVO TRANSDUCERS (IN TERMS OF EQUIVALENT LASER FREQUENCY ν)

1. POCKELS CELLS

$$2\pi \nu_{laser} = \frac{\partial \phi_{laser}}{\partial t} \; ; \quad \phi_{laser} = 2\pi \nu_0 t + \phi_{pc} \quad \phi_{pc} = \frac{2\pi n_{pc} l_{pc}}{\lambda} \; ;$$

$$n_{pc} l_{pc} = K + \alpha V_{pc} \qquad (\alpha \simeq .22 \text{ nm}/V \text{ for FM-25})$$

$$\phi_{pc} = 2\pi (K + \alpha V_{pc})/\lambda$$

$$\Rightarrow \delta \nu_{laser} = \frac{2\pi\alpha}{\lambda} \frac{dV_{pc}}{dt}$$

i.e., for $V_{pc} = V_0 \sin(2\pi f t)$ (single Fourier component at f)

$$\frac{\partial(\delta \nu_{laser})}{\partial V_0} = 2.7 \times 10^{-3} \frac{f}{V_0} = 2.7 \text{ Hz} \left(\frac{f}{1 \text{kHz}}\right)\left(\frac{1 \text{ volt}}{V_0}\right)$$

NOTE: We're using 3 phase-adjusting pockels cells in series, driven in parallel

2. FAST PIEZO MIRROR

Since $\frac{dV_{FPZT}}{dl} = 550$ V/order and the laser is ~2.3 meters long

$$\Rightarrow c/2l = 65 \text{ MHz} = 1 \text{ order}$$

$$\Rightarrow \frac{\partial \nu}{\partial V_{FPZT}} = \frac{65 \text{ MHz}}{550 \text{ V}} \simeq \frac{120 \text{ kHz}}{\text{volt}}$$

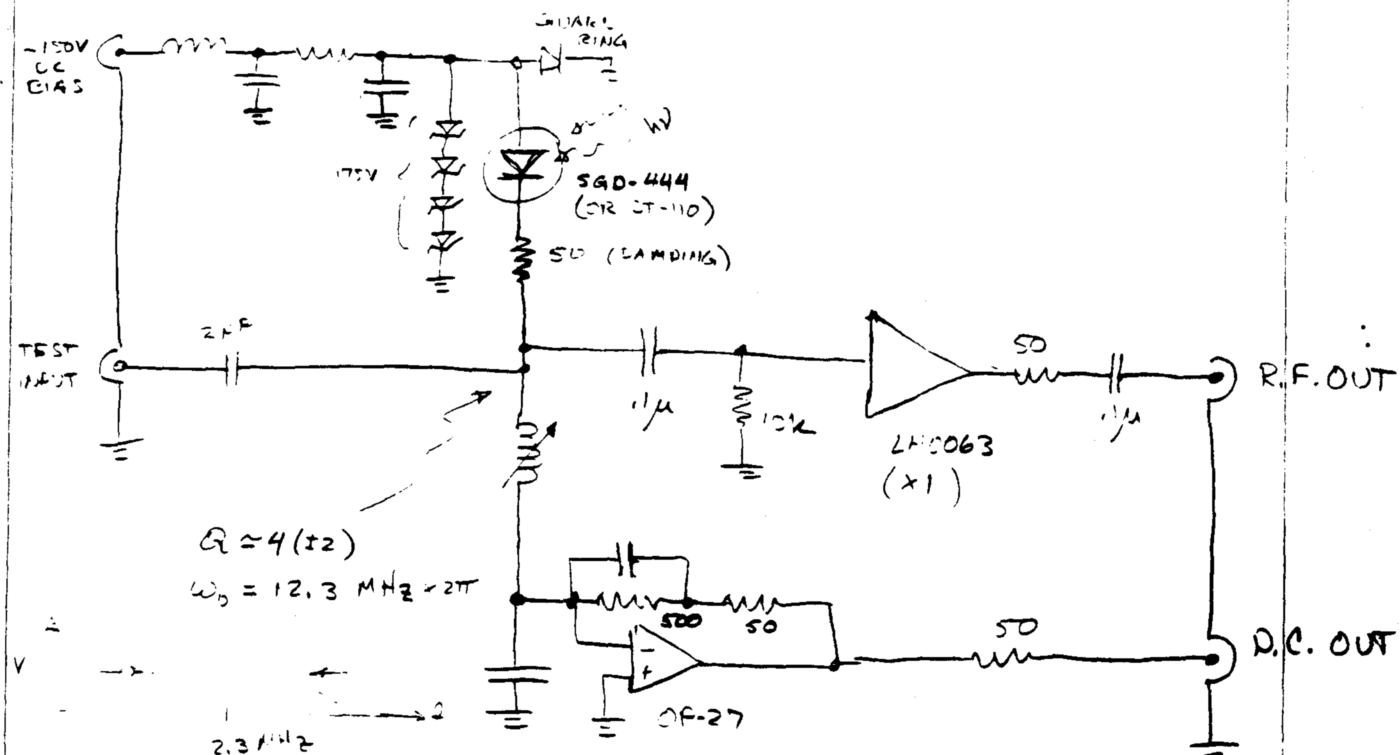
3. SLOW PIEZO MIRROR

Similarly, with $\frac{dV_{SPZT}}{dl} \simeq 70$ V/order, we get

$$\frac{\partial \nu}{\partial V_{SPZT}} = \frac{65 \text{ MHz}}{70 \text{ V}} \simeq \frac{930 \text{ kHz}}{\text{volt}}$$

11/14/88 ME

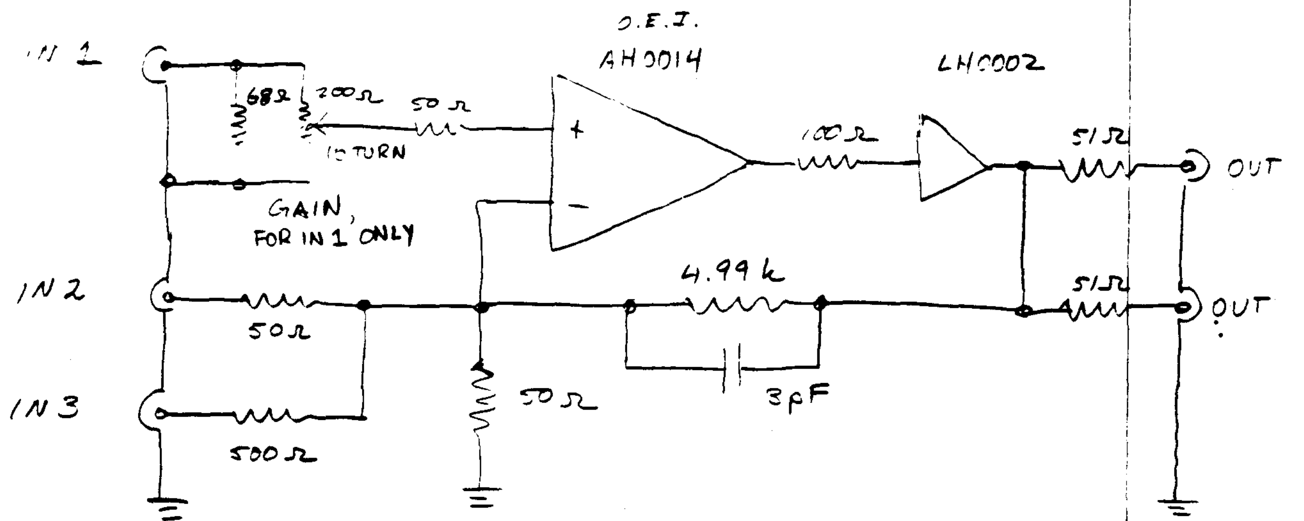
MODE CLEANER SERVO PHOTODIODE / BUFFER
(STANDARD CALTECH FRONT END)



R.F. DARK NOISE ≃ SHOT NOISE AT 1mW, 5145 Å

11/14/88 MEG

MODE CLEANER SERVO "FAST #3" AMPLIFIER

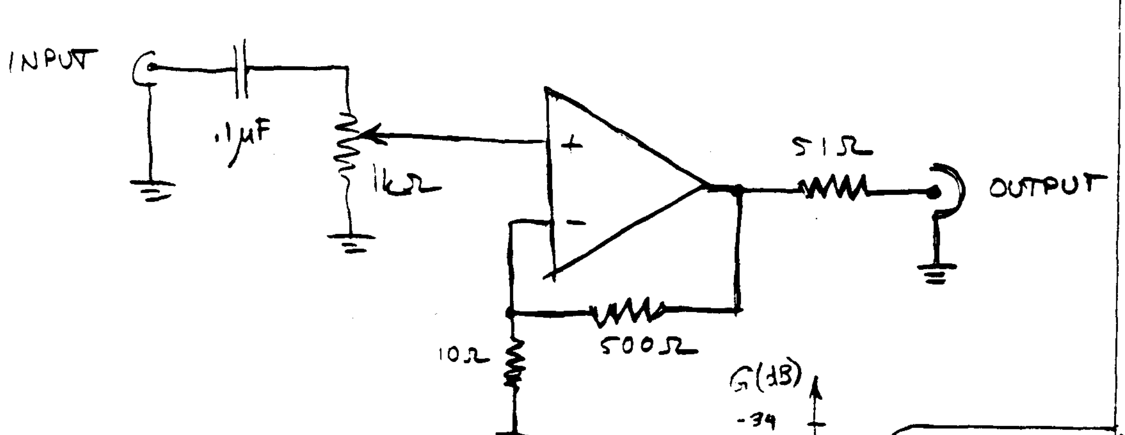


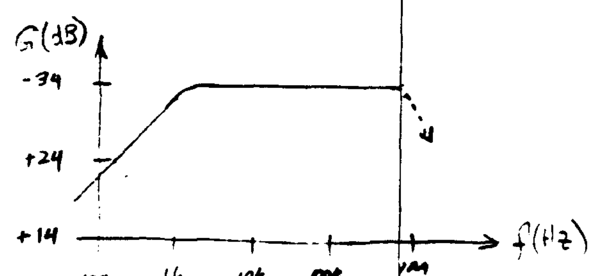
GAIN; IN1 x 0 → x100 , DC - 10 MHz

IN2 x -100

IN3 x 10

"50k" AMPLIFIER



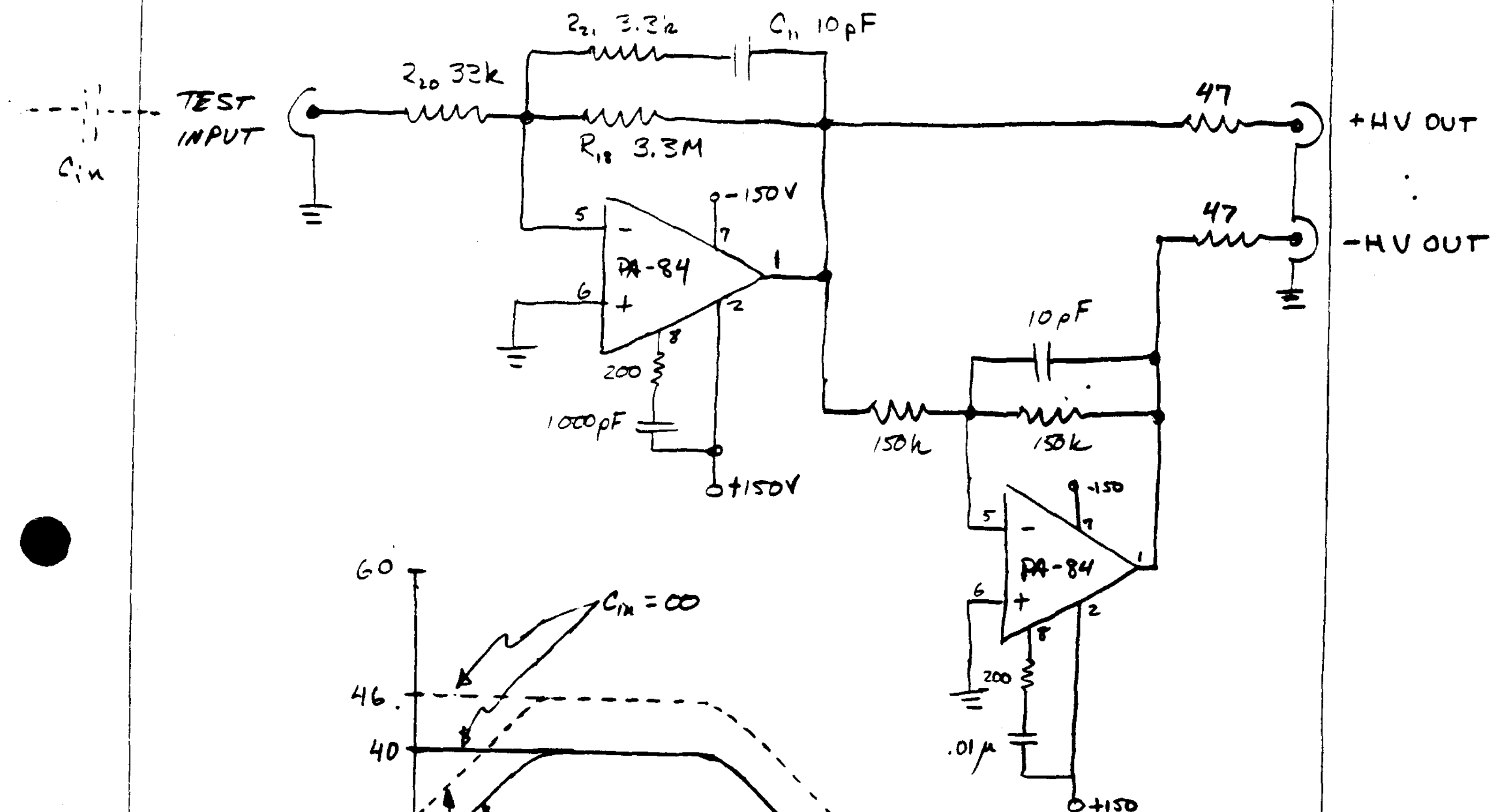


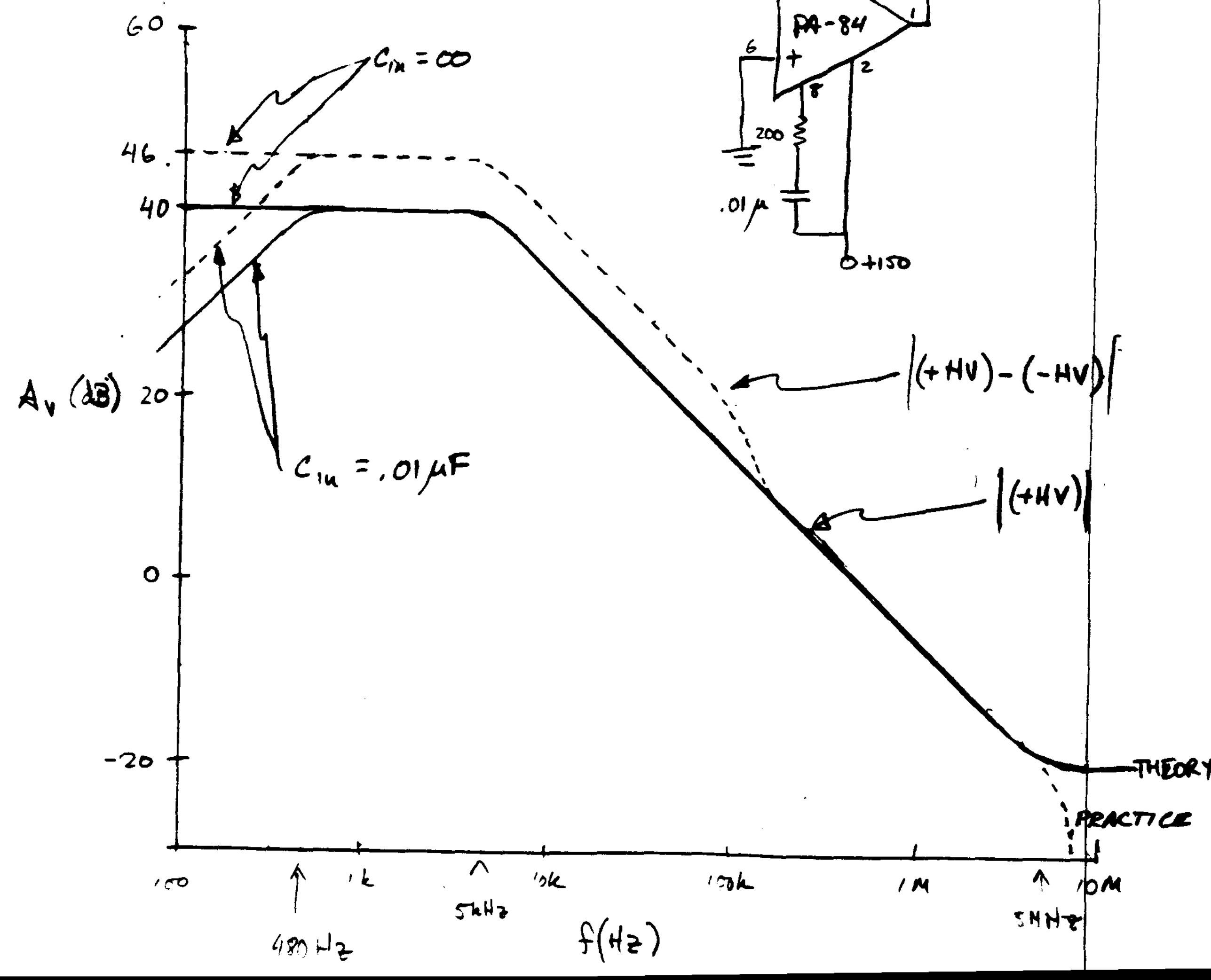
GAIN; x50 MAX., 1.5 kHz → ~7[illegible] kHz

11/15/88 MEZ

MODE CLEANER SERVO LOOP "HV#6" AMP

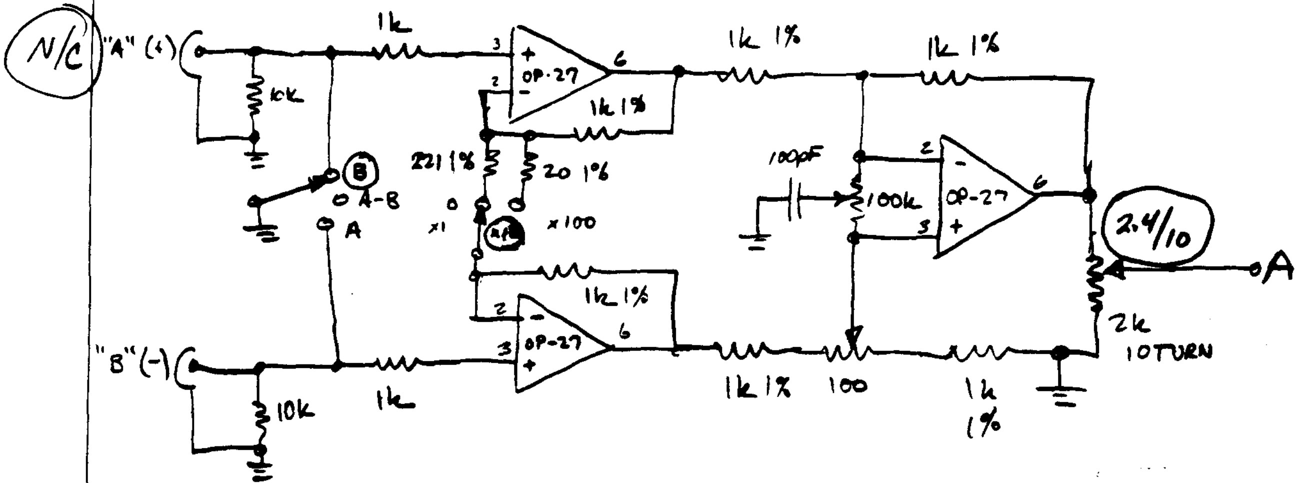
(IMPORTANT CIRCUITRY SHOWN – SEE GENERAL "HV AMP" SCHEMATIC FOR FULL DETAILS)

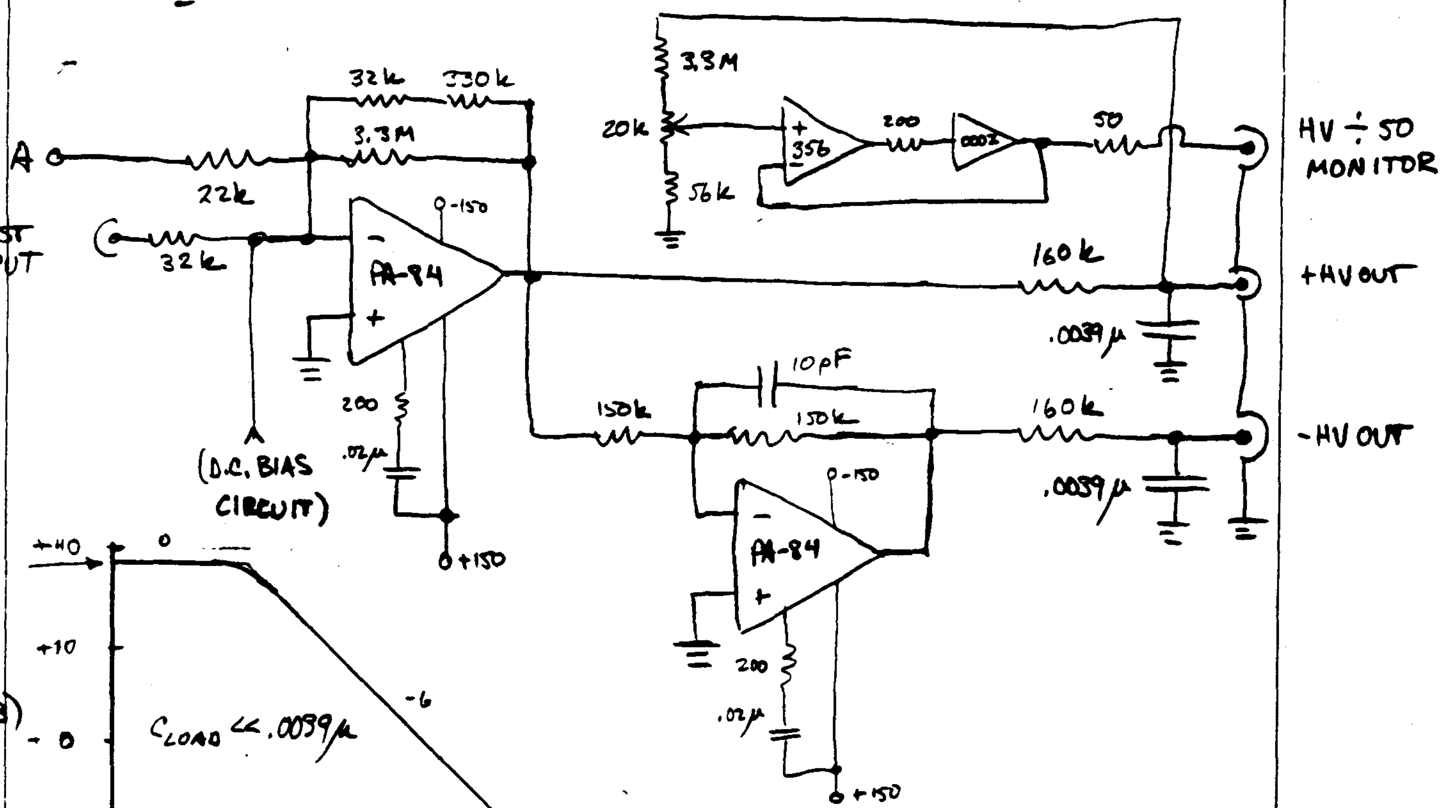


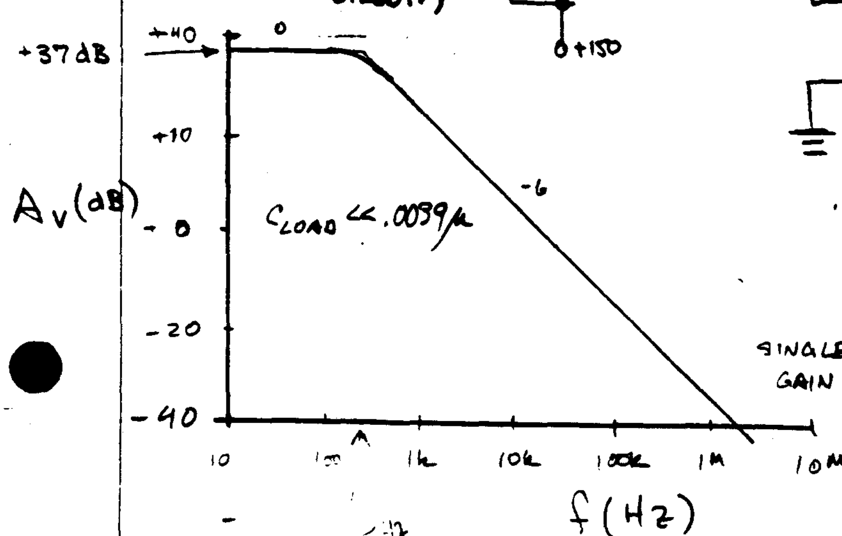


11/15/88 MEZ

MODE CLEANER SERVO LOOP "HV #1" AMP
(IMPORTANT CIRCUITRY SHOWN – SEE GENERAL "HV AMP" SCHEMATIC FOR DETAILS).



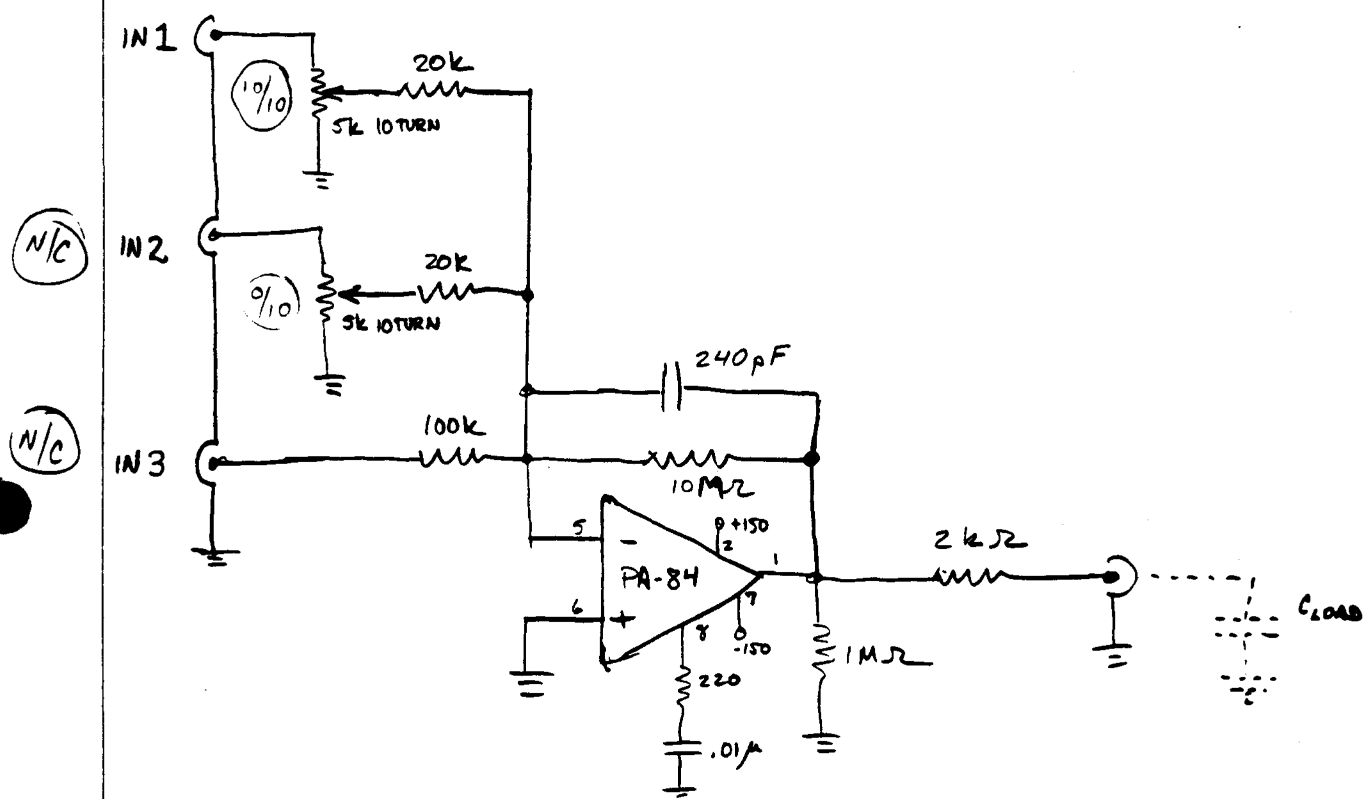


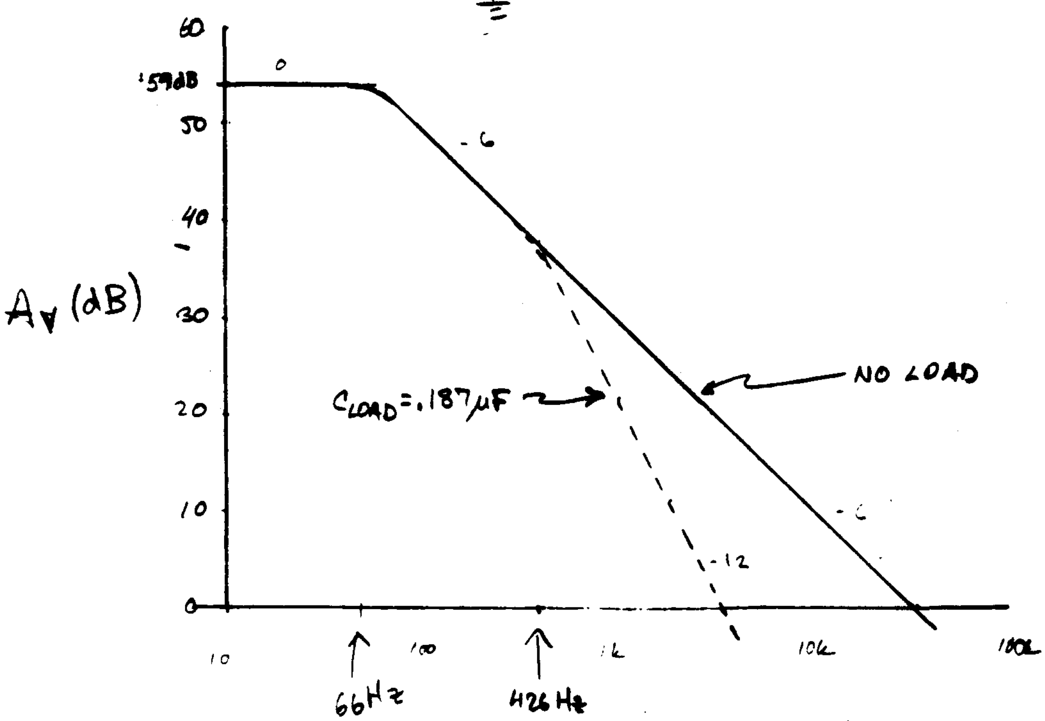


SINGLE-ENDED,
GAIN RANGE x10, VERNIER 2.4/10

11/15/88

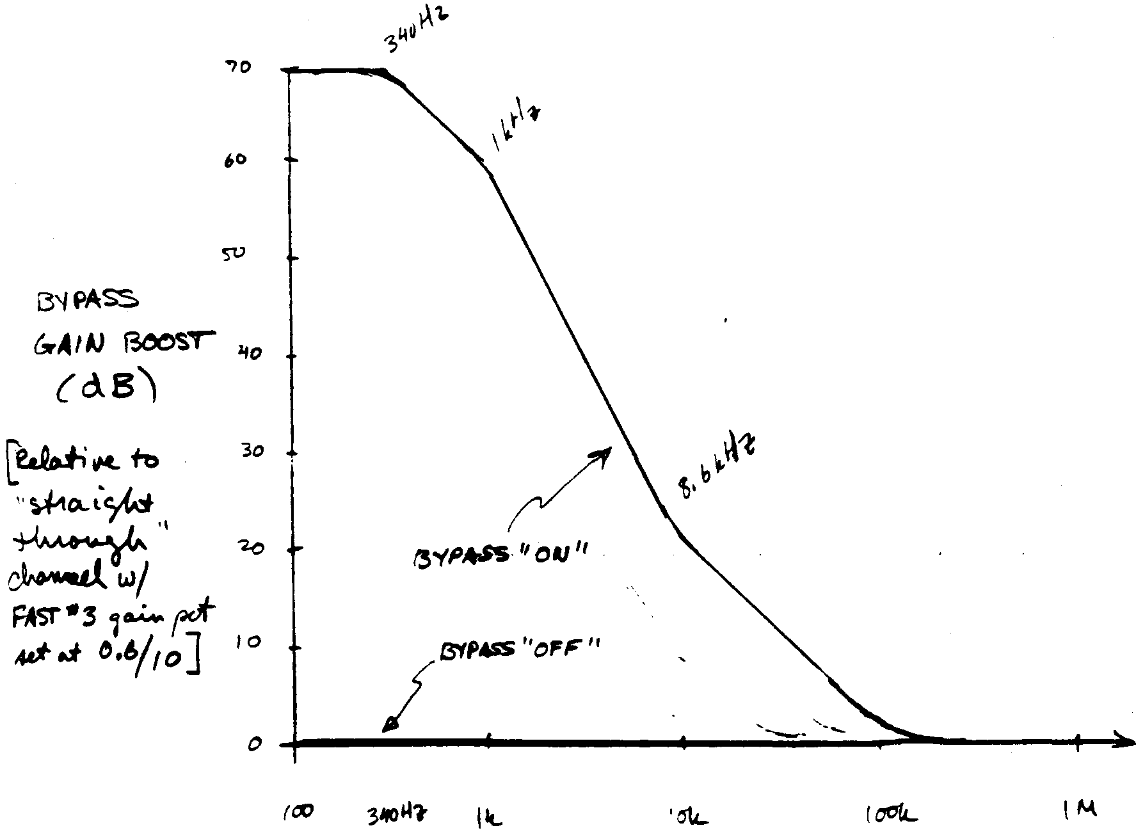
MODE CLEANER SERVO LOOP "VECTOR H.V. AMP"

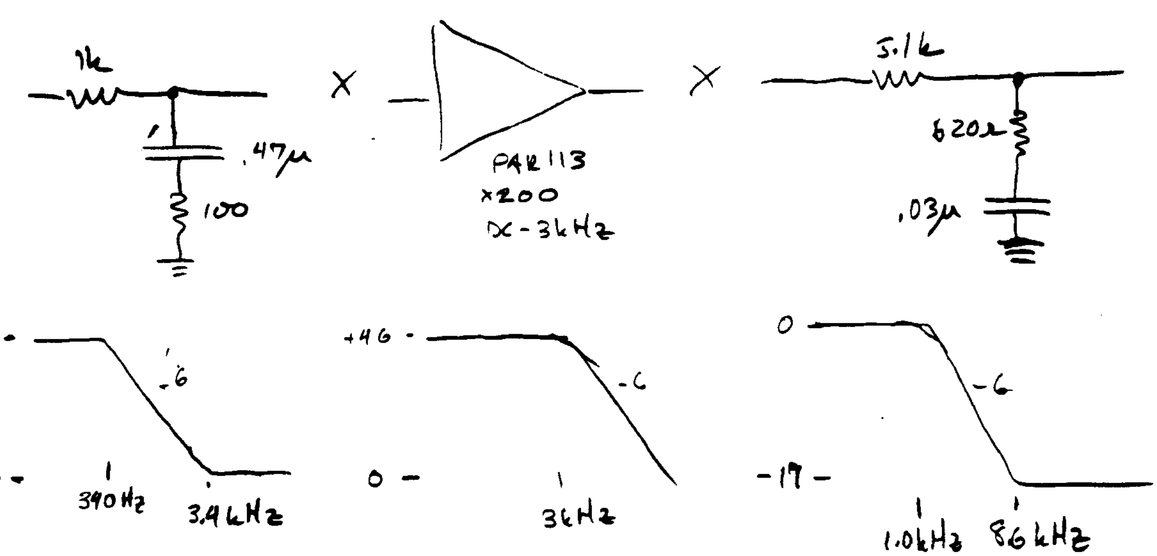




11/15/88 MEZ

MODE CLEANER SERVO BYPASS GAIN ENHANCEMENT

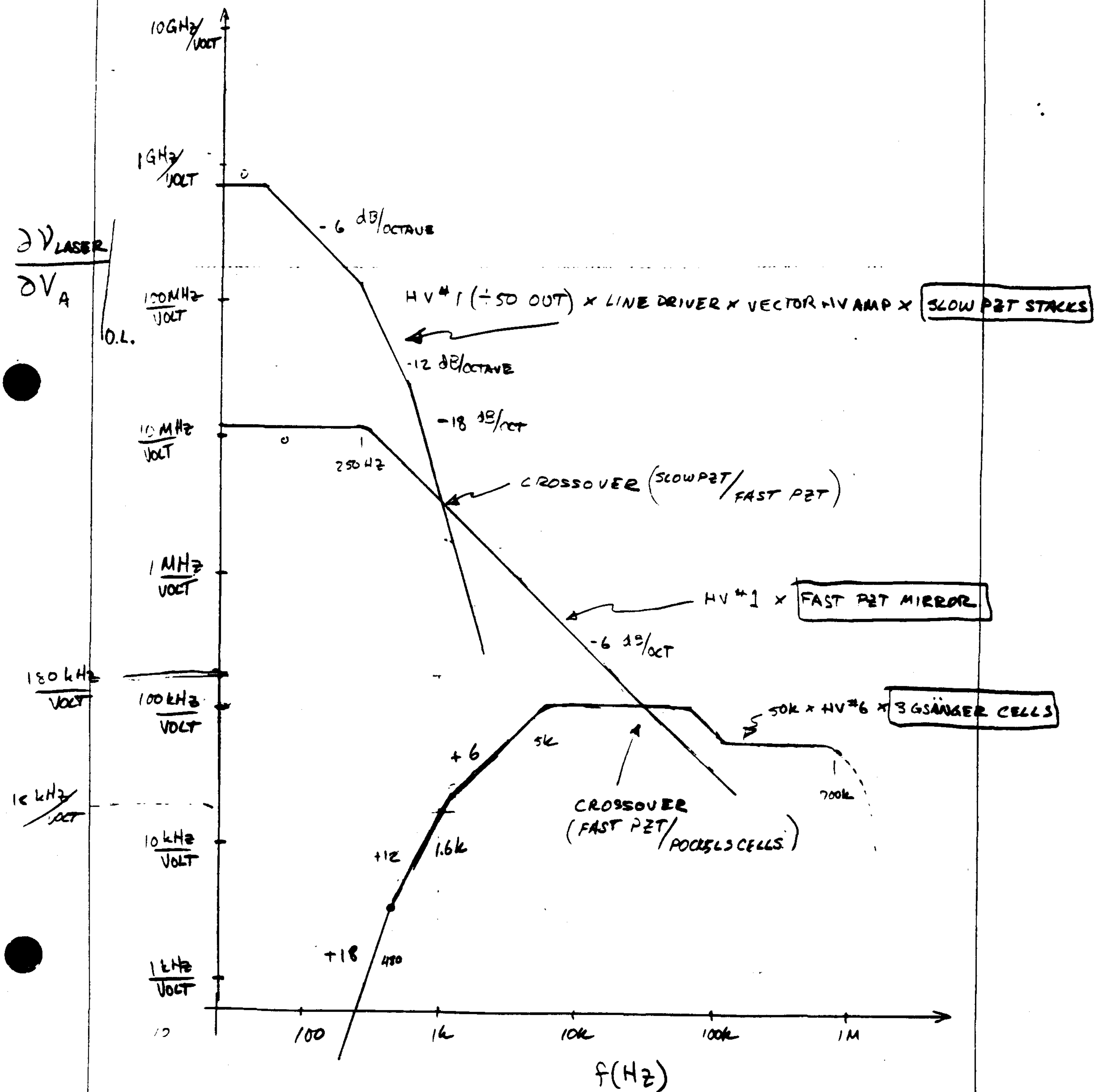




11/15/88 MEZ

MODE CLEANER SERVO ELECTRONIC AND TRANSDUCER OPEN-LOOP TRANSFER FUNCTION

LASER FREQUENCY EXCURSION PER VOLT APPLIED AT POINT "A" (OPEN-LOOP)



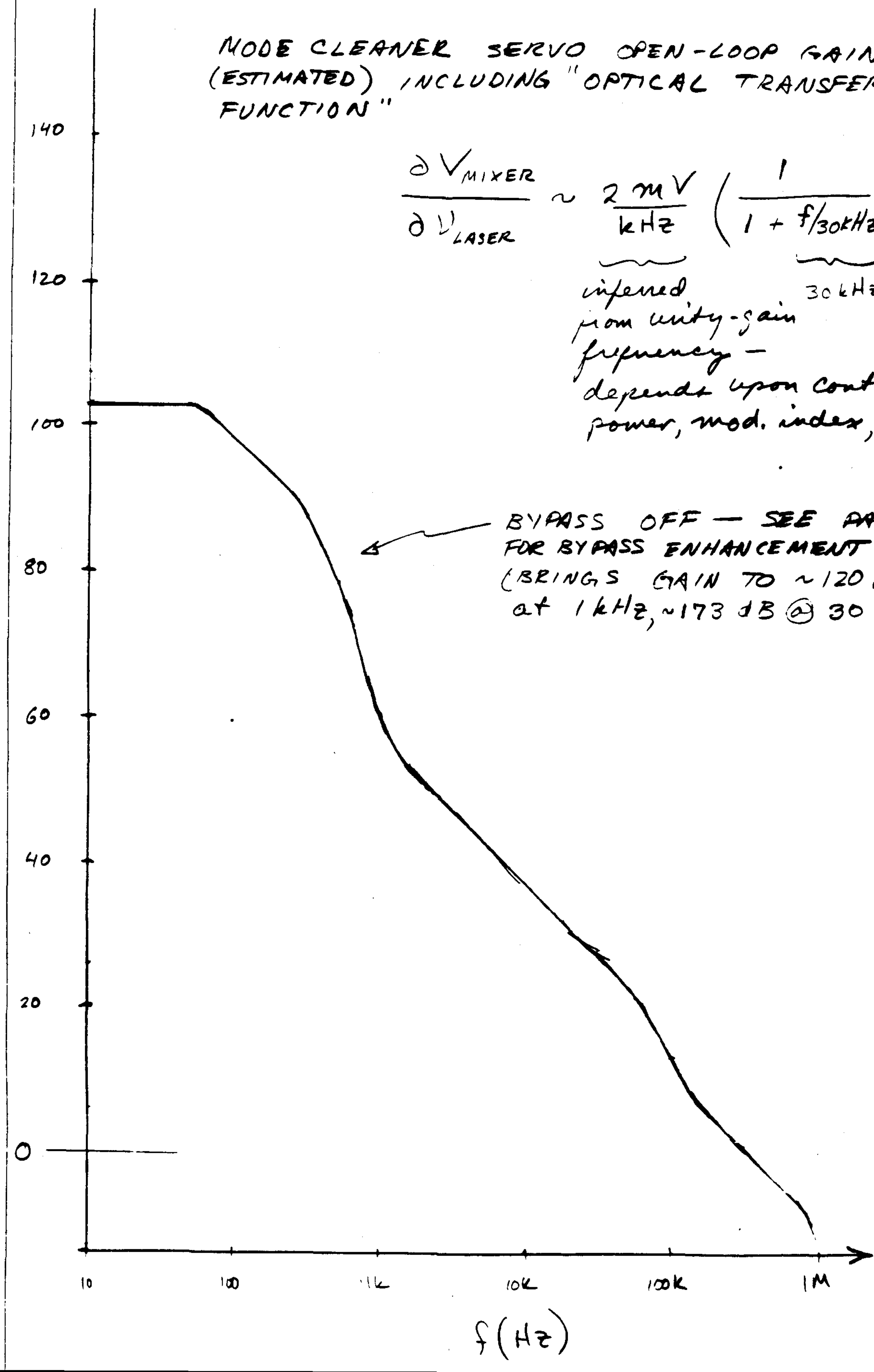
11/15/88 meg

MODE CLEANER SERVO OPEN-LOOP GAIN (ESTIMATED) INCLUDING "OPTICAL TRANSFER FUNCTION"

$$\frac{\partial V_{MIXER}}{\partial \nu_{LASER}} \sim \frac{2\,mV}{kHz}\left(\frac{1}{1 + f/30kHz}\right)$$

$\frac{2\,mV}{kHz}$: inferred from unity-gain frequency — depends upon contrast, power, mod. index, ...

$30\,kHz = \frac{1}{4\pi\tau_c}$

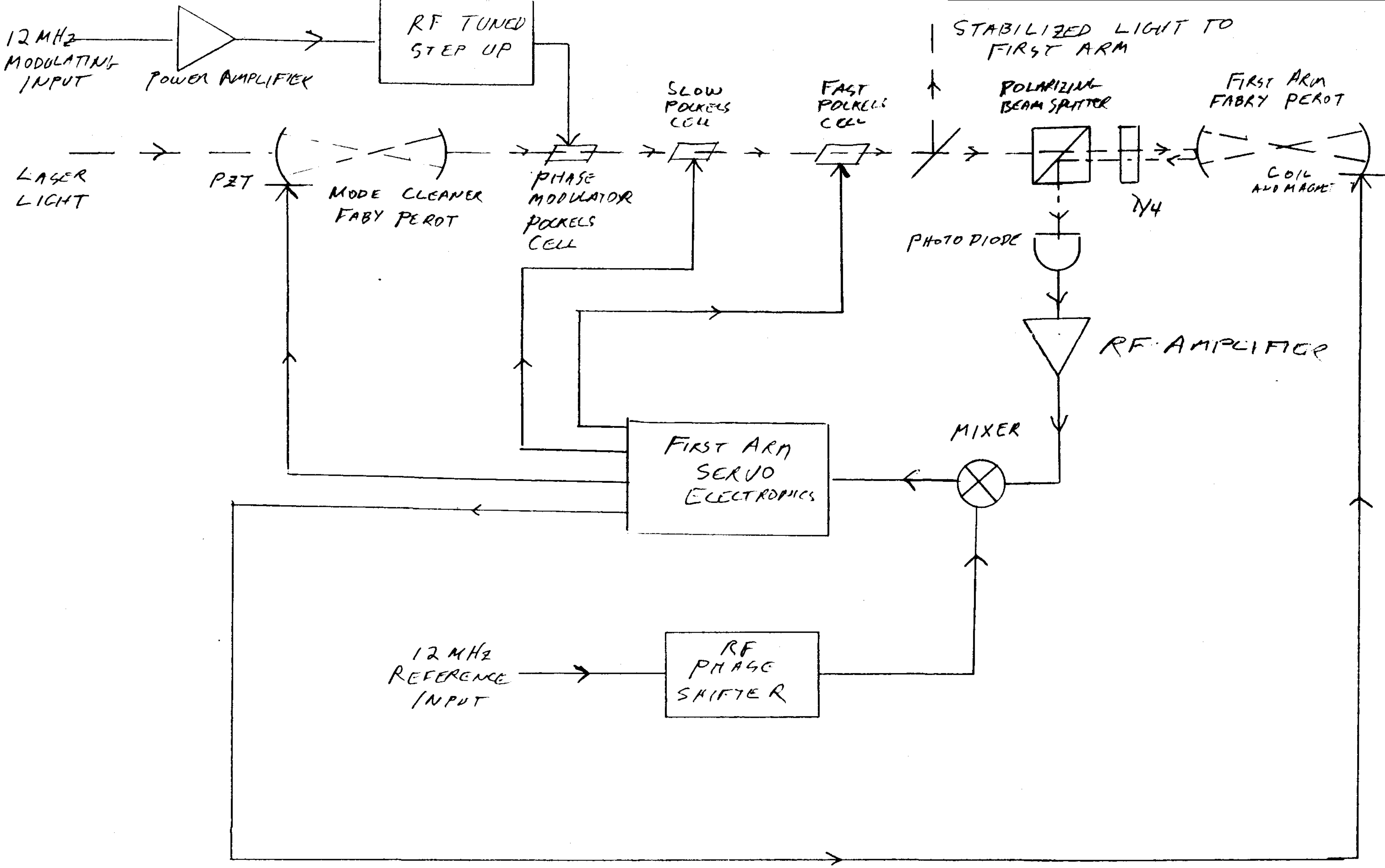


BATCH START

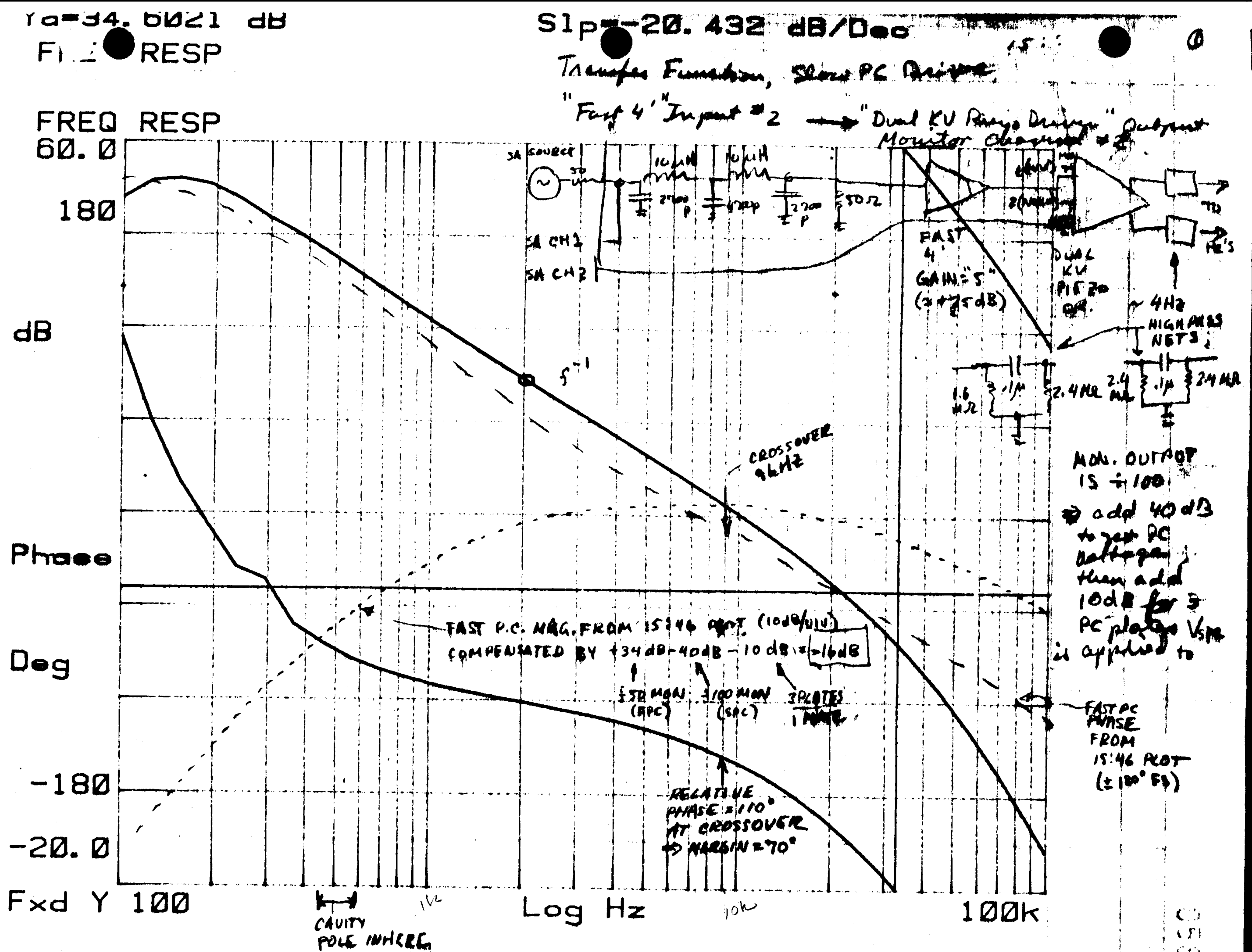
First Arm

STAPLE OR DIVIDER

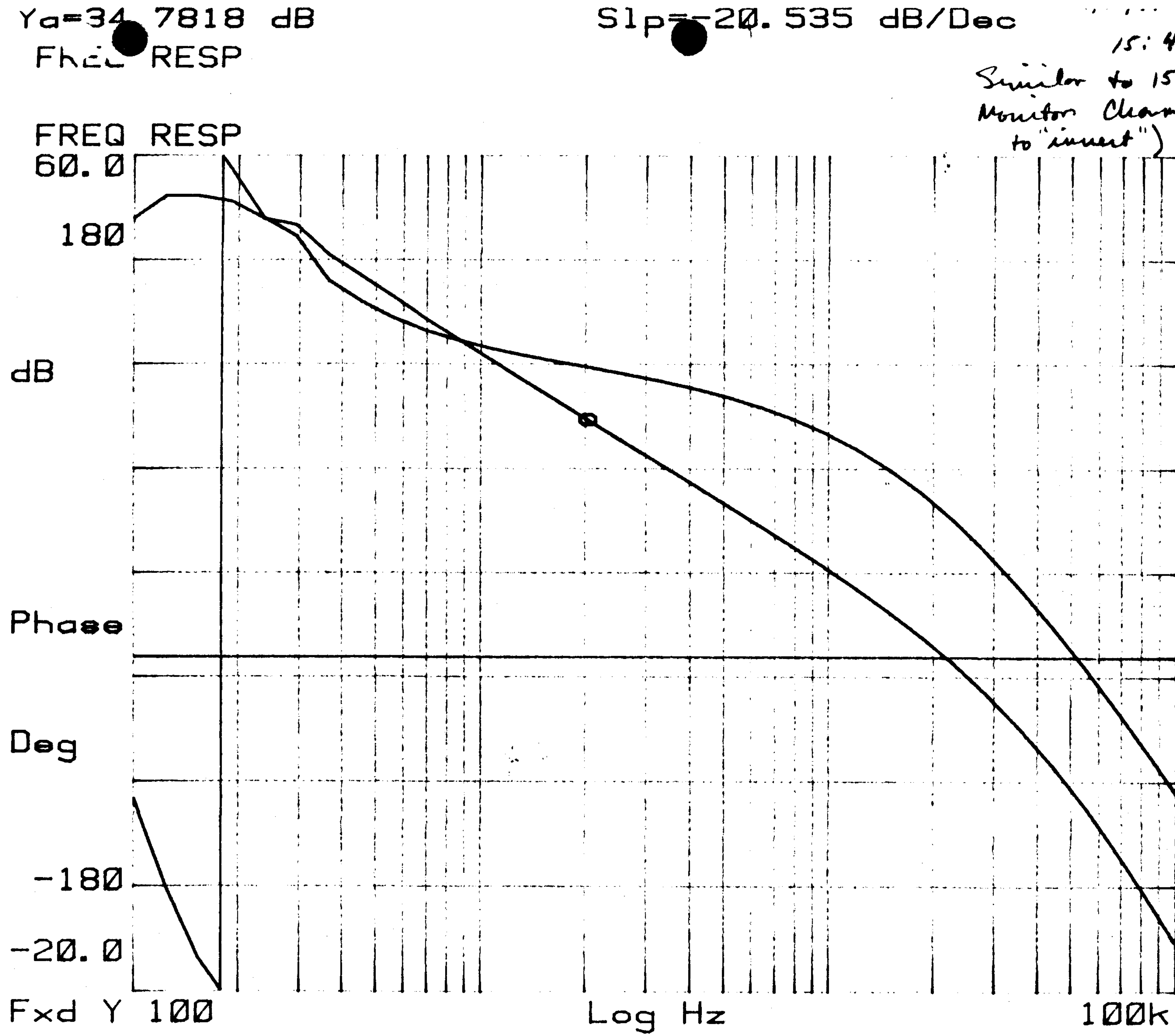
FIRST ARM SERVO ADDITIONS



FIRST ARM (LIGHT STABILIZATION) SERVO



Ya=34.6021 dB
Slp=-20.432 dB/Dec
FREQ RESP
Transfer Function, Slow PC Driver
"Fast 4" Input #2 → "Dual KV Pengo Driver" Output Monitor Channel #2
60.0
180
dB
Phase
Deg
-180
-20.0
Fxd Y 100
Log Hz
100k
1k
10k
SA SOURCE
10μH
10μH
2700 p
470p
2700 p
50Ω
SA CH1
SA CH2
FAST 4
GAIN="5" (≈+15dB)
DUAL KV PIEZO DR.
~4Hz HIGH PASS NETS
1.6 MΩ
.1μ
2.4 MΩ
2.4 MΩ
.1μ
2.4 MΩ
f⁻¹
CROSSOVER 9kHz
MON. OUTPUT IS ÷100
⇒ add 40 dB to get PC voltage; then add 10dB for 3 PC plates Vsm is applied to
FAST P.C. MAG. FROM 15:46 PLOT (10dB/DIV)
COMPENSATED BY +34dB - 40dB - 10 dB = -16dB
÷50 MON (FPC)
÷100 MON (SPC)
3PLATES 1 PLATE
FAST PC PHASE FROM 15:46 PLOT (±180° FB)
RELATIVE PHASE = 110° AT CROSSOVER ⇒ MARGIN = 70°
CAVITY POLE INHERE



15:4

Similar to 15:36 but Monitor Channel 1 (set to "invert")

Ya=36.915 dB

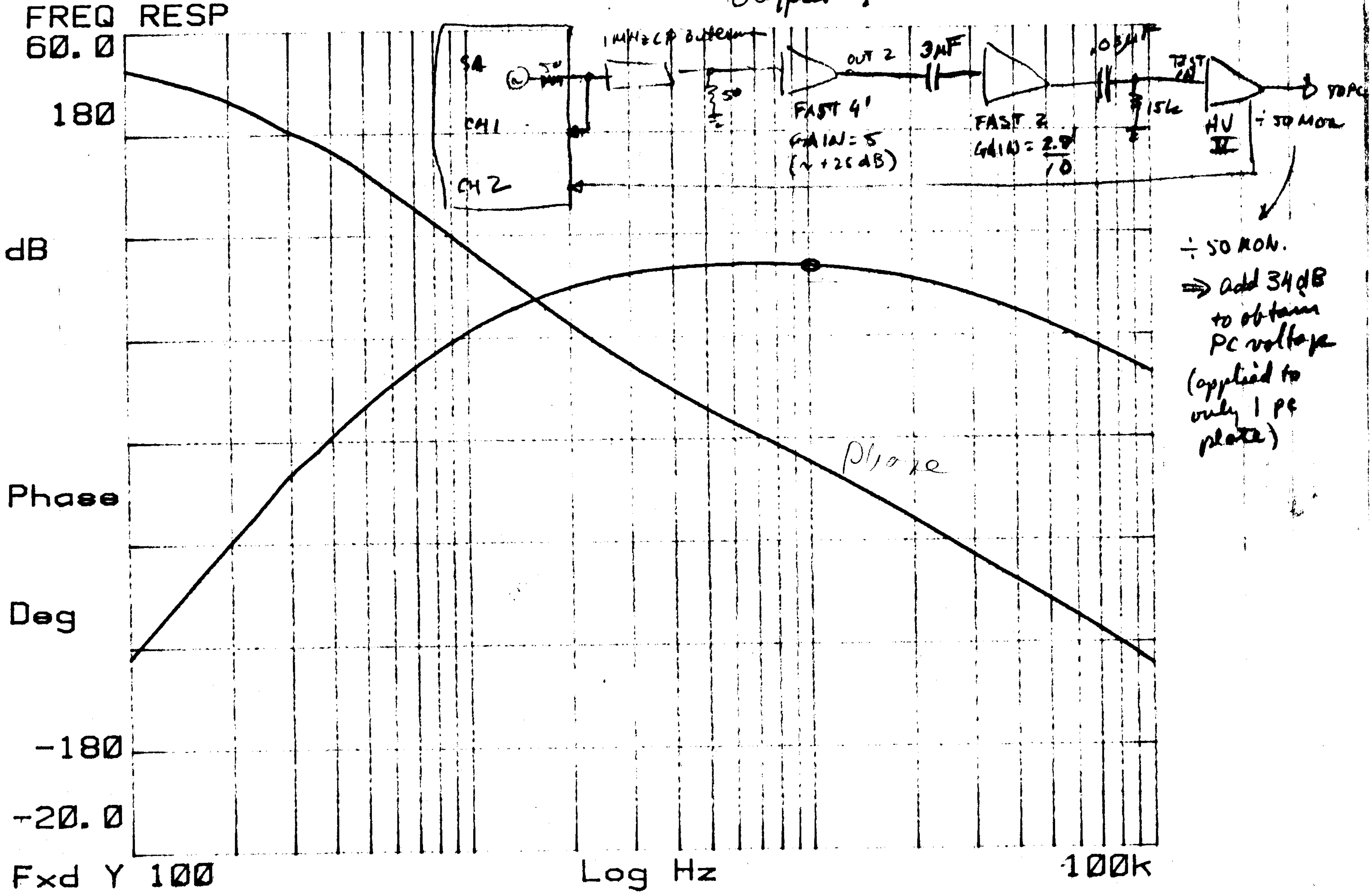
FREQ RESP

Fast PC Driving

Transfer Function, Fast 4' Input 2 → HV II

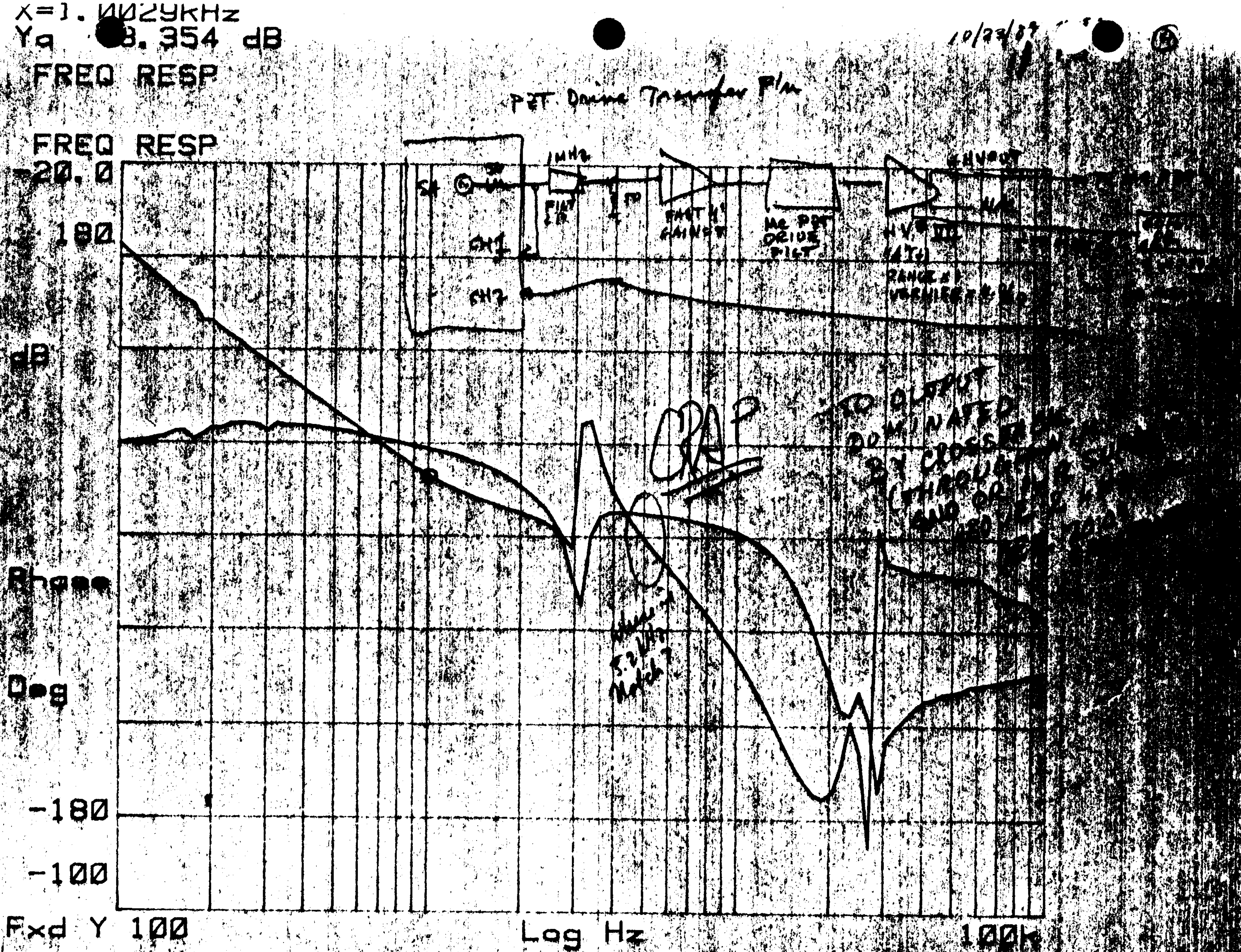
Output ÷50 Mon

③



÷ 50 MON.

⇒ add 34 dB to obtain PC voltage (applied to only 1 PC plate)



X=1.0029kHz
Ya 3.354 dB
FREQ RESP
PZT Drive Transfer F/n
FREQ RESP
-20.0
180
dB
Phase
Deg
-180
-100
CH1
CH2
CRAP
Fxd Y 100
Log Hz
100k

^=2.5704kHz
Ya= [illegible].766 dB
FREQ RESP

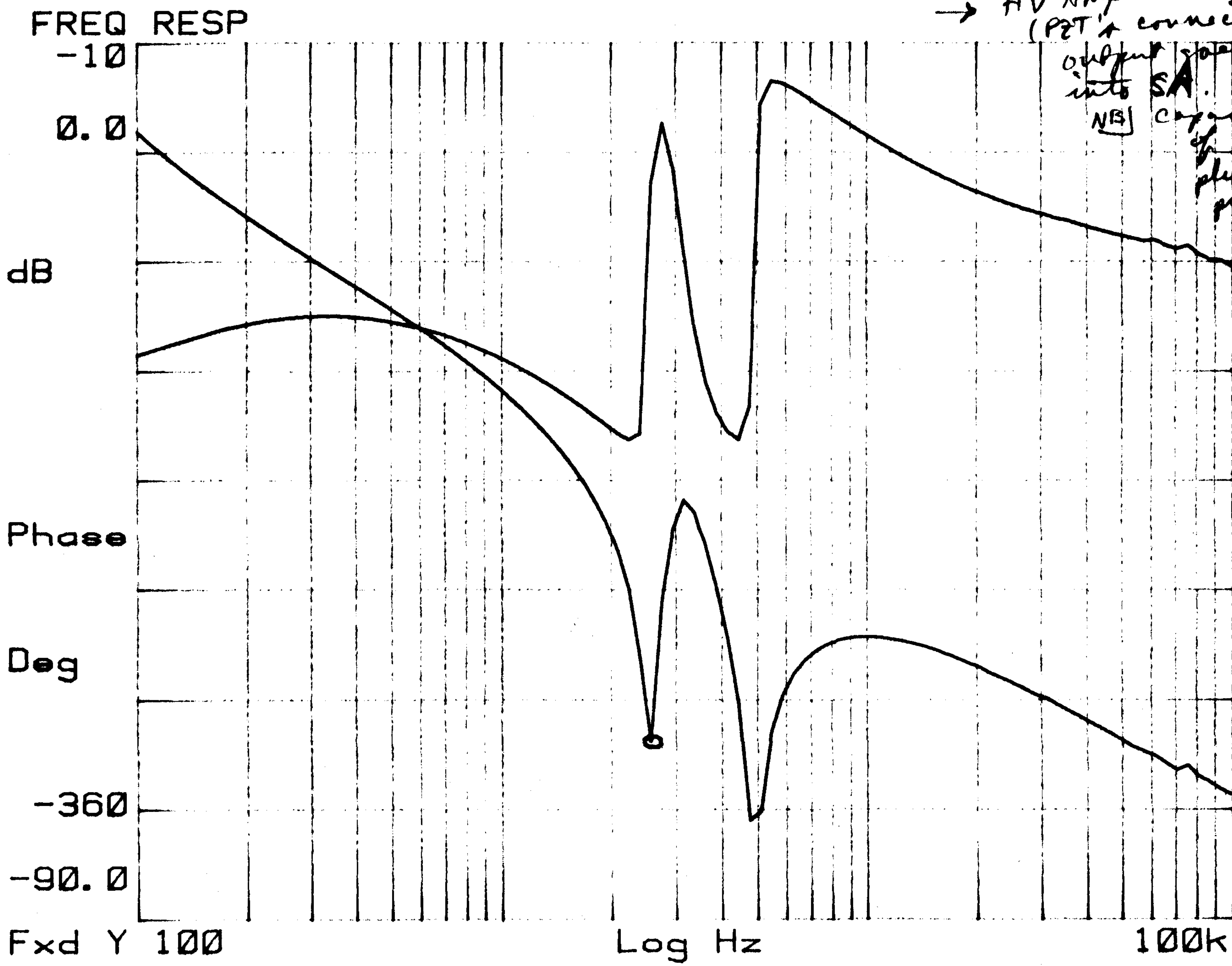
WITHOUT FCH 4'

10/23/89 MS 20°C

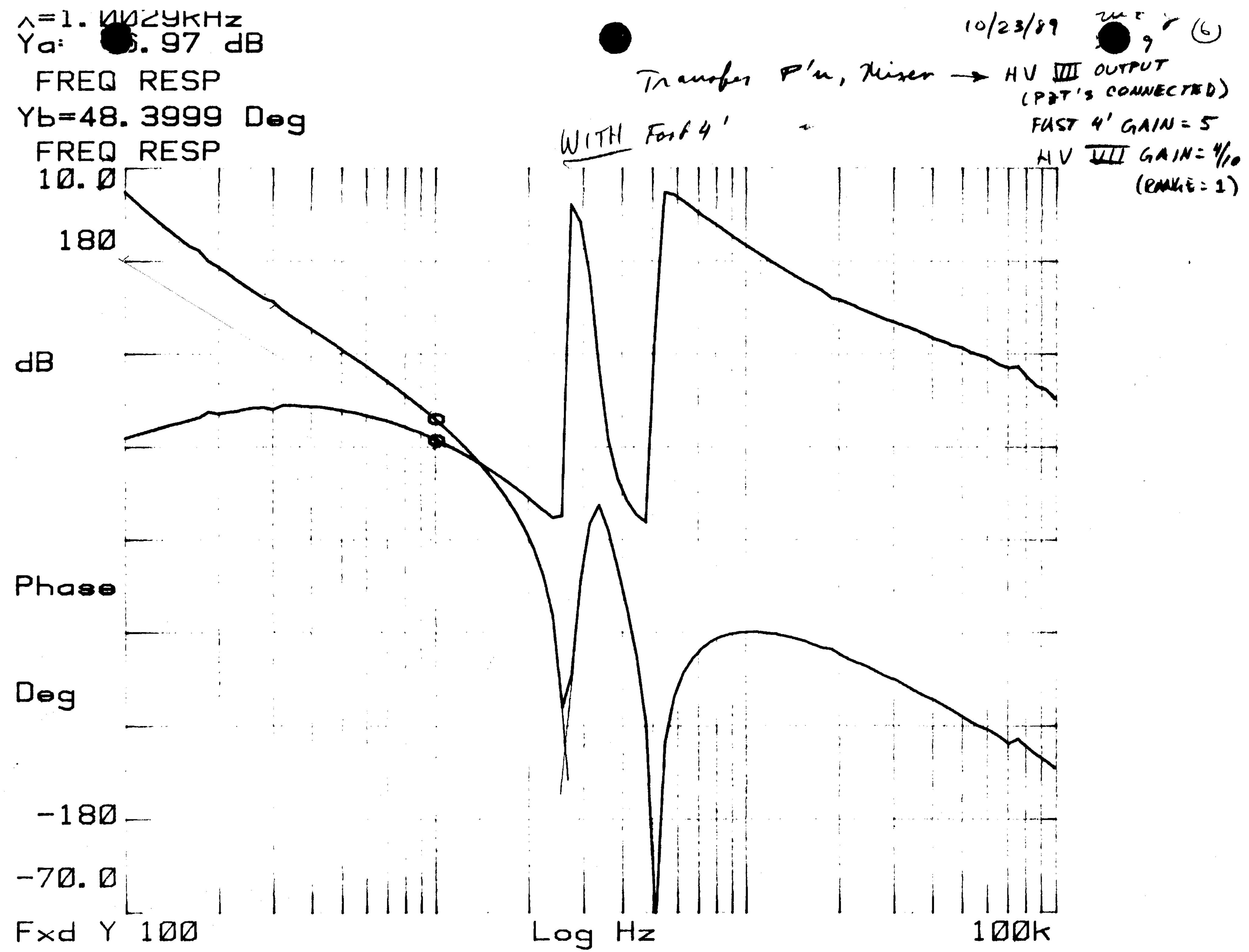
(5)

Transfer F'n, MC PZT Servo Filter Input → HV Amp VII Output (PZT's connected — output goes right into SA).

NB capacitive load of 100pF or so plus R of 1MΩ probably affects measurement!

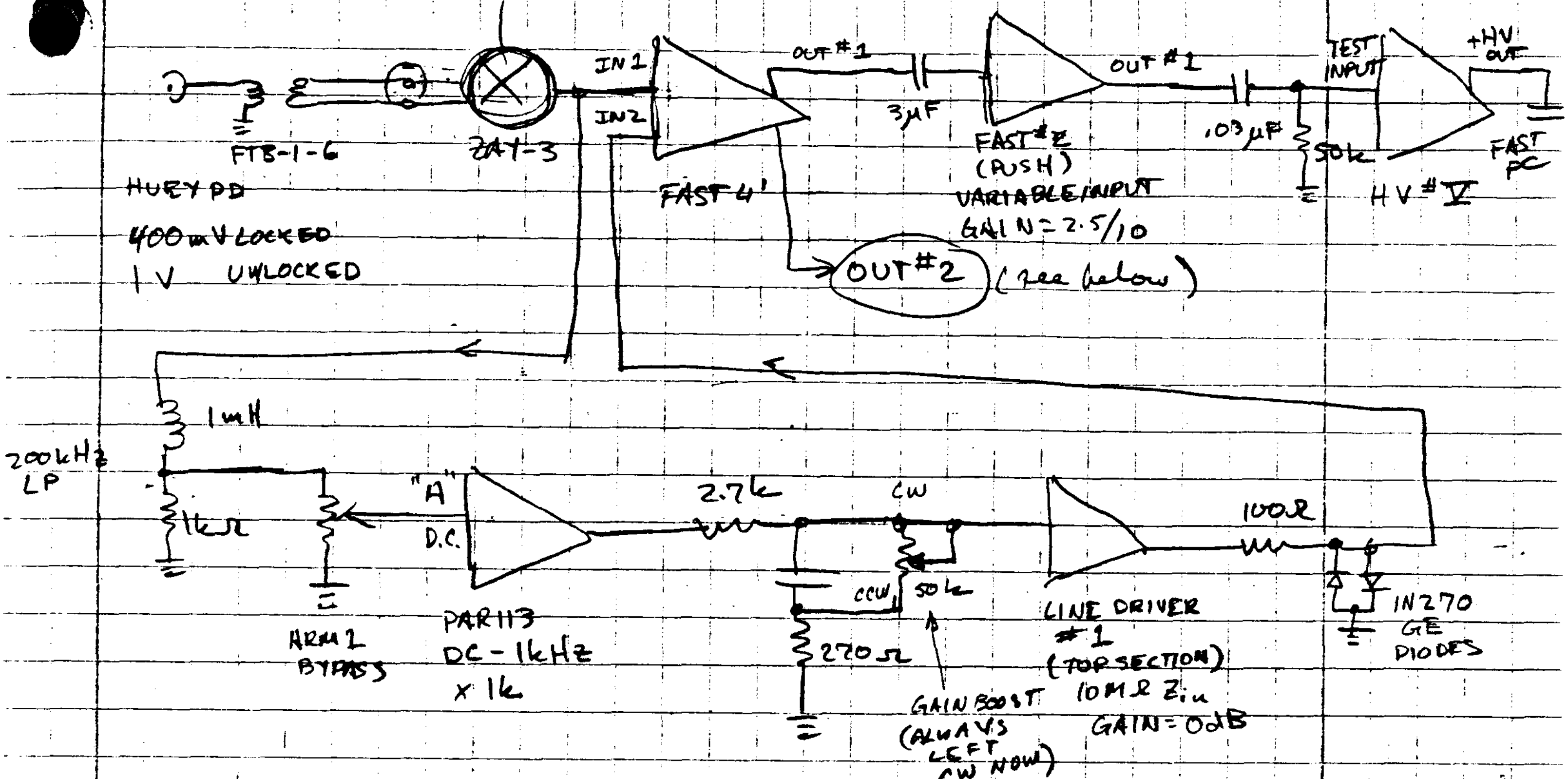


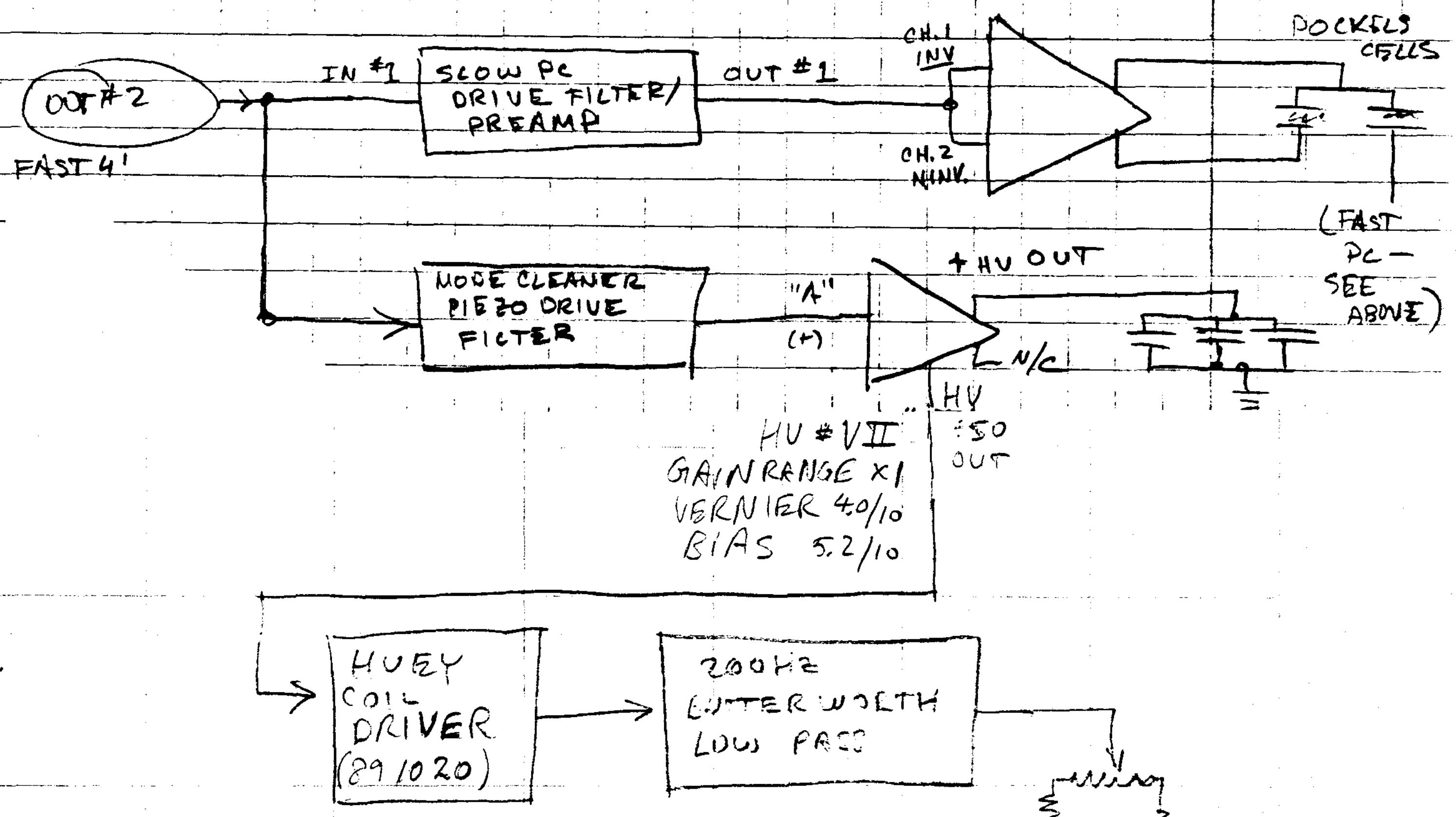
FAST 4' GAIN = 5.
HV VII GAIN = 4/10
(RANGE = 1)


^=1.0029kHz
Ya: .97 dB
FREQ RESP
Yb=48.3999 Deg
FREQ RESP
10/23/89
(6)
Transfer F'n, Mixer → HV III OUTPUT
(PZT's CONNECTED)
WITH Fast 4'
FAST 4' GAIN = 5
HV III GAIN = 4/10
(RANGE: 1)
10.0
180
dB
Phase
Deg
-180
-70.0
Fxd Y 100
Log Hz
100k

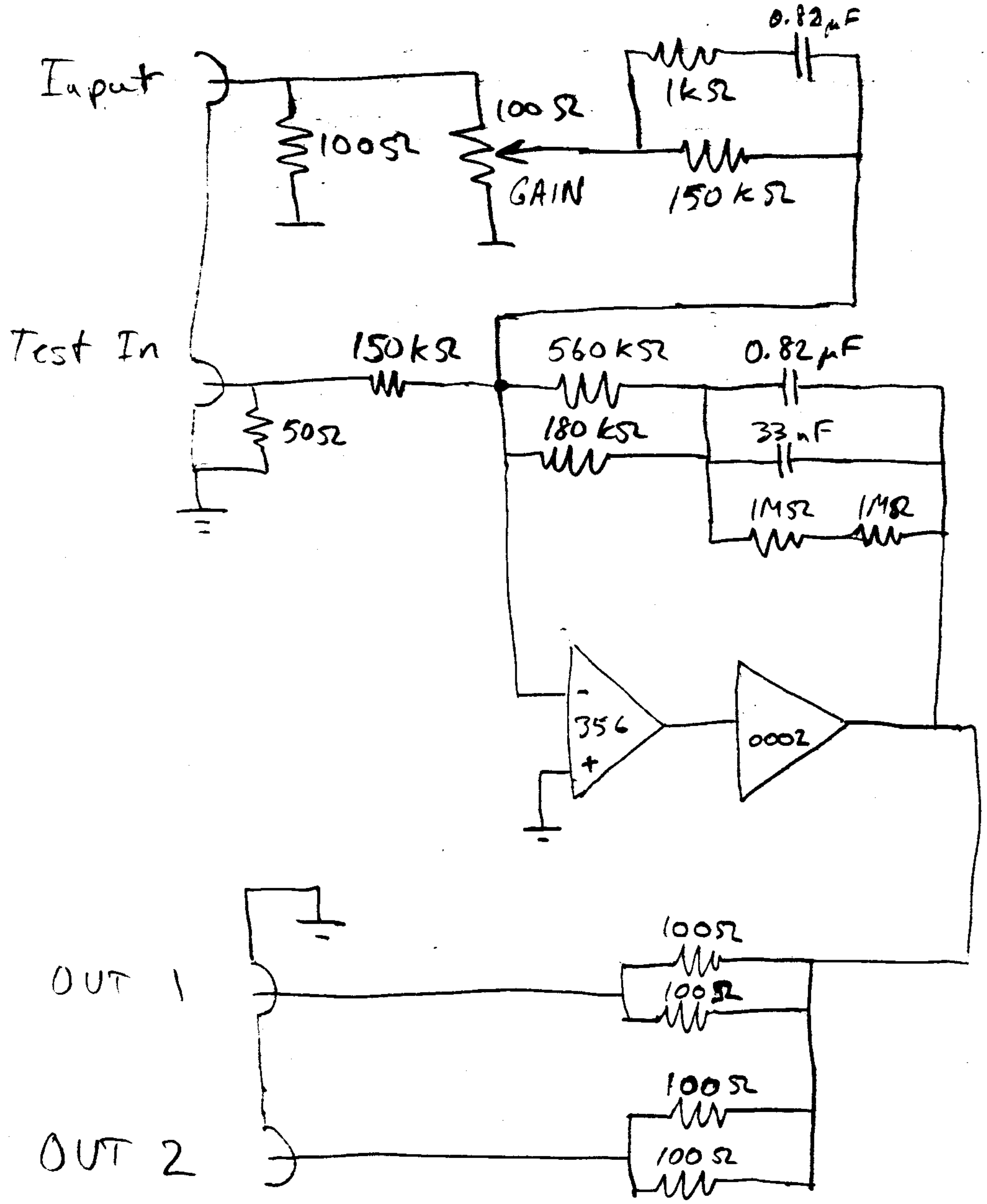
~~10/18/89~~ 10/20/89

Latest Arm 1 Servo Arrangement (Locks Very Well)

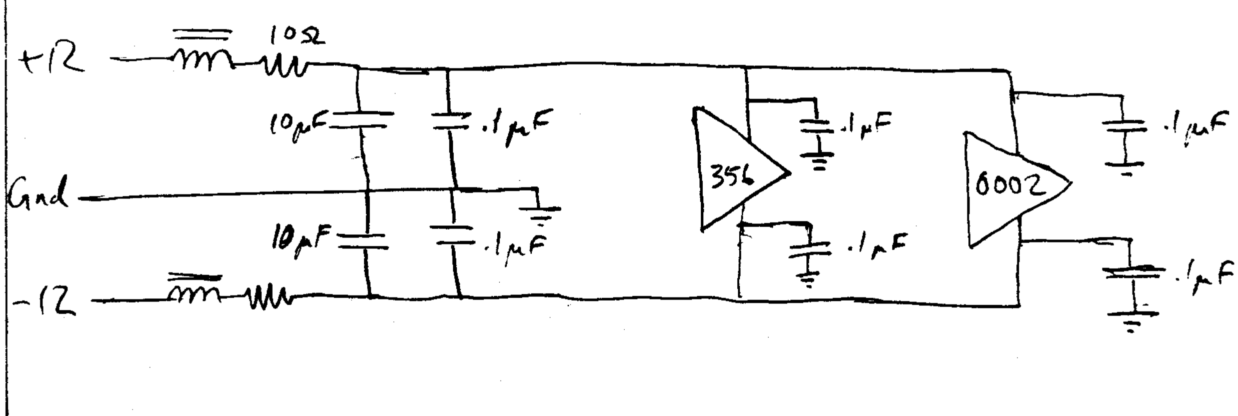


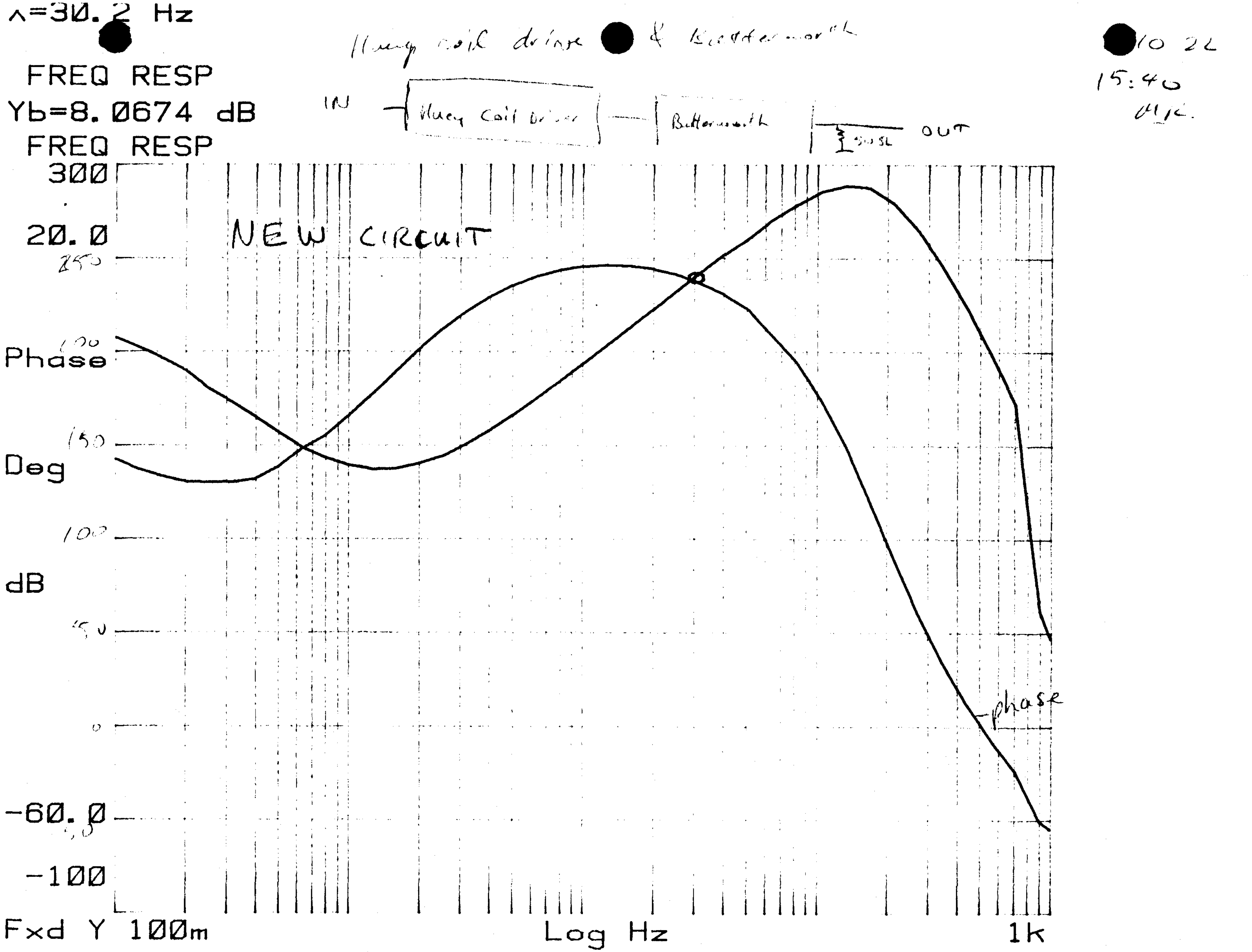


Huey Coil Driver 891020 MWR

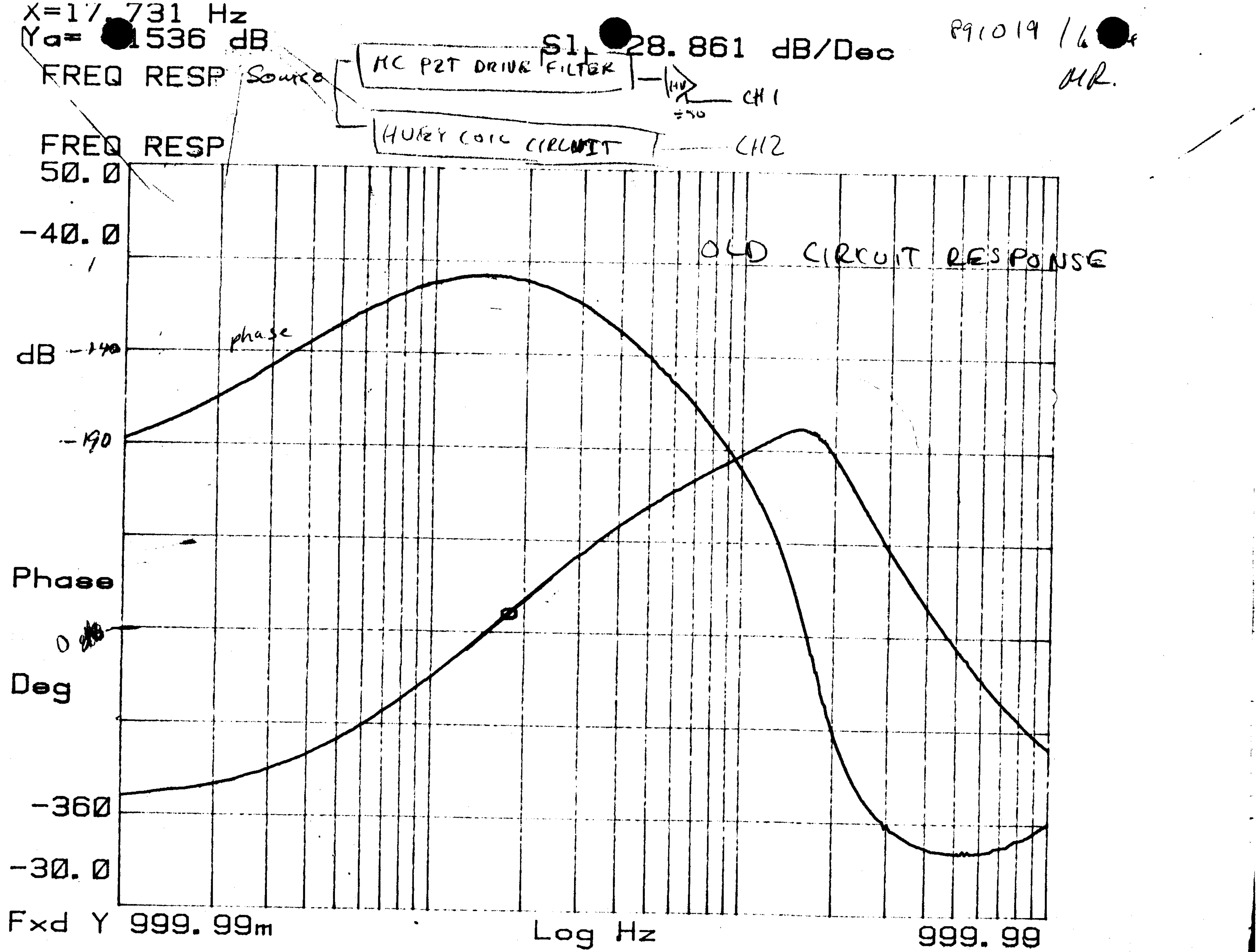


POWER





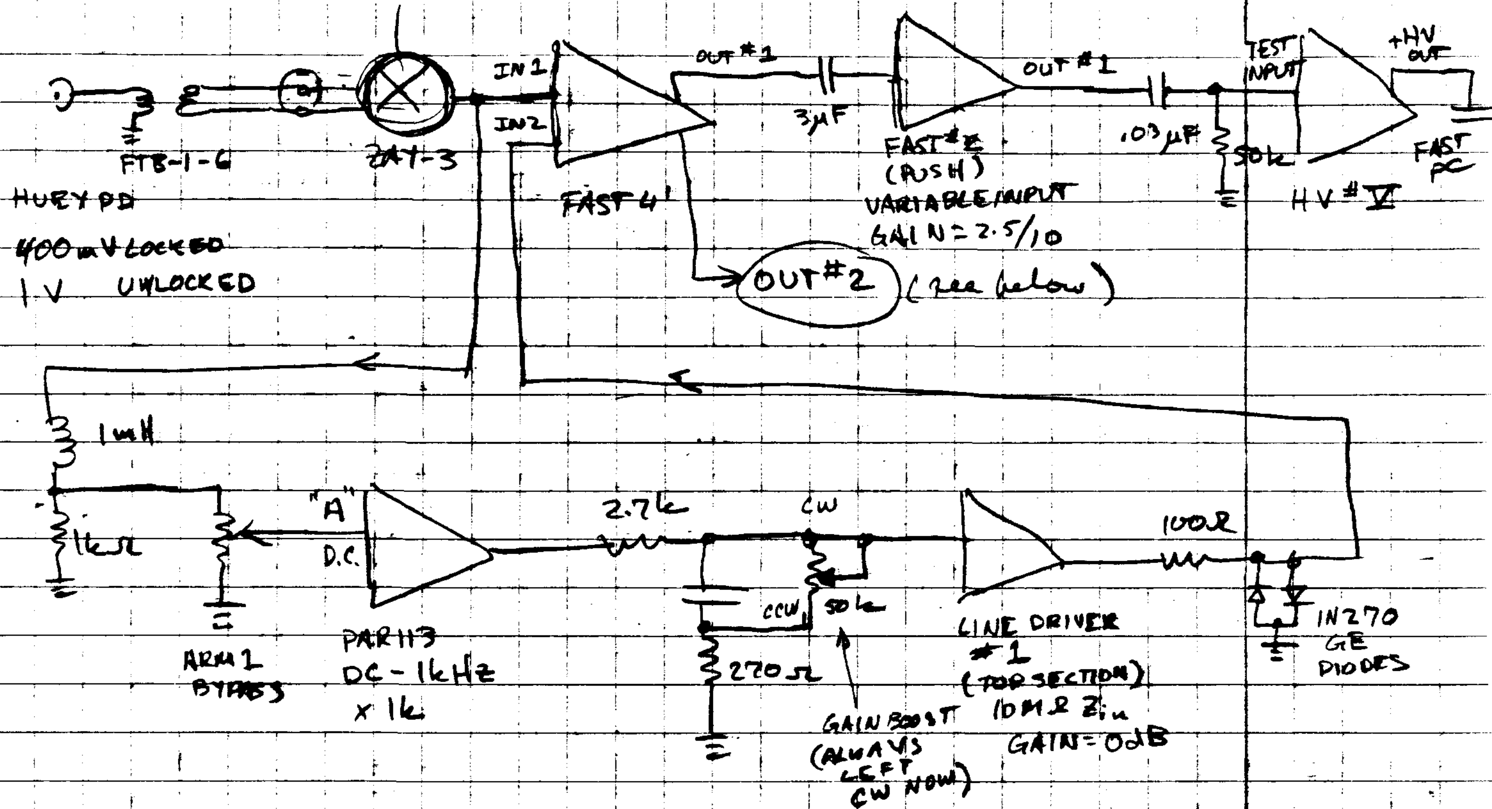
^=30.2 Hz
FREQ RESP
Yb=8.0674 dB
FREQ RESP
IN
Butterworth
OUT
15:40
300
20.0
Phase
Deg
dB
-60.0
-100
NEW CIRCUIT
phase
Fxd Y 100m
Log Hz
1k

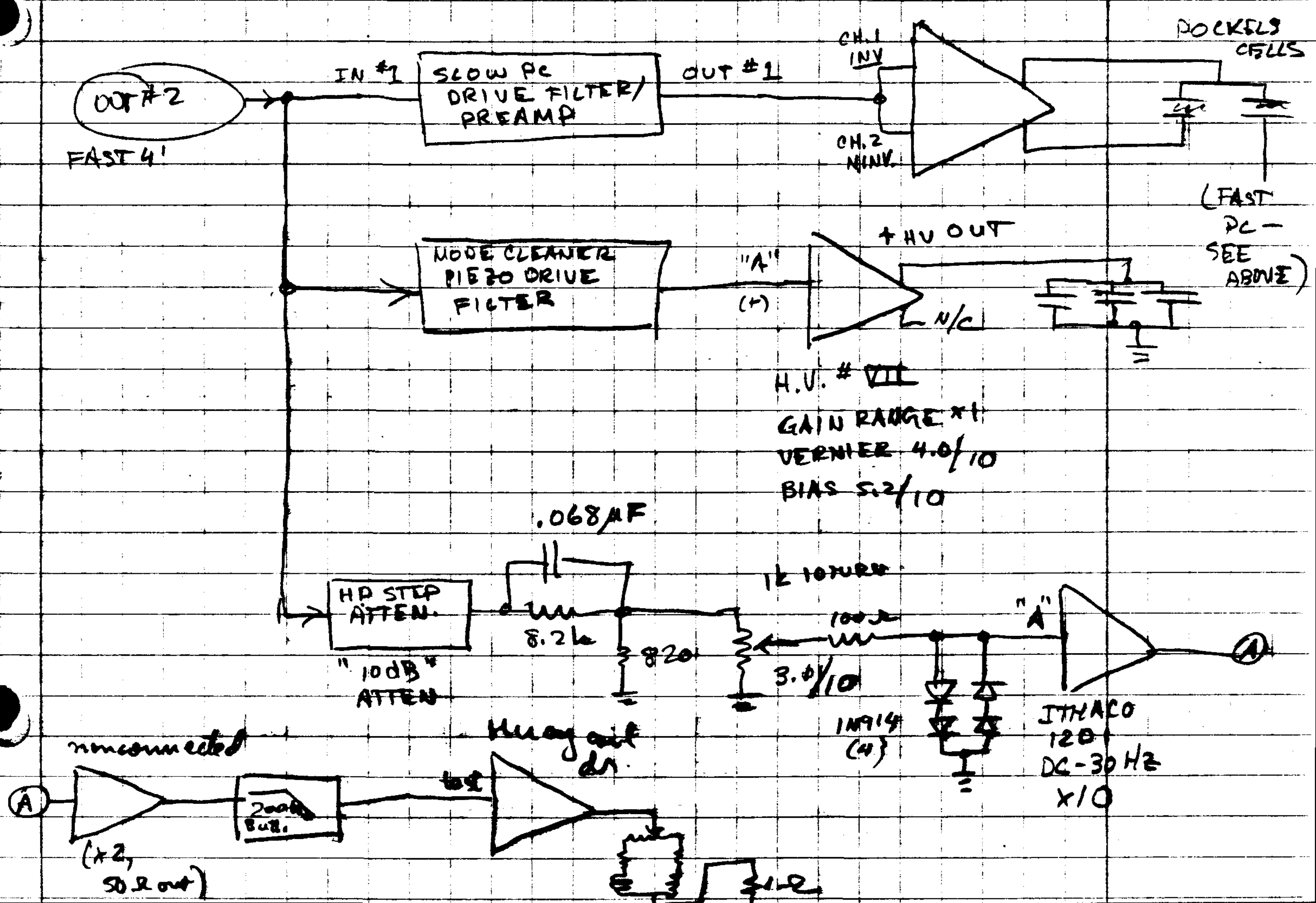


X=17.731 Hz
Ya= 1536 dB
S1 28.861 dB/Dec
891019
FREQ RESP
Source
MC PZT DRIVE FILTER
CH1
HURY COIL CIRCUIT
CH2
FREQ RESP
50.0
-40.0
OLD CIRCUIT RESPONSE
dB
phase
-140
-190
Phase
0
Deg
-360
-30.0
Fxd Y 999.99m
Log Hz
999.99

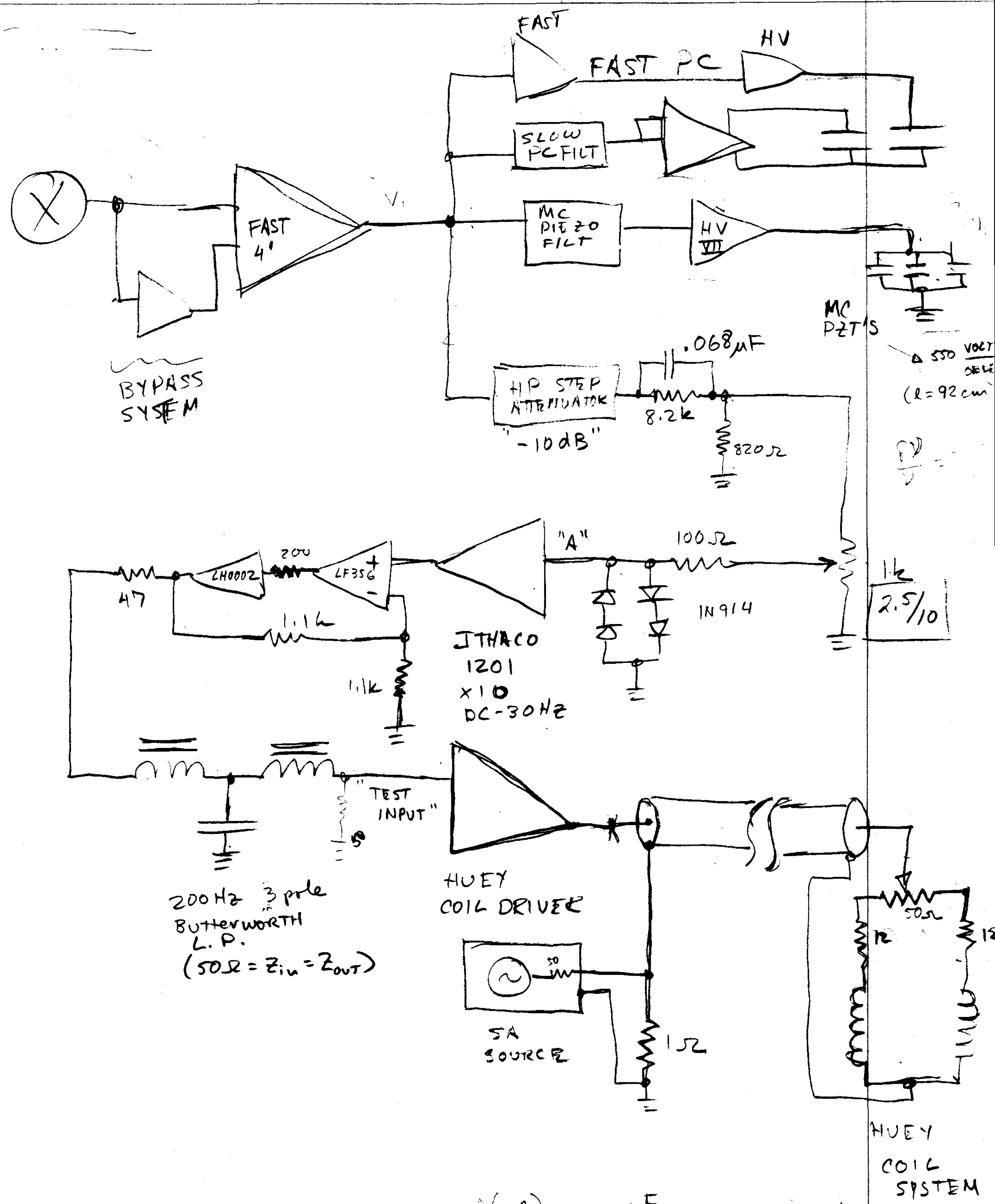
10/18/89

Latest Arm 1 Servo Arrangement (Locks Very Well)





10/18/89 MWR



$$\frac{c}{2\ell} = 1501 \text{ Hz}$$

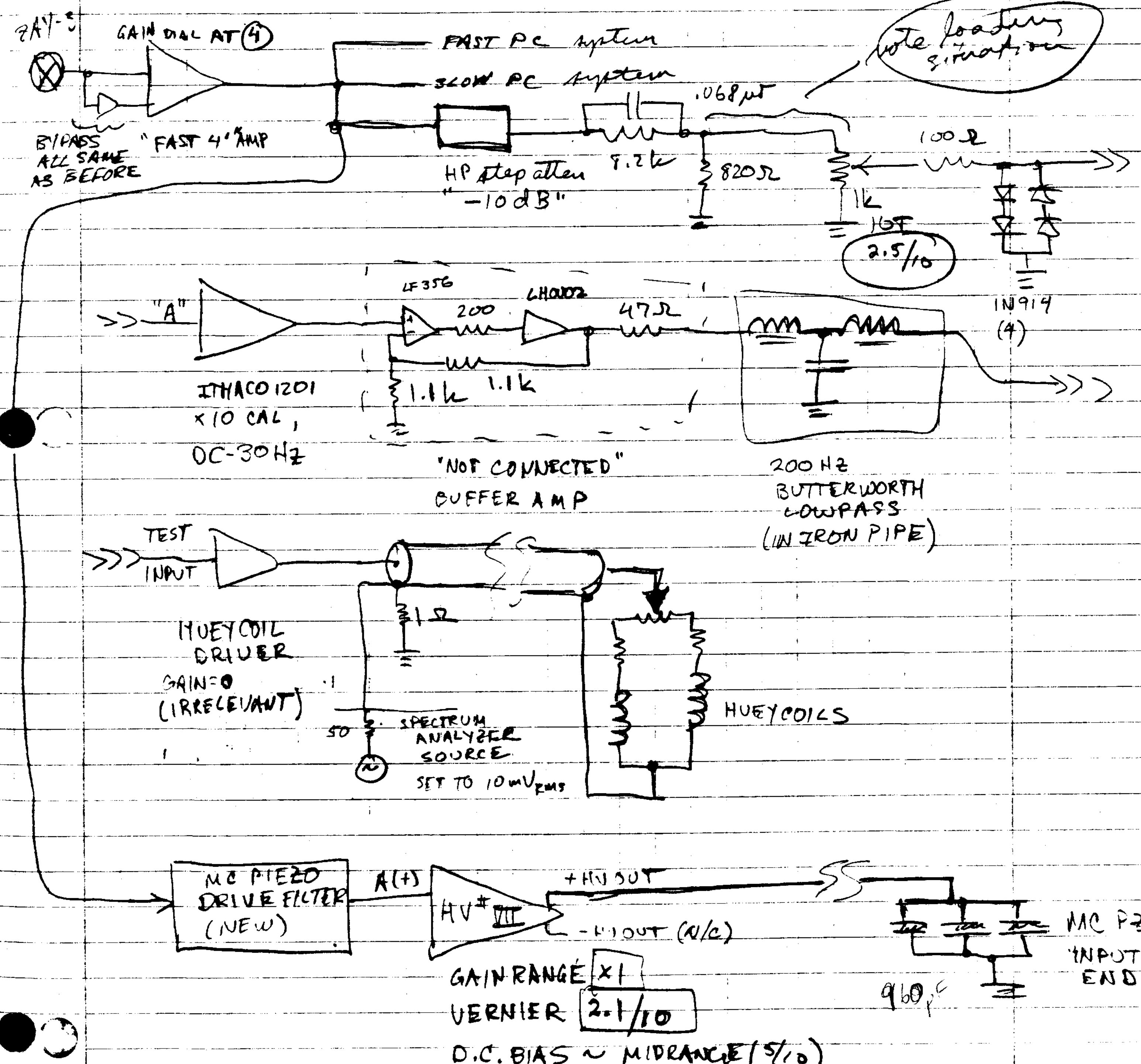
$$\frac{d(ma)}{di} = \frac{dF_{\ldots}}{d(\text{current})} = m\frac{d(\omega^2 x)}{di}$$

$$= m\omega^2 \frac{dx}{di} = m\omega^2 \frac{\ell}{\nu}\frac{d\nu}{di}$$

10/6/89 MEZ

Documentation of Successful Mode Cleaner PZT drive setup;

Found the following setup to work well for driving the MC piezo:

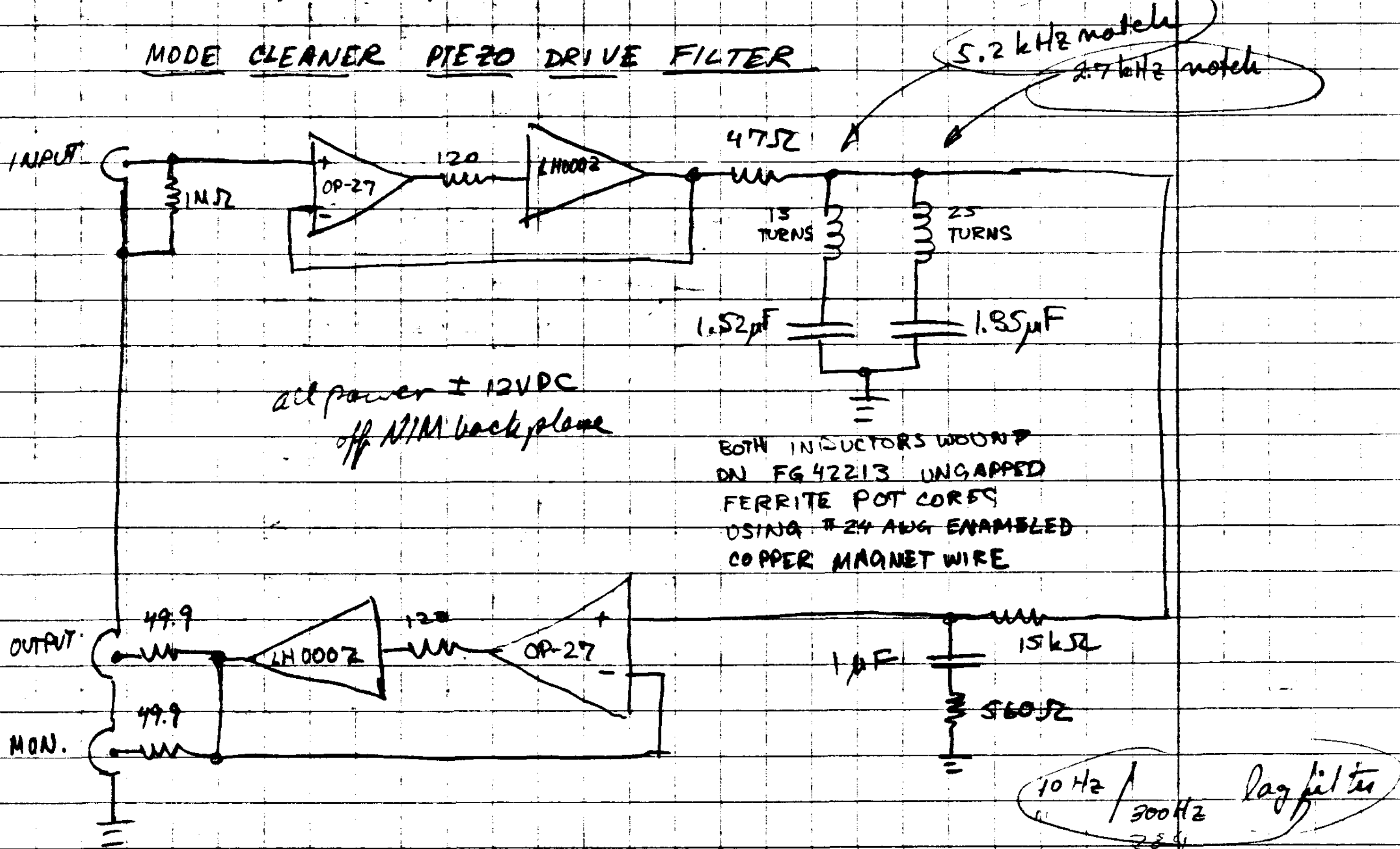


CIRCUIT DIAGRAMS TO FOLLOW

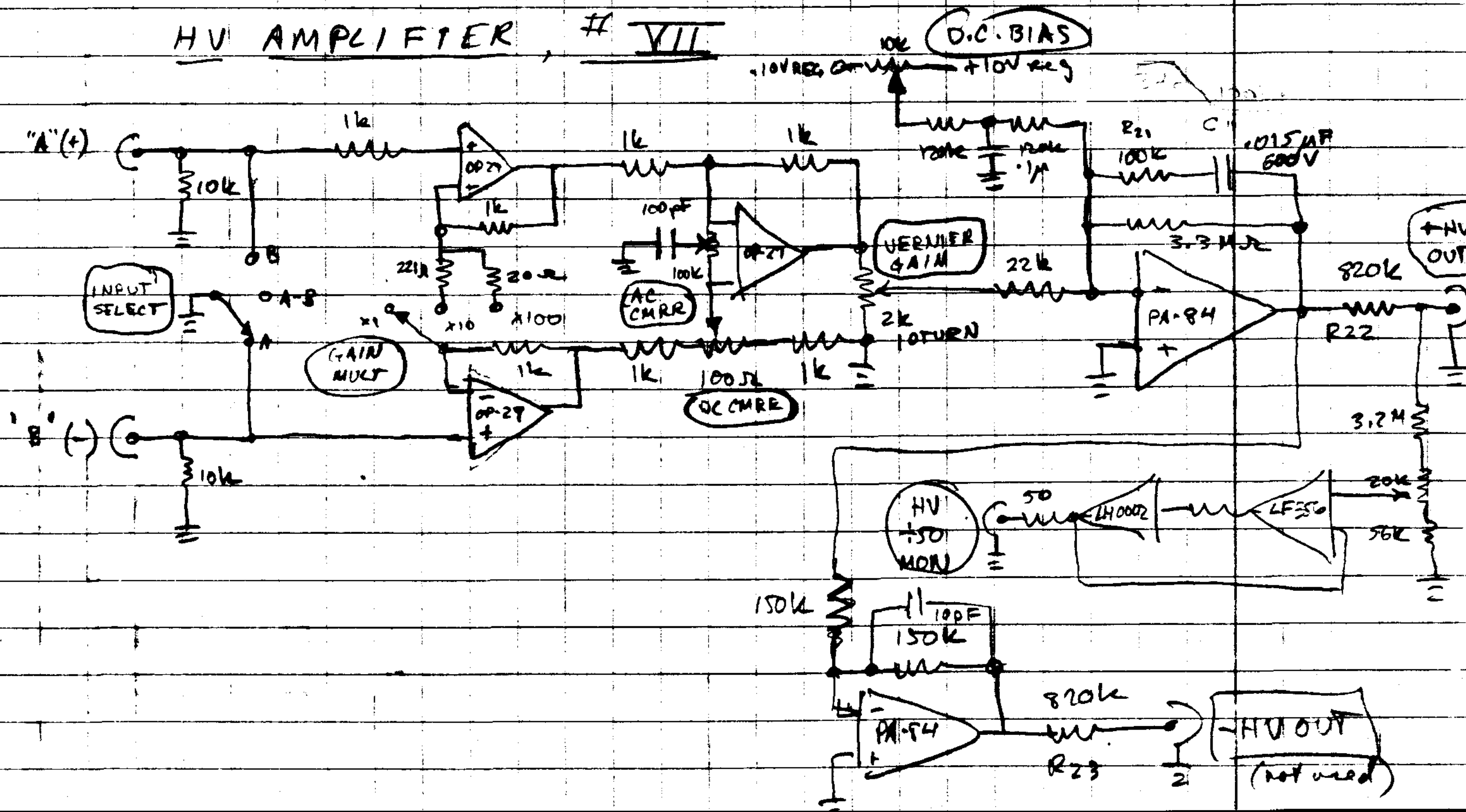
10/6/89

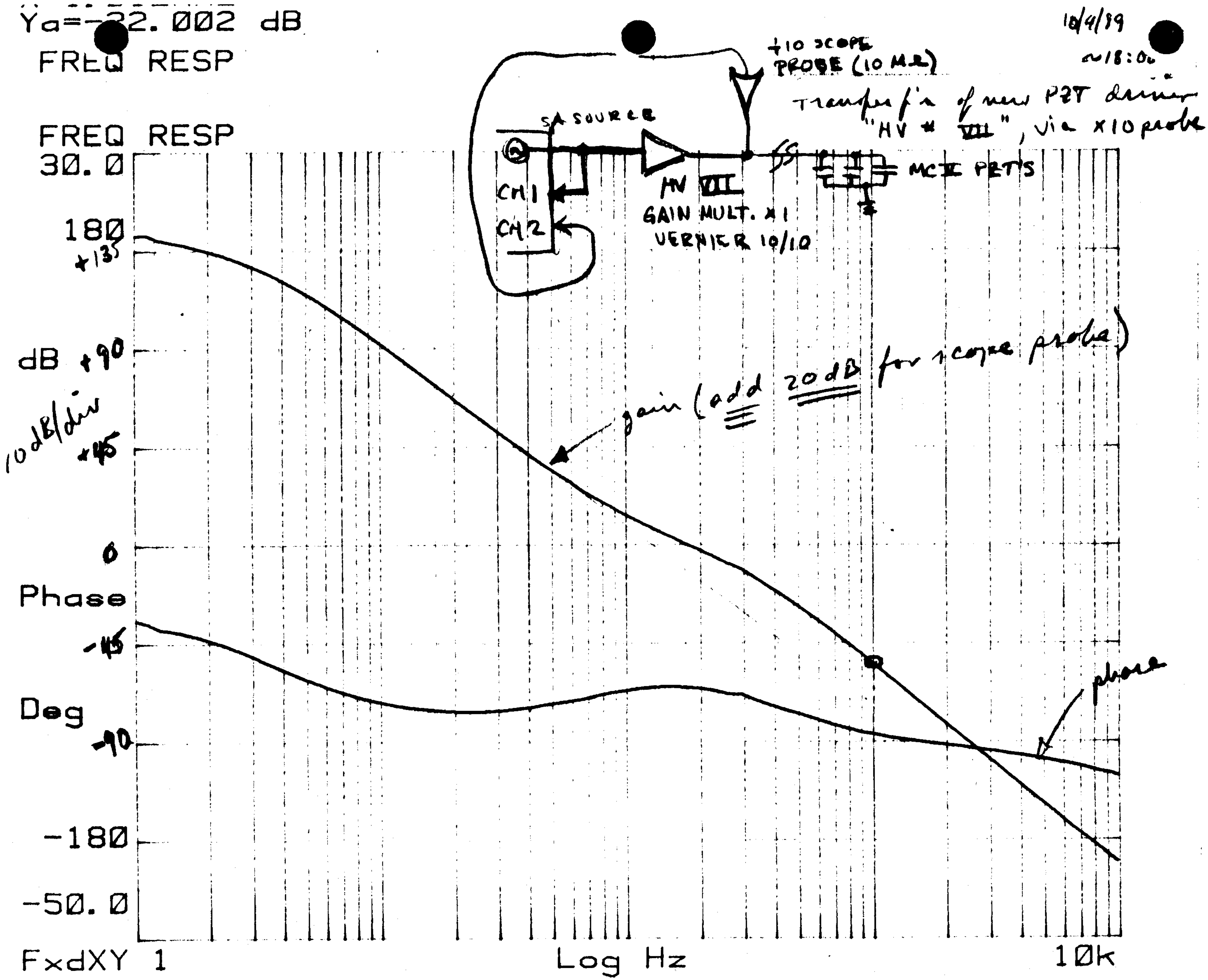
Circuit Diagrams of New PZT Drive System Components

MODE CLEANER PIEZO DRIVE FILTER



HV AMPLIFIER, # VII



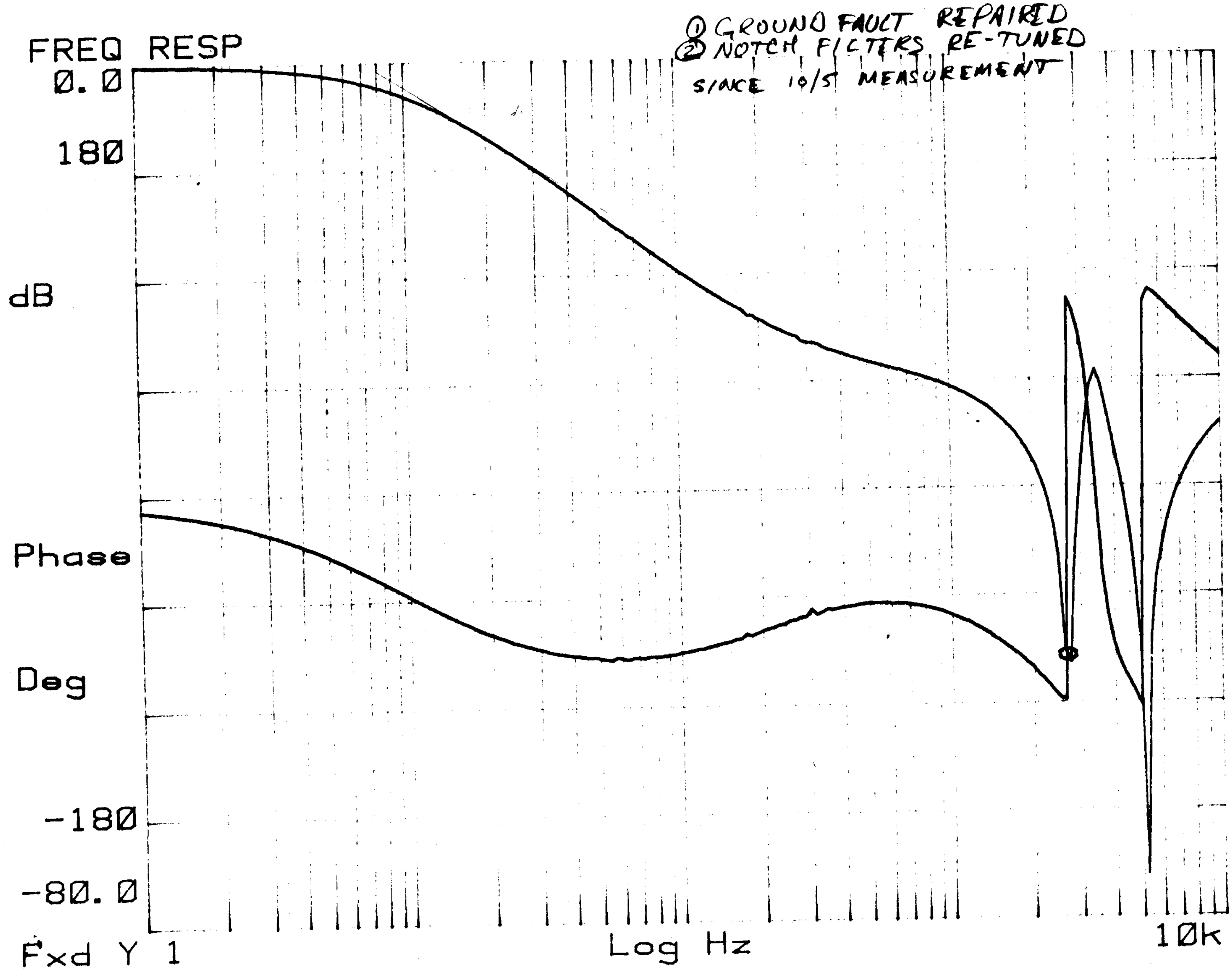


Ya=-22.002 dB
FREQ RESP
10/4/89
~18:00
÷10 SCOPE PROBE (10 MΩ)
Transfer f'n of new PZT driver "HV # VII", via x10 probe
SA SOURCE
CH1
CH2
HV VII
GAIN MULT. x1
VERNIER 10/10
MC II PZT'S
FREQ RESP
30.0
180
+135
dB +90
10dB/div
+45
0
Phase
-45
Deg
-90
-180
-50.0
gain (add 20dB for scope probe)
phase
FxdXY 1
Log Hz
10k

X=2.[illegible]91kHz
Ya=-55.698 dB
FREQ RESP

MODE CLEANER PIEZO
DRIVE FILTER

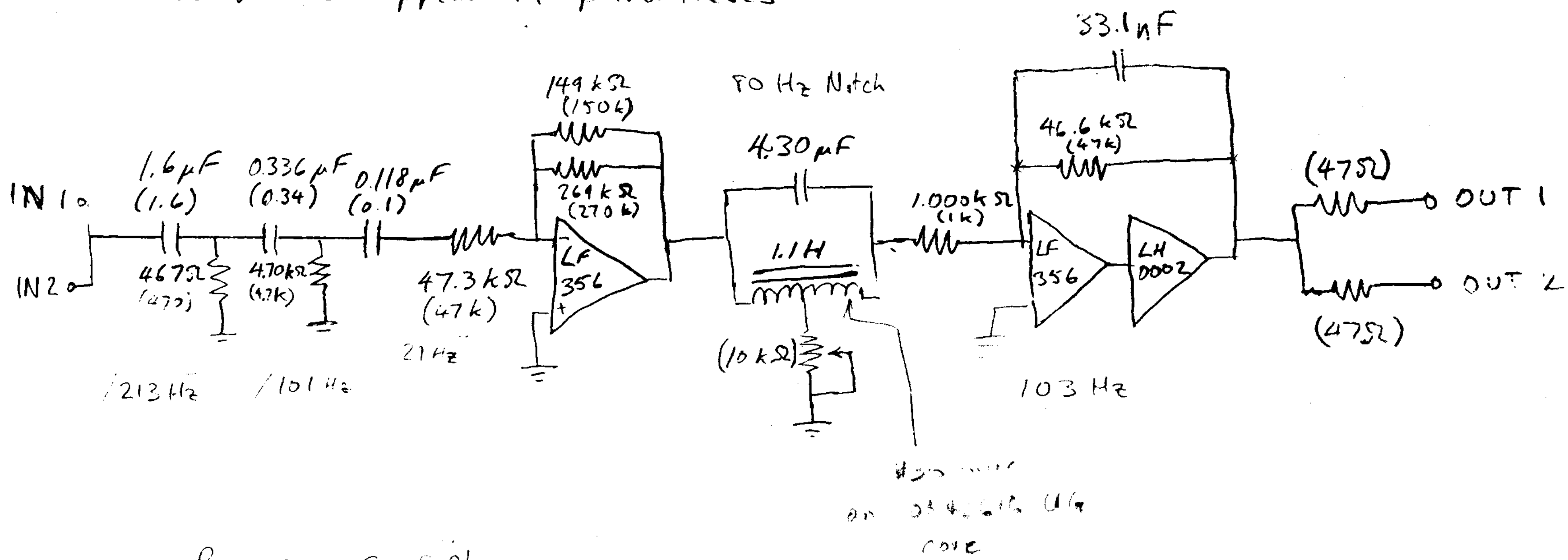
89 10 06 11:38
MWR



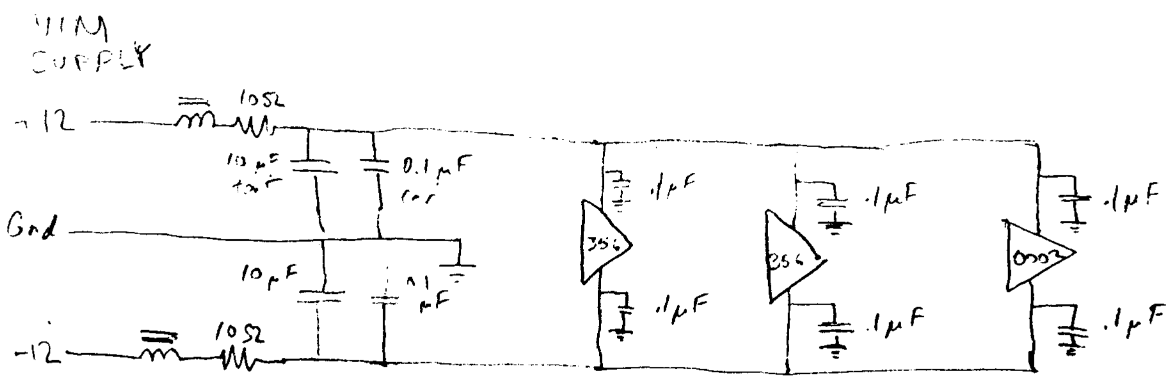
New First Arm Locking Slow Pockell's Cell Drive Filter / Preamp

891017 MWR

Component values shown are measured values;
Nominal values appear in parentheses

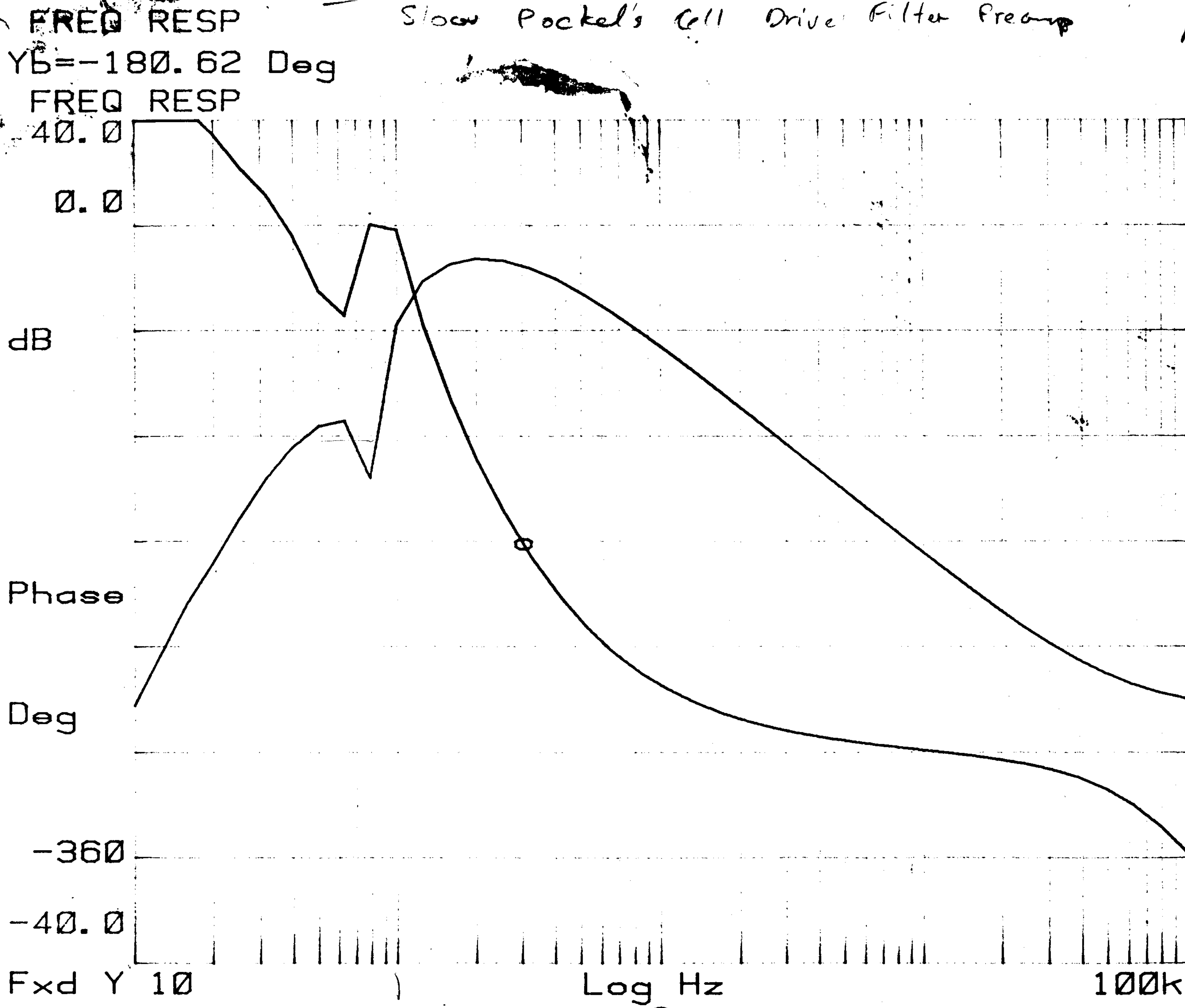


Power supply

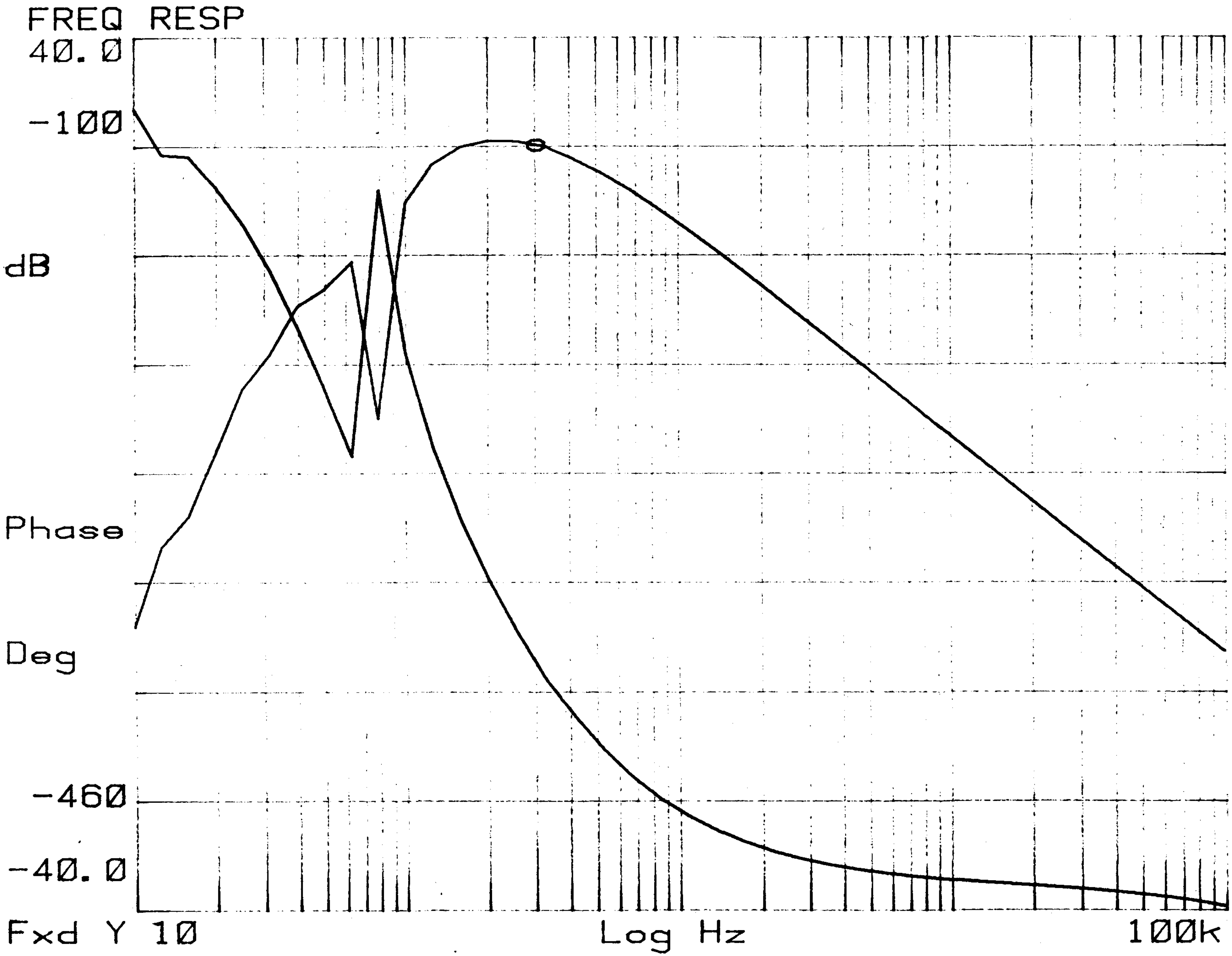


(old) First Arm Servo Loop 891016 / 15:44

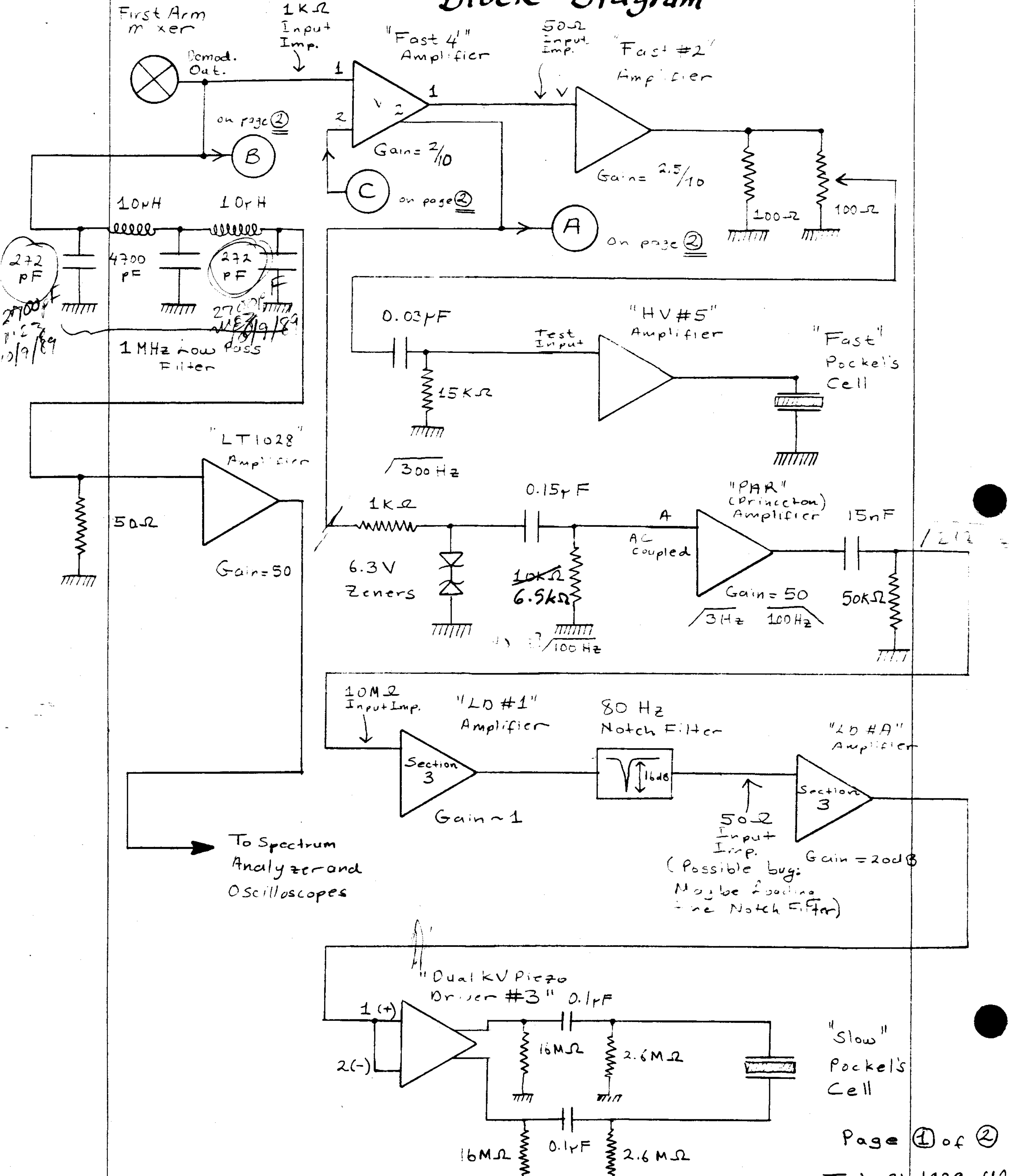
Slow Pockel's Cell Drive Filter Preamp MEZ

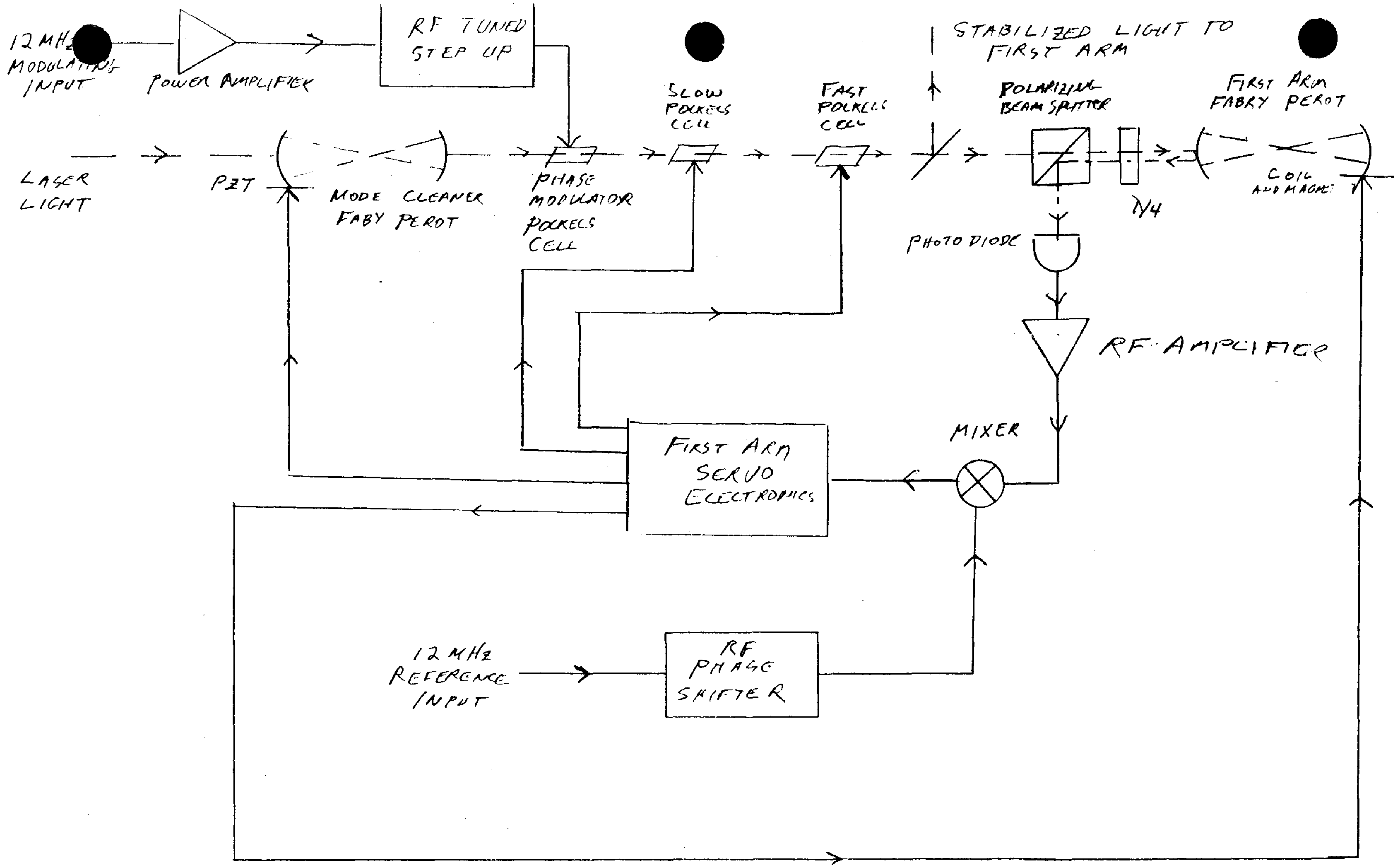


X=302 Hz
Ya=[redacted]0.2342 dB New First A[redacted] Servo loop P9101[redacted] / 15:52
FREQ RESP Slow Pockel's Cell Drive Filter / Preamp



First Arm Servo Loop Block Diagram

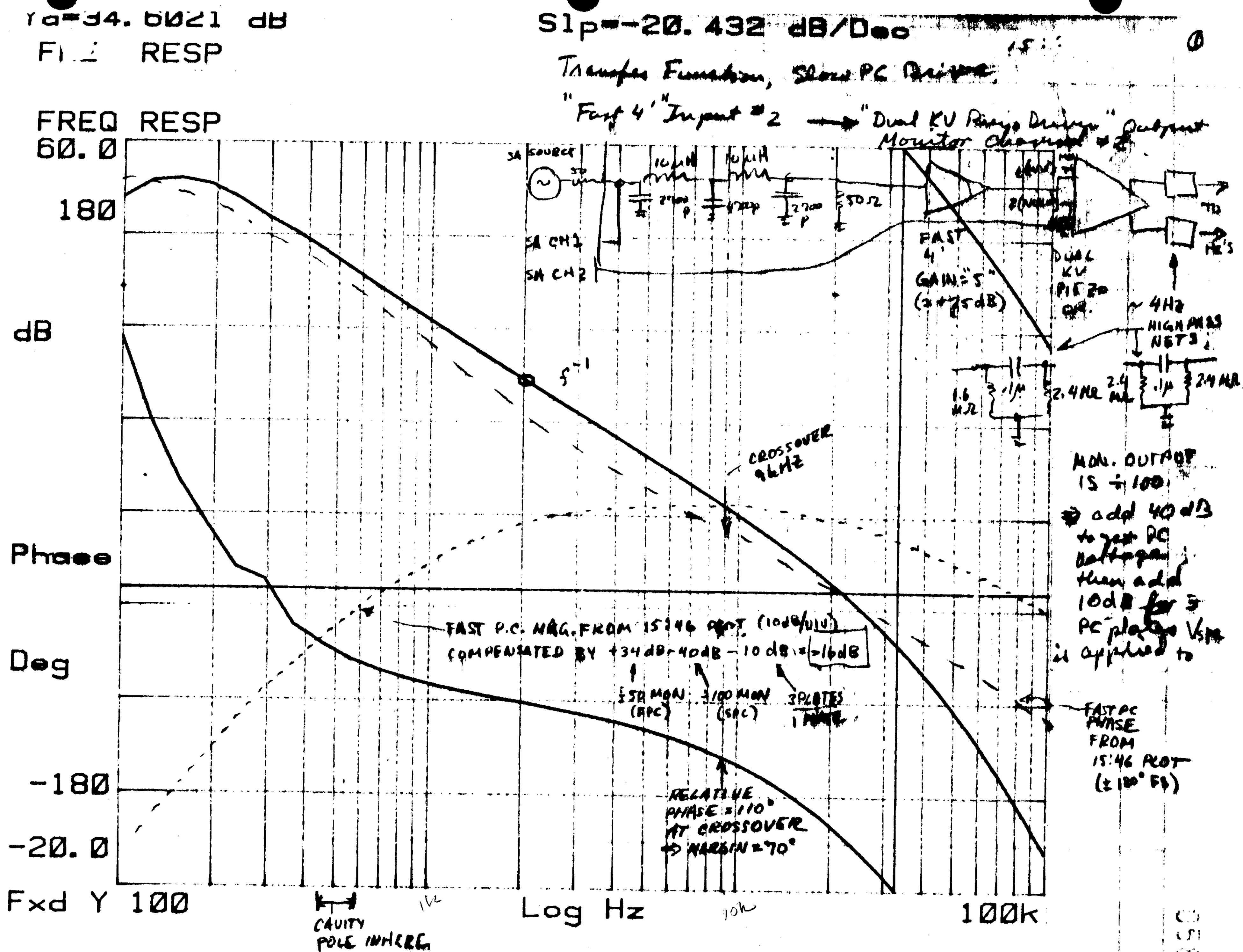




FIRST ARM (LIGHT STABILIZATION) SERVO

J. Kaiser[?]

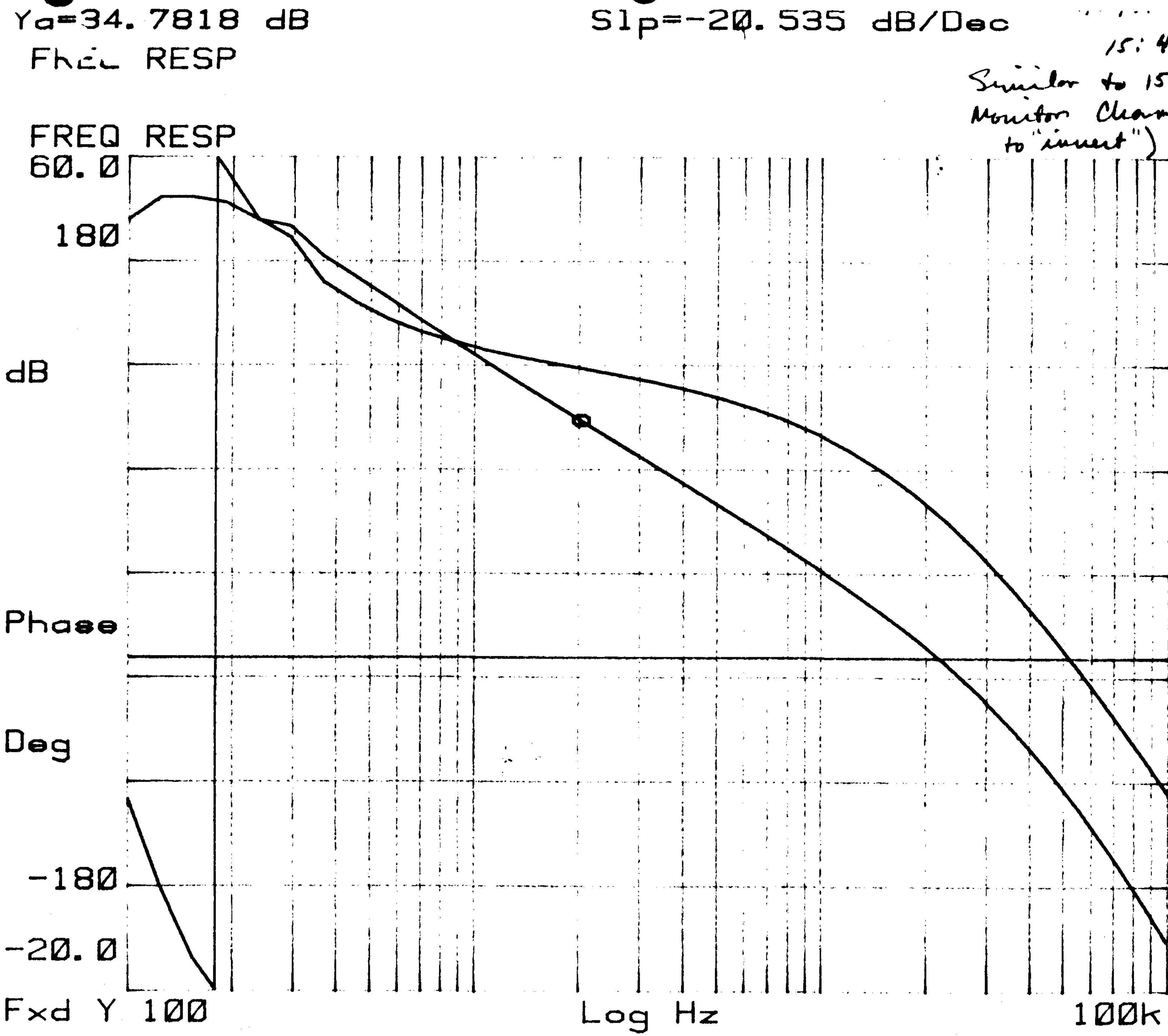
10/20/99



Ya=34.6021 dB
Slp=-20.432 dB/Dec
RESP
Transfer Function, Slow PC Driver
"Fast 4" Input #2 → "Dual KV Piezo Driver" Output
Monitor channel #2
FREQ RESP
60.0
180
dB
Phase
Deg
-180
-20.0
Fxd Y 100
Log Hz
100k
1k
10k
SA SOURCE
10μH
2700 p
50Ω
SA CH1
SA CH2
FAST 4'
GAIN = 5 (≈14 dB)
DUAL KV PIEZO AMP.
~4Hz HIGH PASS NETS
.1μ
2.4 MΩ
1.6 MΩ
f^{-1}
CROSSOVER 9kHz
MON. OUTPUT IS ÷100
⇒ add 40 dB to get PC voltage, then add 10 dB for 3 PC plates Vsm is applied to
FAST P.C. MAG. FROM 15:46 PLOT (10dB/DIV)
COMPENSATED BY +34 dB - 40 dB - 10 dB = -16 dB
÷50 MON (FPC)
÷100 MON (SPC)
3 PLATES / 1 PLATE
FAST PC PHASE FROM 15:46 PLOT (±180° FS)
RELATIVE PHASE = 110° AT CROSSOVER ⇒ MARGIN = 70°
CAVITY POLE INHERENT

15:4

Similar to 15:36 but Monitor Channel 1 (set to "invert")

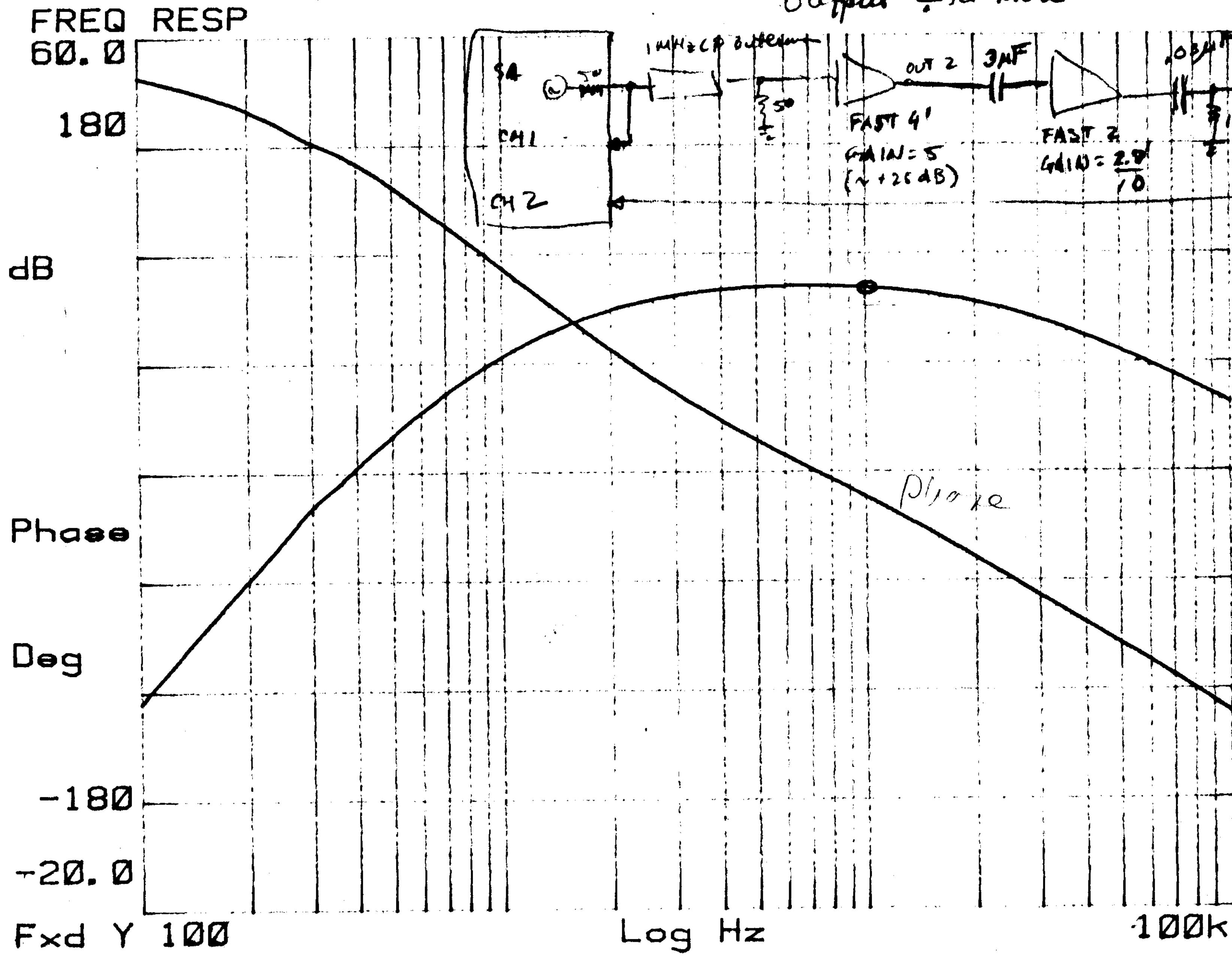


Ya=36.915 dB

FREQ RESP

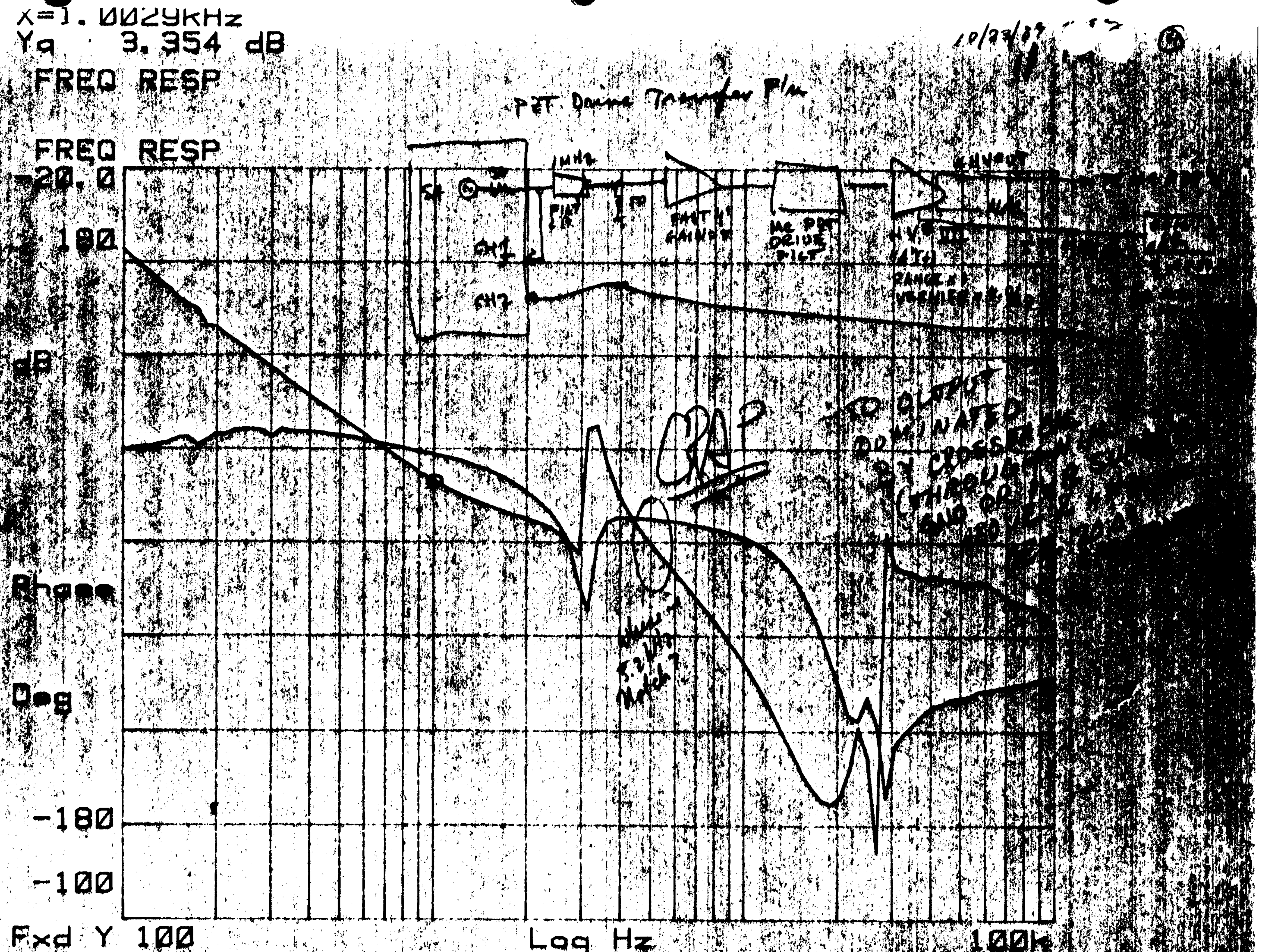
Fast PC Driving

Transfer Function, Fast 4' Input 2 → HV V, Output ÷50 Mon



÷ 50 MON.

⇒ Add 34 dB to obtain PC voltage (applied to only 1 PC plate)


X=1.0029kHz
Ya 3.354 dB
FREQ RESP
PZT Drive Transfer F/n
FREQ RESP
-20.0
180
dB
Phase
Deg
-180
-100
Fxd Y 100
Log Hz
100k
CH1
CH2
CRAP

^=2.5?04kHz
Ya= ?.766 dB
FREQ RESP

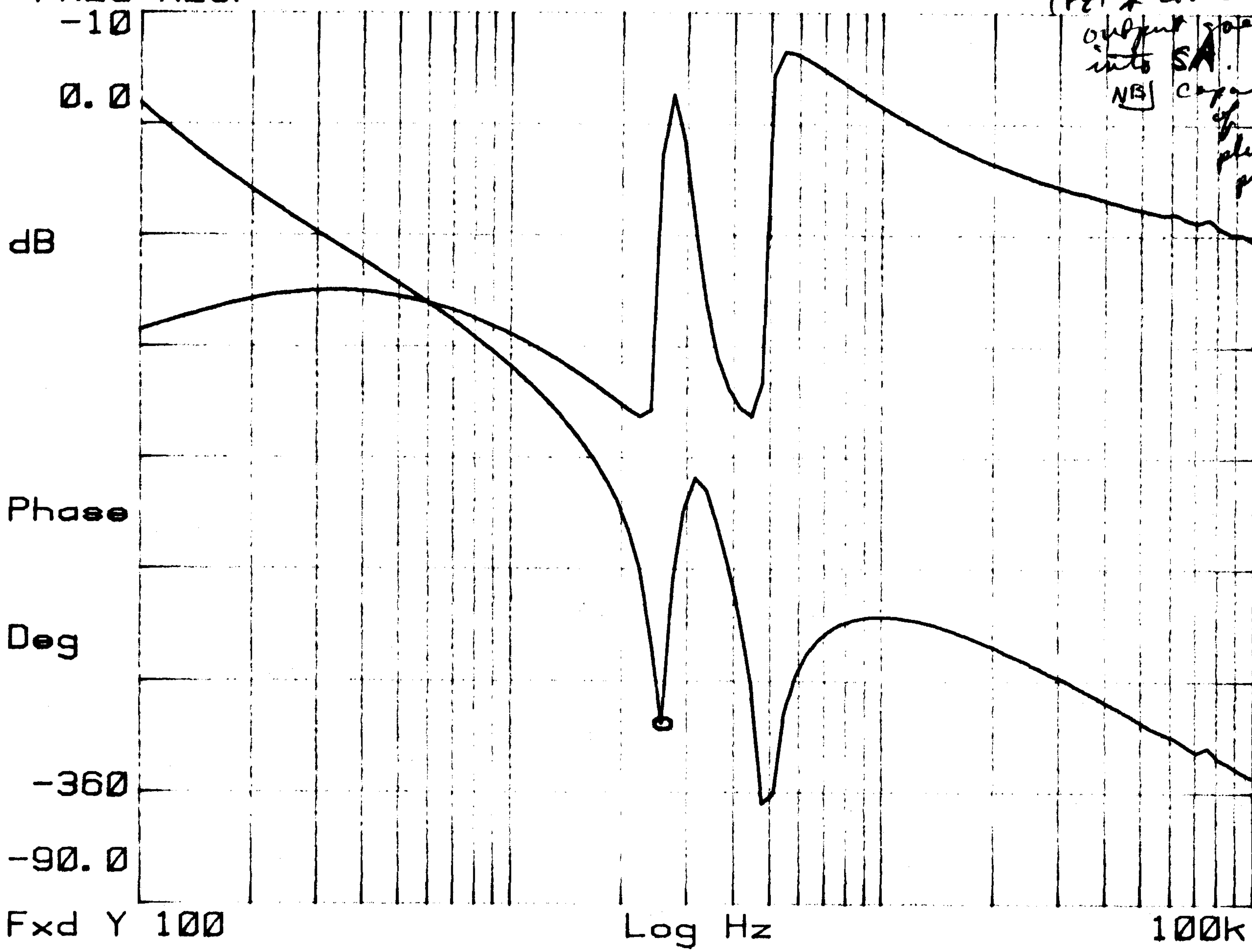
WITHOUT FOH 4'

10/23/89 ms
20:0

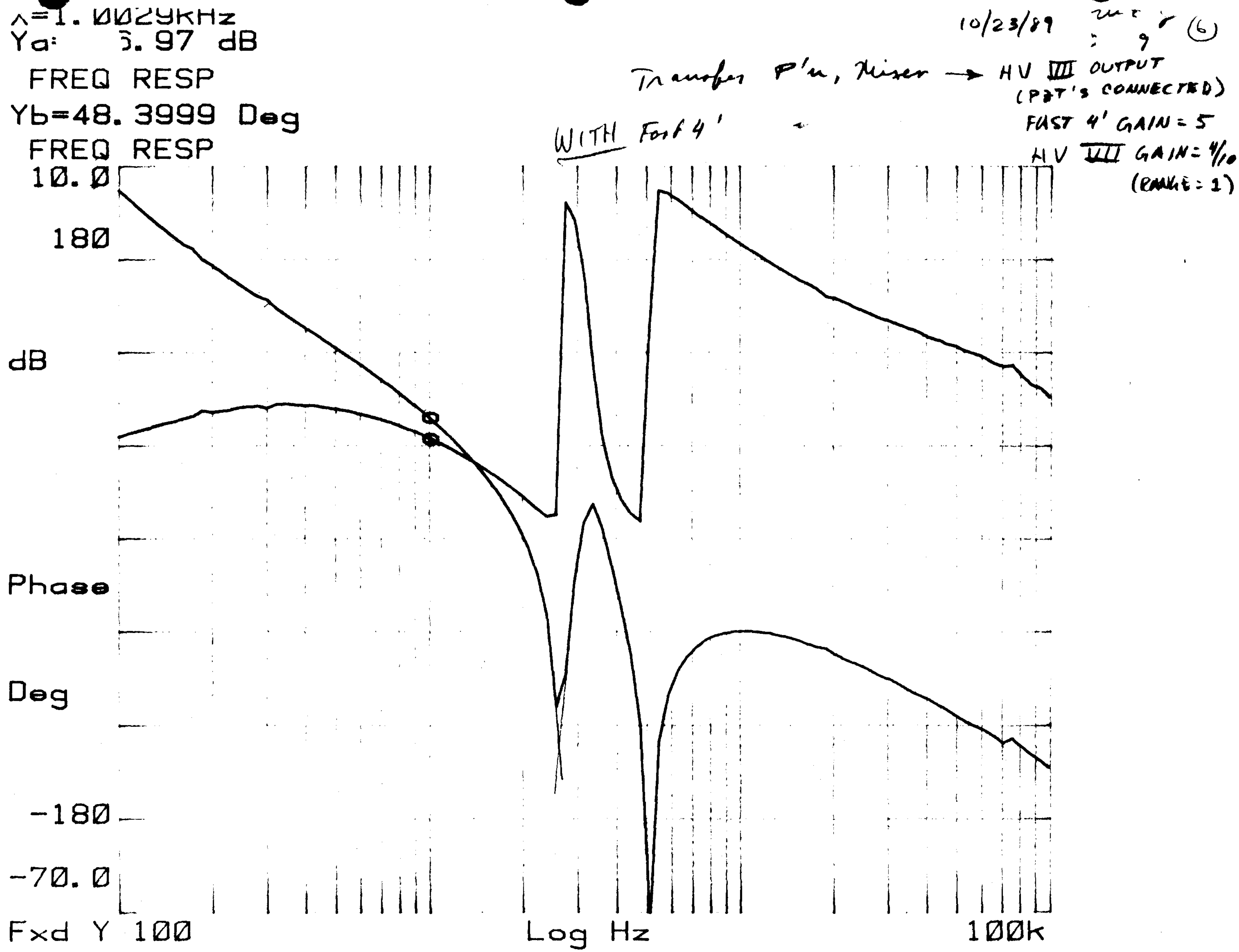
(5)

Transfer F'n, Filter Input
MC PZT Servo
→ HV Amp VII Output
(PZT's connected —
output goes right
into SA.
NB capacitive load
of 100 pF or so
plus R of 1MΩ
probably affects
measurement!

FREQ RESP



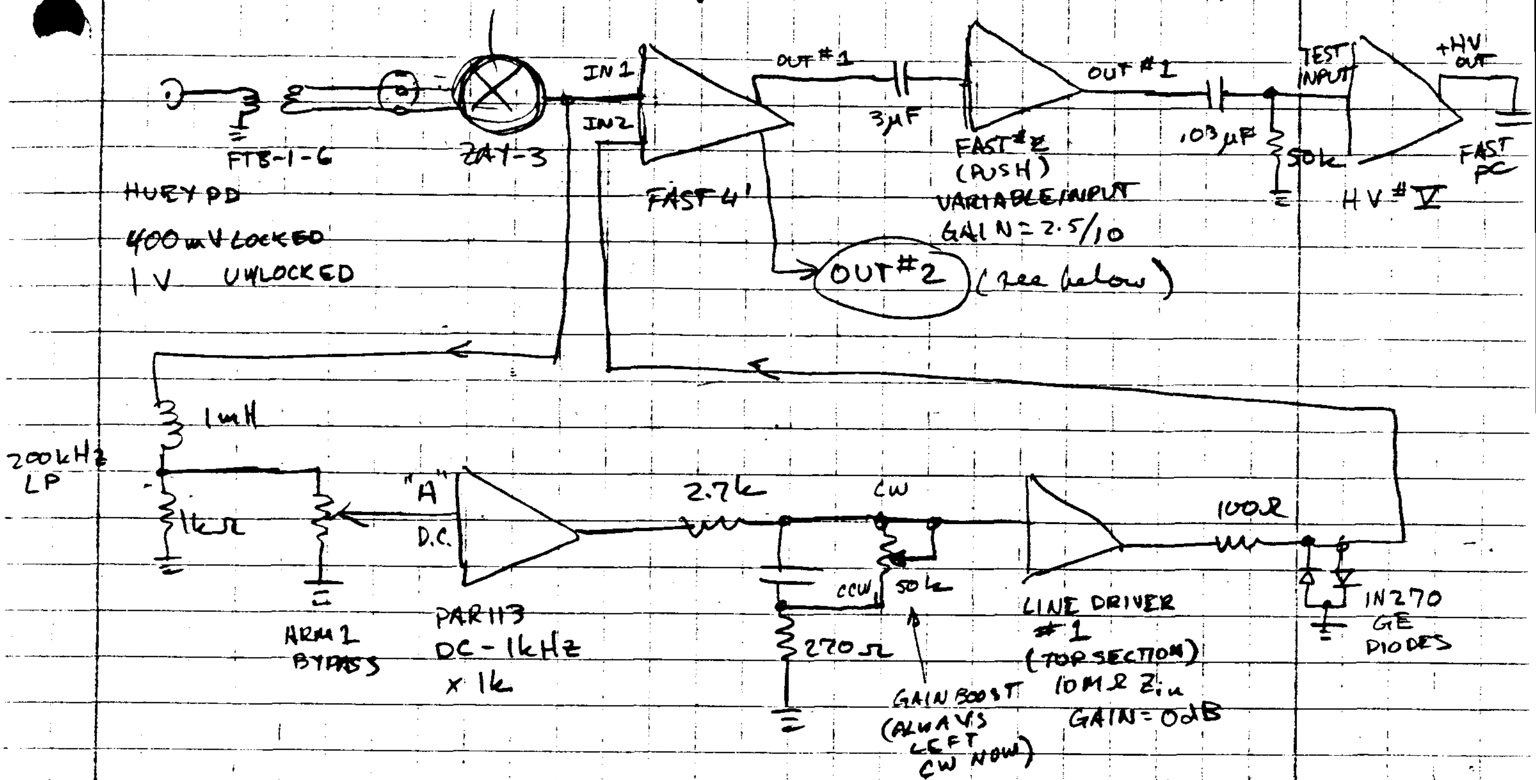
FAST 4' GAIN = 5.
HV VII GAIN = 4/10
(RANGE = 1)

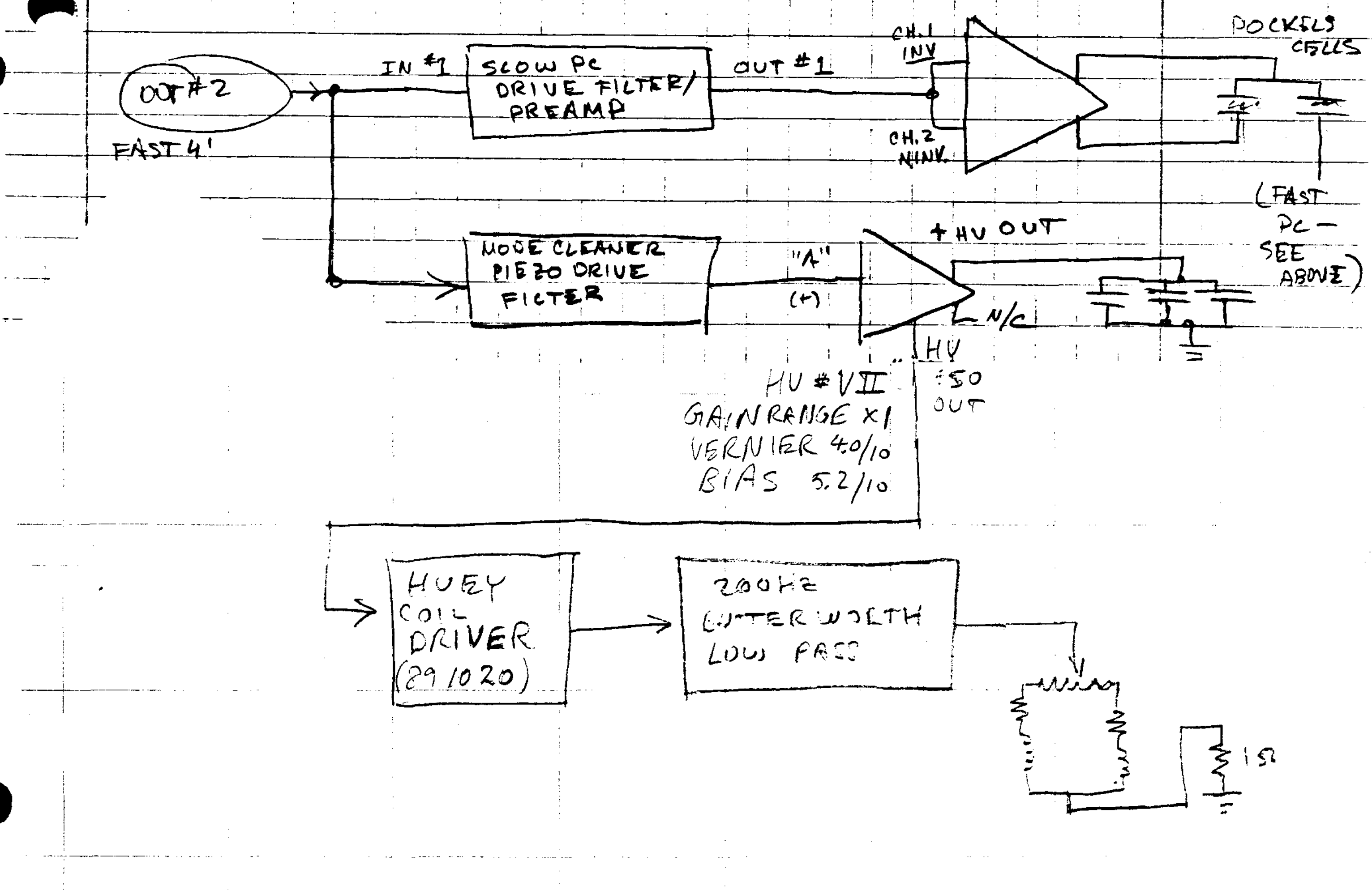


A=1.0029kHz
Ya: 5.97 dB
FREQ RESP
Yb=48.3999 Deg
FREQ RESP
10.0
180
dB
Phase
Deg
-180
-70.0
Fxd Y 100
Log Hz
100k
10/23/89
Transfer F'n, Mixer → HV VIII OUTPUT
(PZT's CONNECTED)
WITH Fast 4'
FAST 4' GAIN = 5
HV VIII GAIN = 4/10
(RANGE = 1)

~~10/18/89~~ 10/20/89

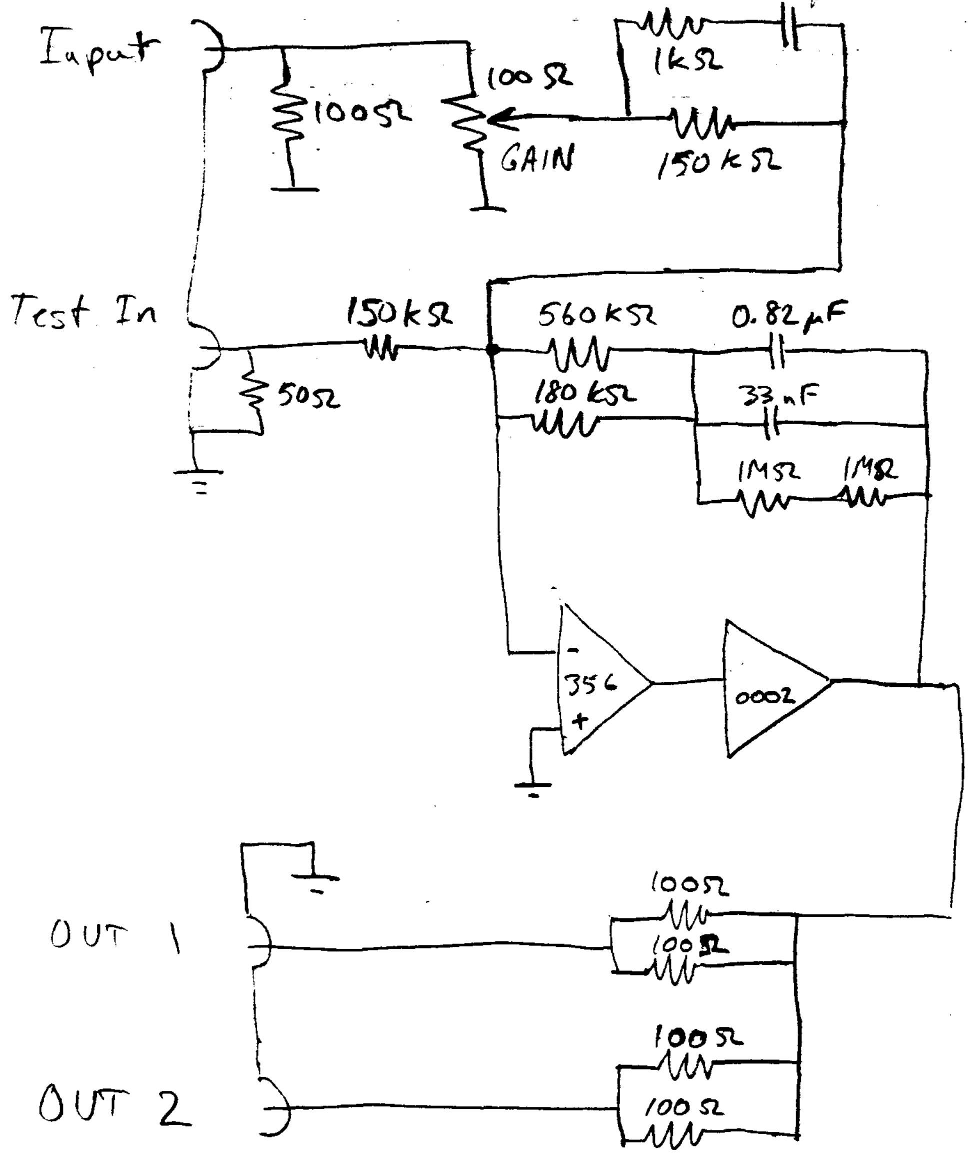
Latest Arm 1 Servo Arrangement (Locks Very Well)



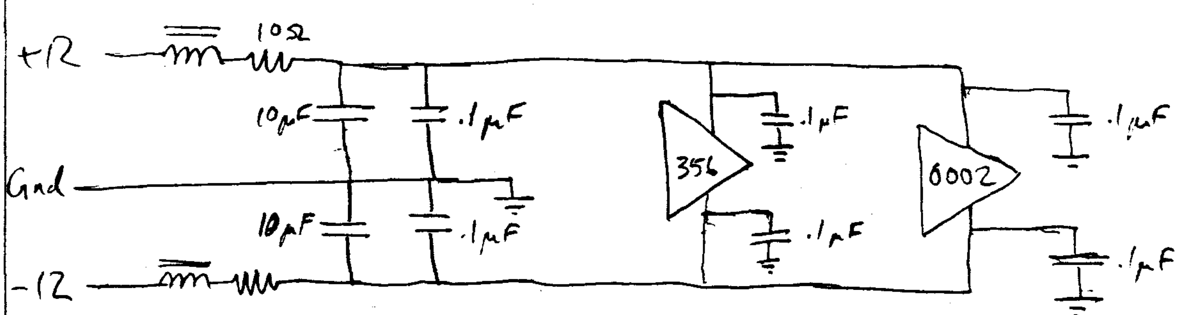


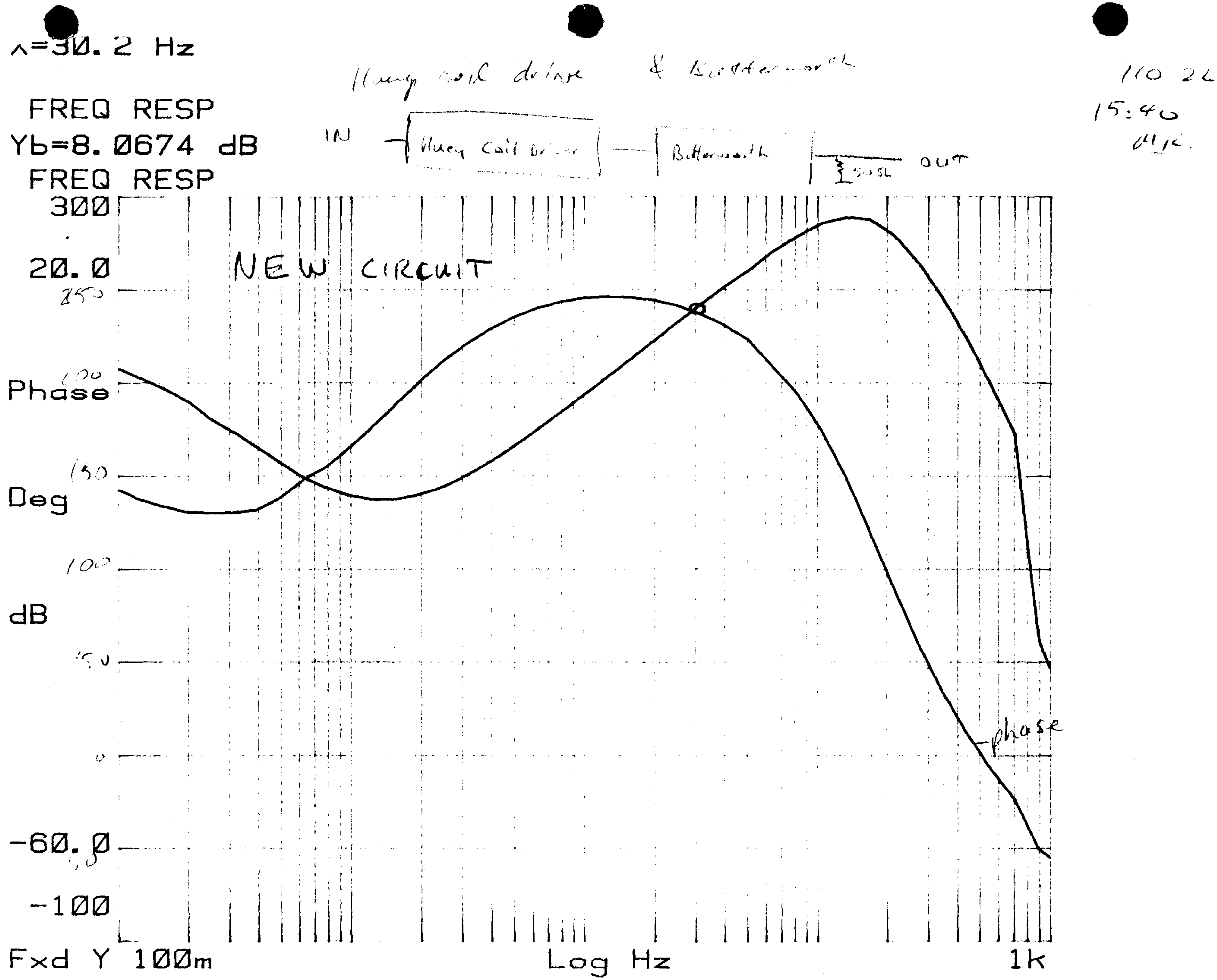
Huey Coil Driver

891020
MWR

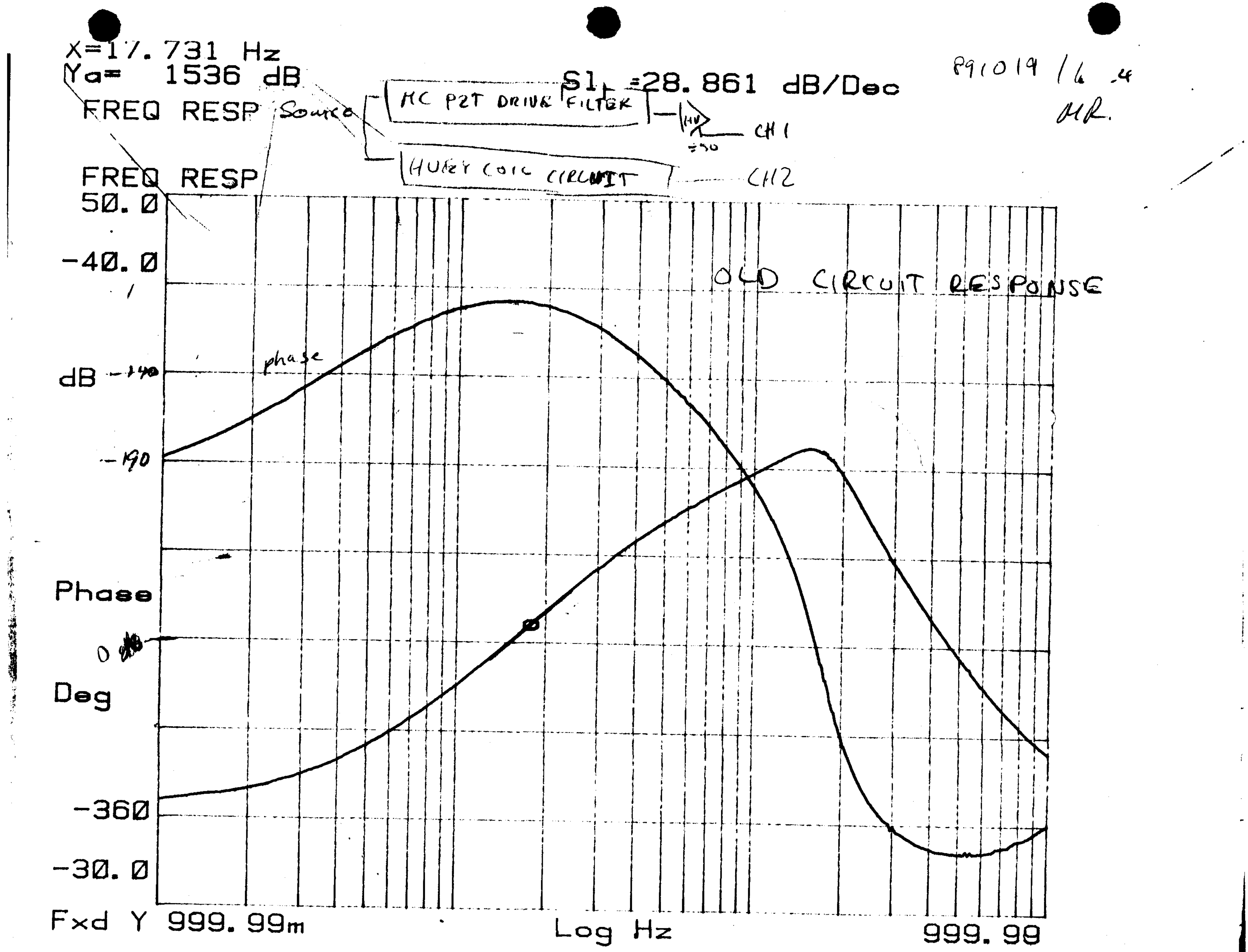


POWER



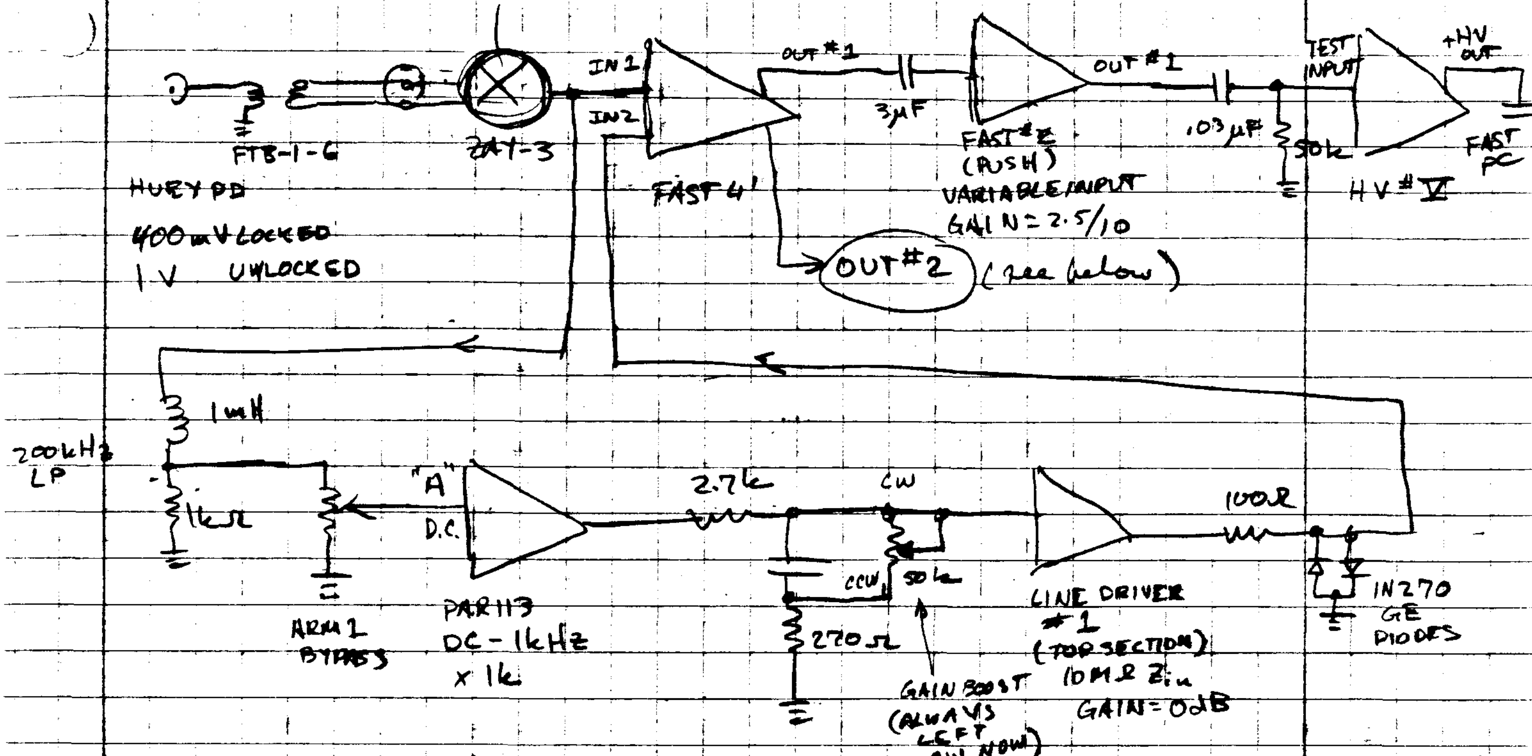


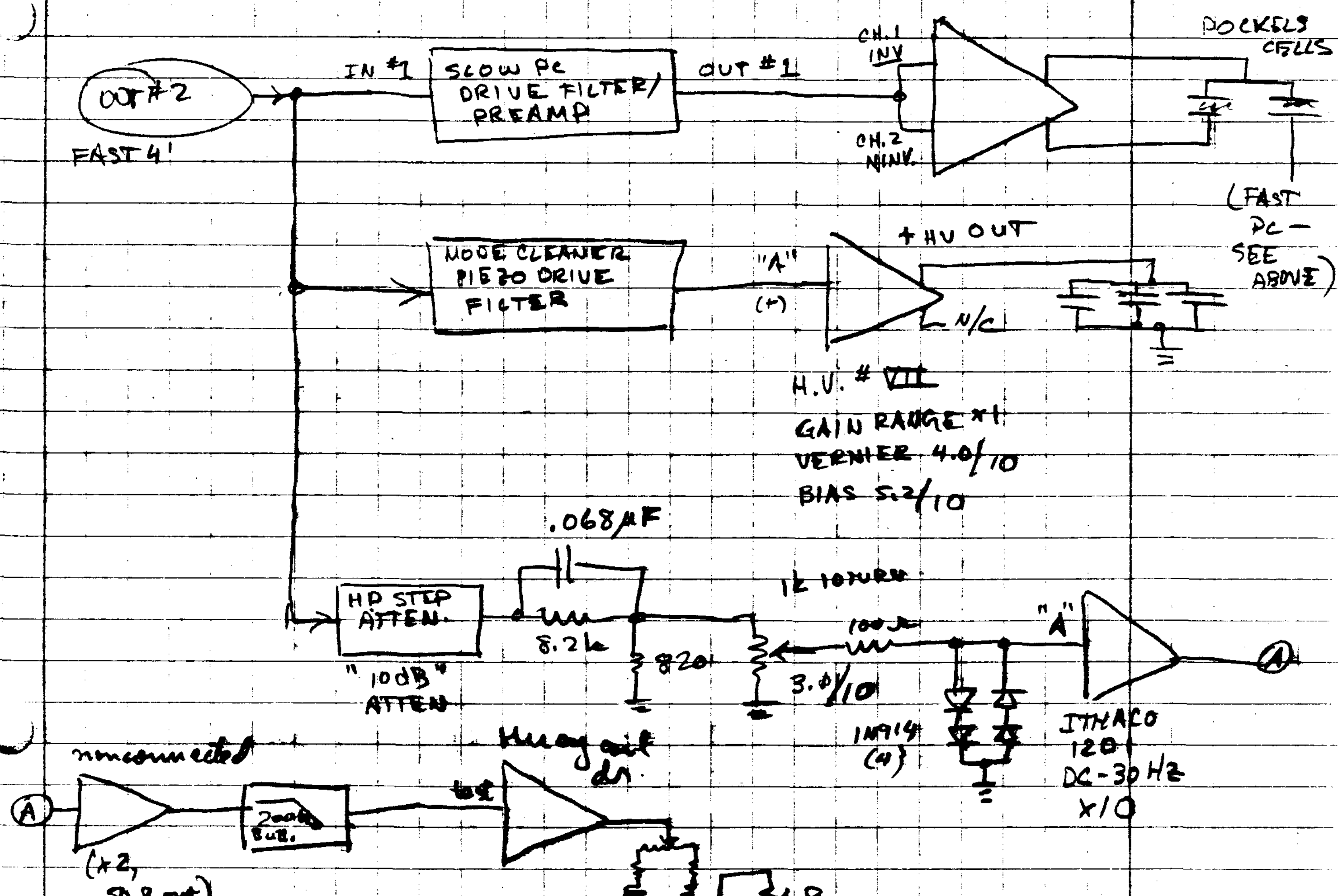
^=30.2 Hz
FREQ RESP
Yb=8.0674 dB
FREQ RESP
IN
Butterworth
OUT
15:40
NEW CIRCUIT
300
20.0
250
Phase
Deg
150
100
dB
50
0
-60.0
-100
phase
Fxd Y 100m
Log Hz
1k


X=17.731 Hz
Ya= 1536 dB
Sl = 28.861 dB/Dec
891019 / 6 .4
FREQ RESP
FREQ RESP
50.0
-40.0
dB
Phase
Deg
-360
-30.0
Fxd Y 999.99m
Log Hz
999.99
MC PZT DRIVE FILTER
HURY COIL CIRCUIT
CH1
CH2
OLD CIRCUIT RESPONSE
phase
-140
-190
0

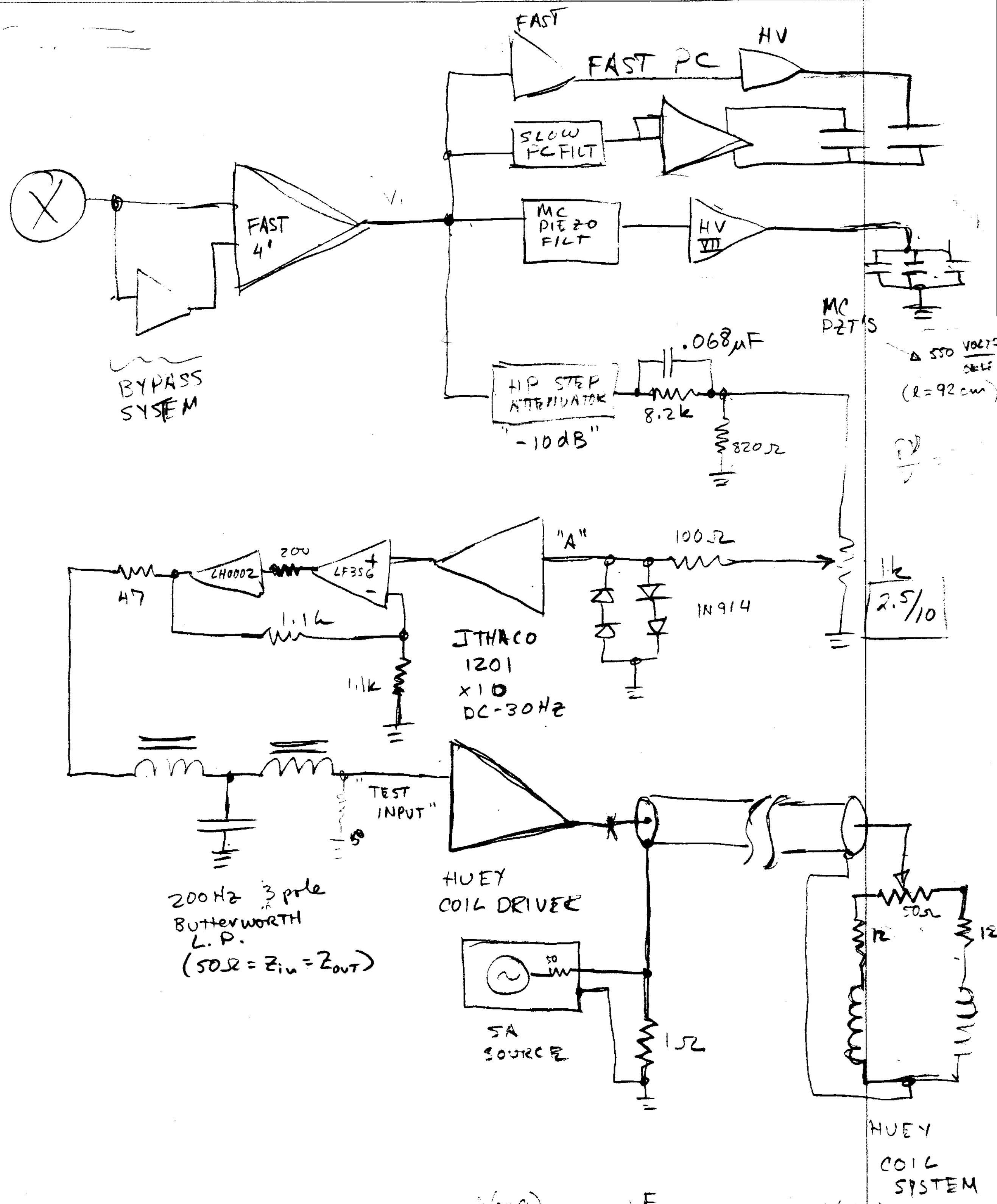
10/18/89

Latest Arm 1 Servo Arrangement (Locks Very Well)





10/17/89 MWR



$$\frac{c}{2l} = 150\,MHz$$

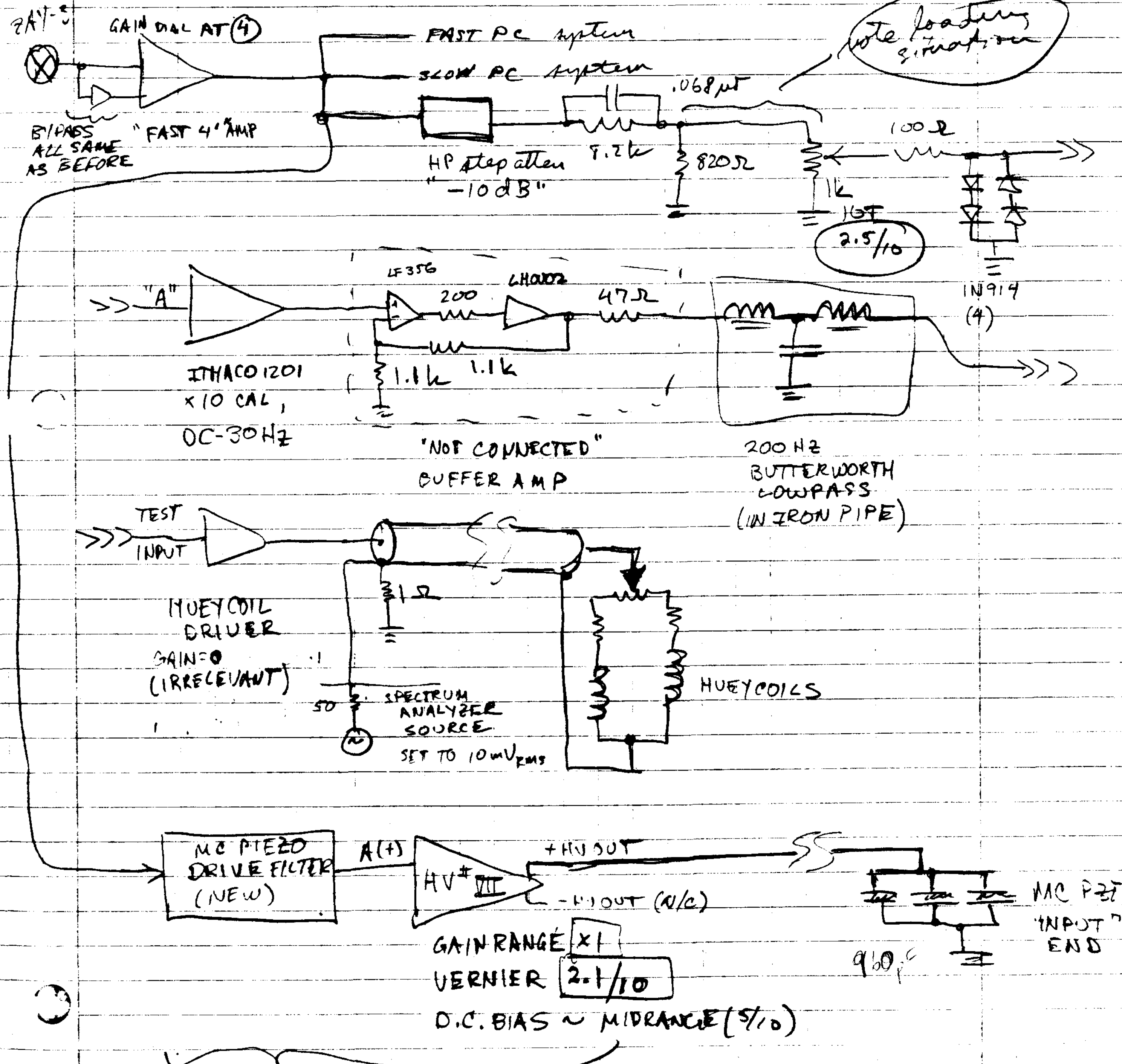
$$\frac{d(ma)}{di} = \frac{dF_{ext}}{d(current)} = m\frac{d(\omega^2 x)}{di}$$

$$= m\omega^2 \frac{dx}{di} = m\omega^2 \frac{l}{\nu}\frac{d\nu}{di}$$

10/6/89 MEZ

Documentation of Successful Mode Cleaner PZT drive setup;

Found the following setup to work well for driving the MC piezo:

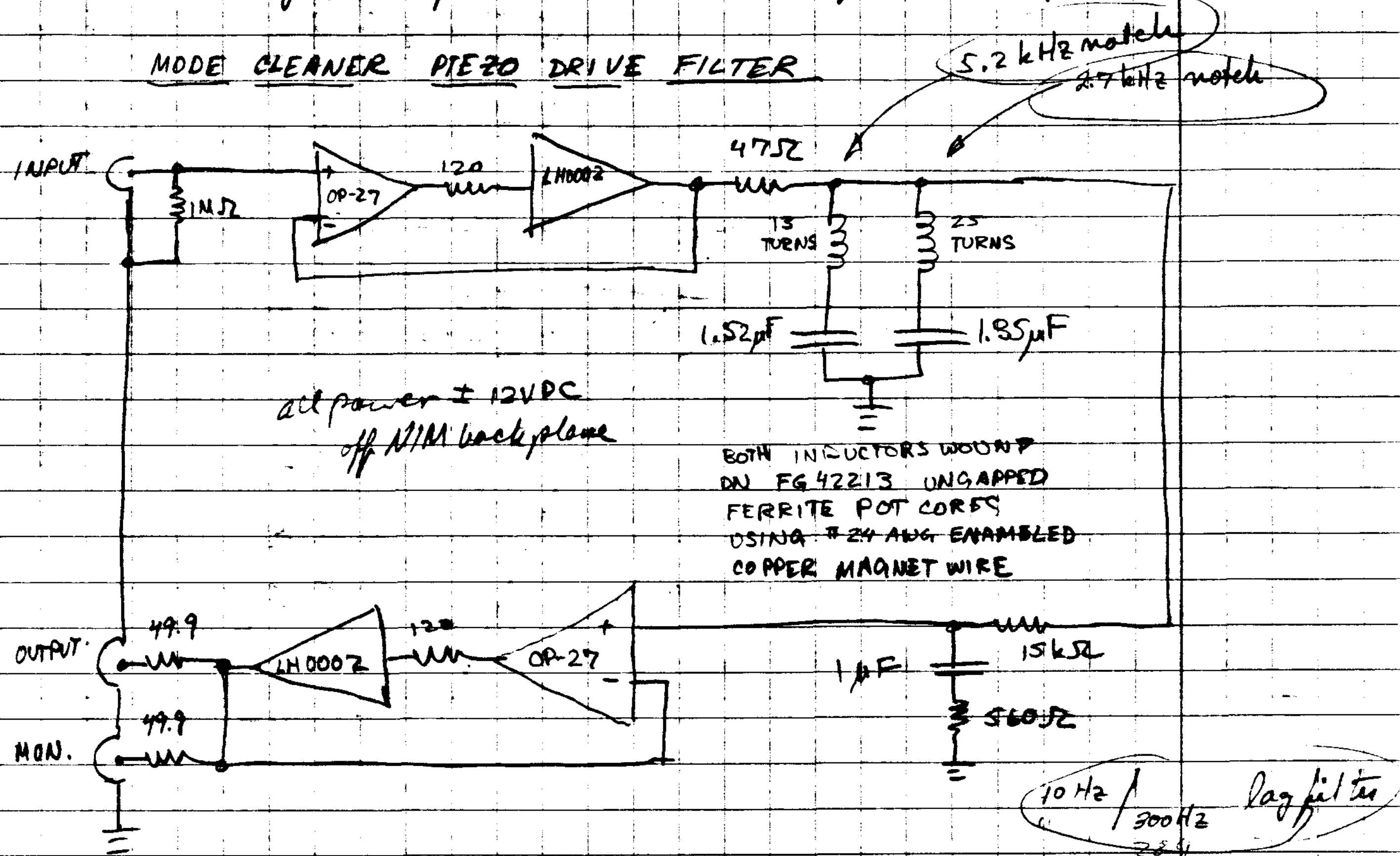


CIRCUIT DIAGRAMS TO FOLLOW

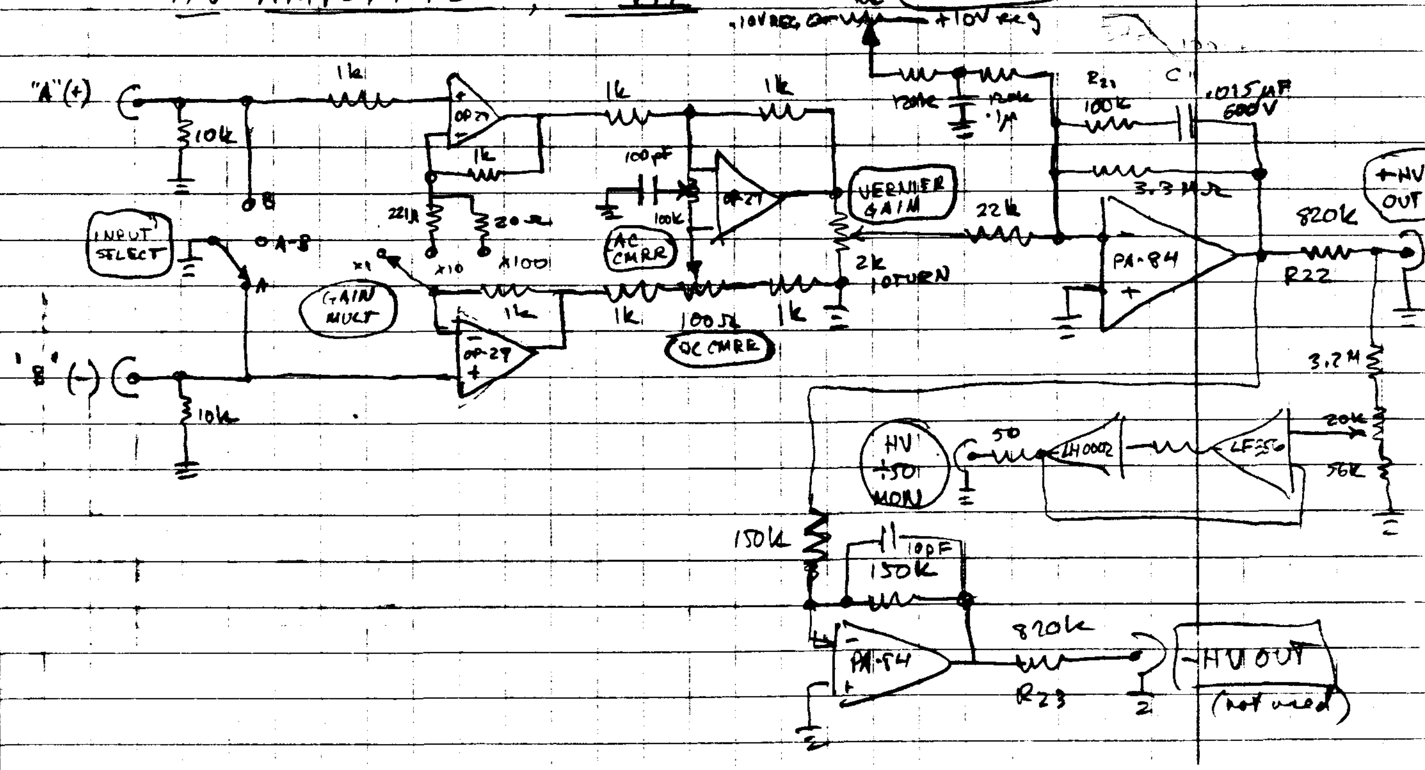
10/6/89

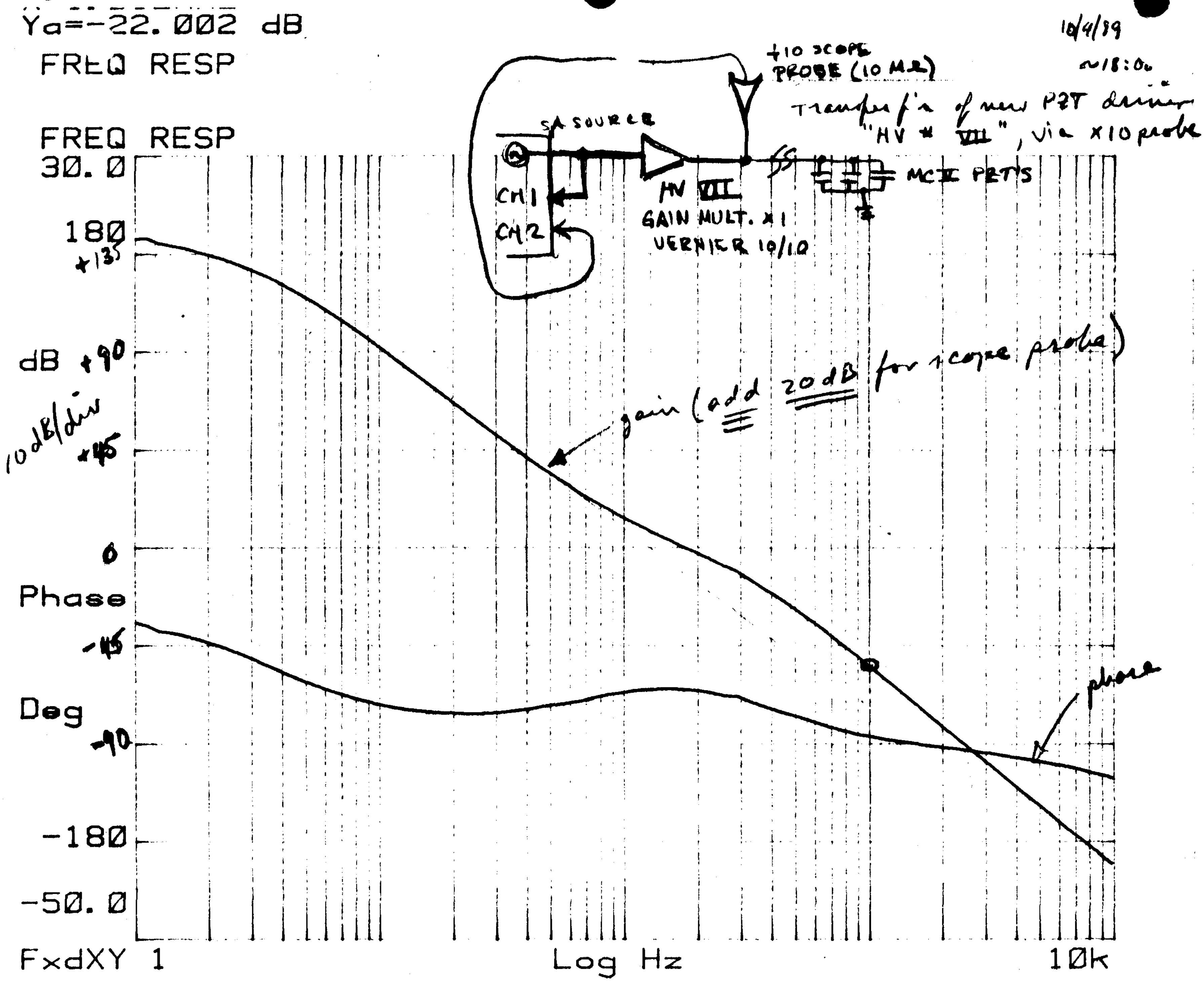
Circuit Diagrams of New PZT Drive System Components

MODE CLEANER PIEZO DRIVE FILTER



HV AMPLIFIER, # VII

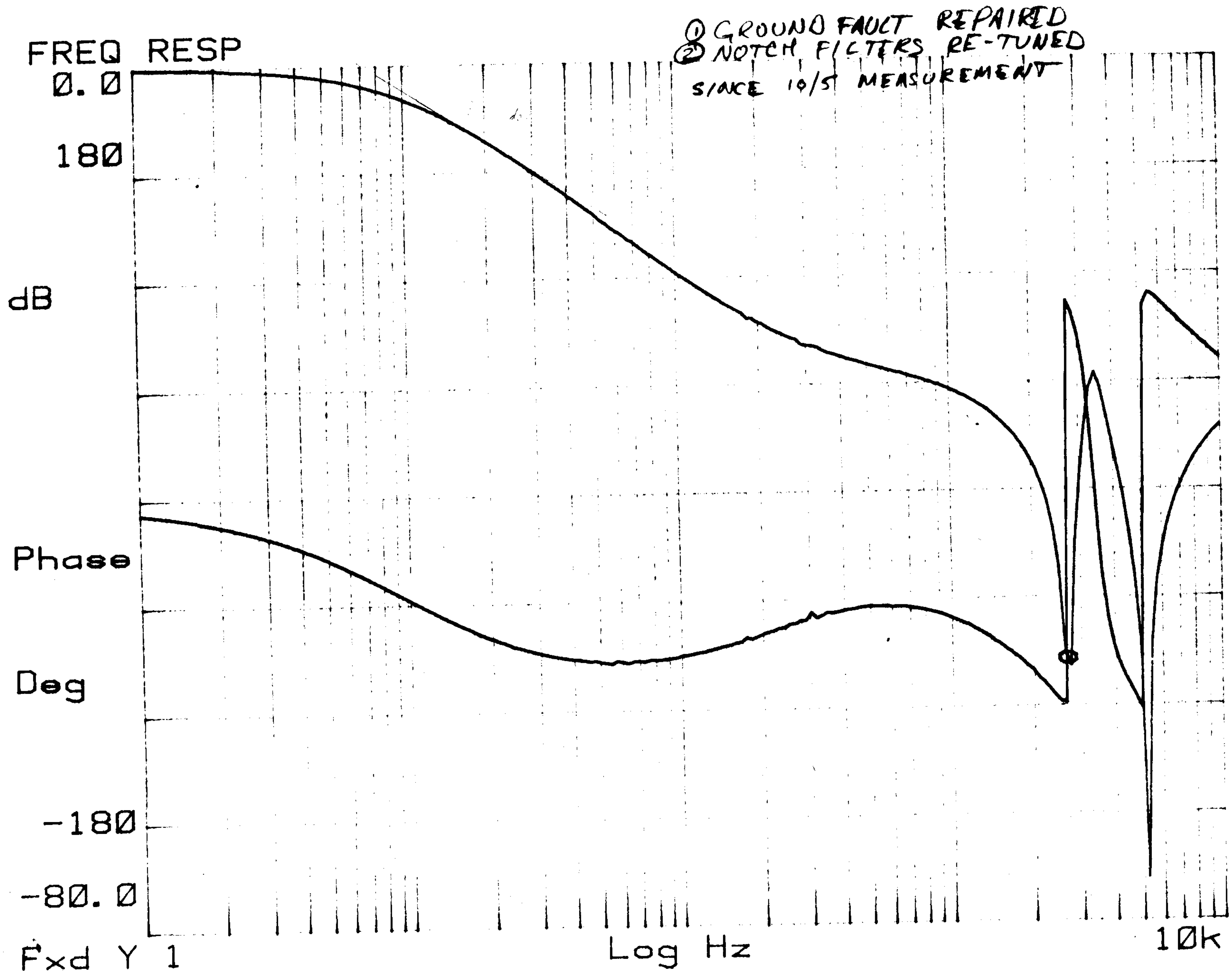



Ya=-22.002 dB
FREQ RESP
FREQ RESP
30.0
180
dB
Phase
Deg
-180
-50.0
FxdXY 1
Log Hz
10k
10/4/99
~18:00
÷10 SCOPE PROBE (10 MΩ)
Transfer f'n of new PZT driver "HV # VII", via x10 probe
SR SOURCE
CH1
CH2
HV VII
GAIN MULT. x1
VERNIER 10/10
MC II PZT'S
gain (add 20dB for scope probe)
10 dB/div
phase
+135
+90
+45
0
-45
-90

X=2.[illegible]91kHz
Ya=-55.698 dB
FREQ RESP

MODE CLEANER PIEZO
DRIVE FILTER

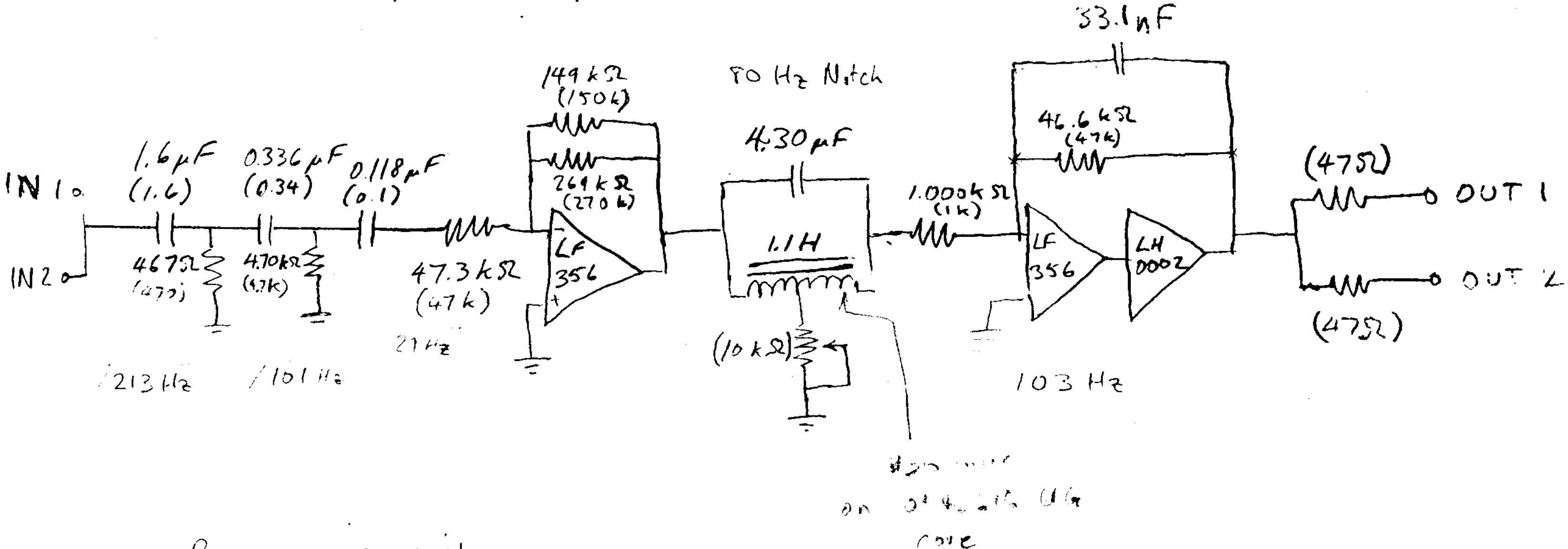
89 10 06 11:38
MWR



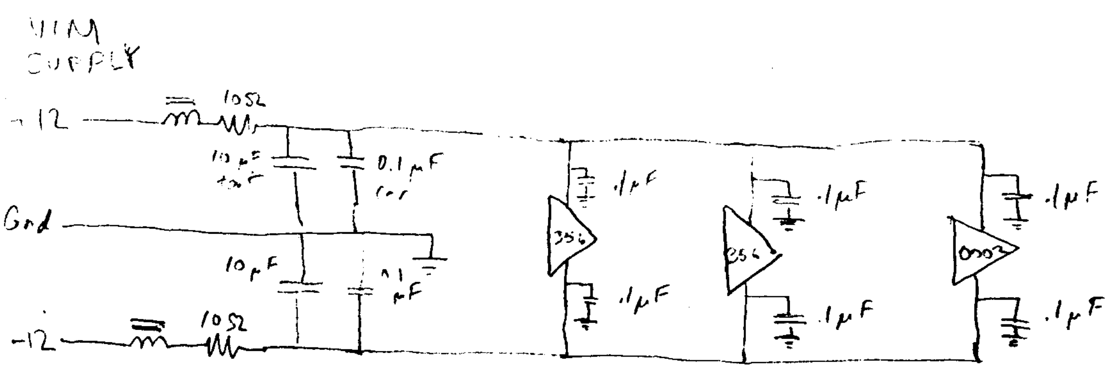
New First Arm Locking Slow Pockell's Cell Drive Filter / Preamp

891017 MWR

Component values shown are measured values;
Nominal values appear in parentheses



Power supply



X=302 Hz

(old) First Arm Servo Loop

891016 | 14[illegible]4

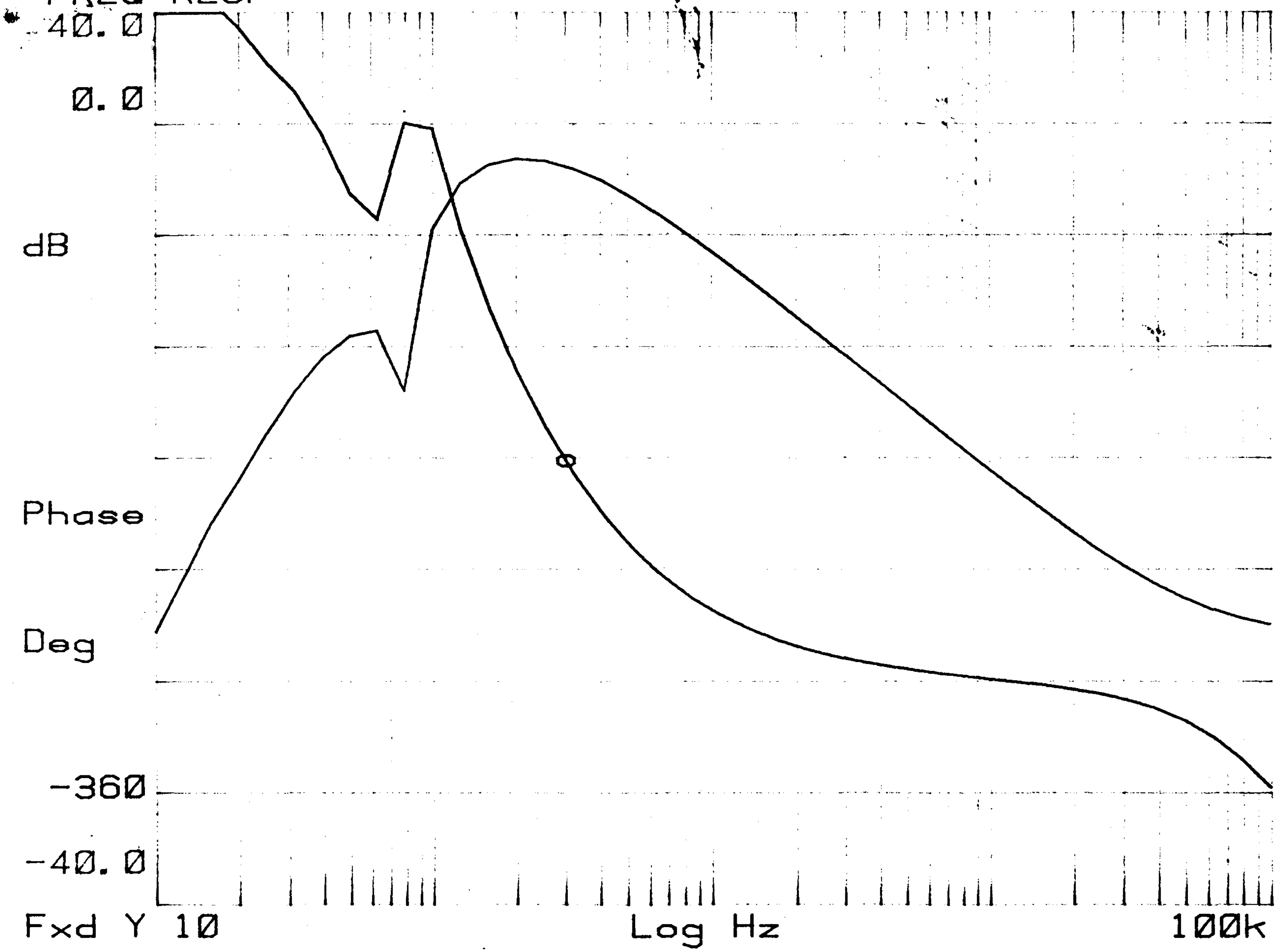
FREQ RESP

Slow Pockel's Cell Drive Filter Preamp

MEZ

Yb=-180.62 Deg

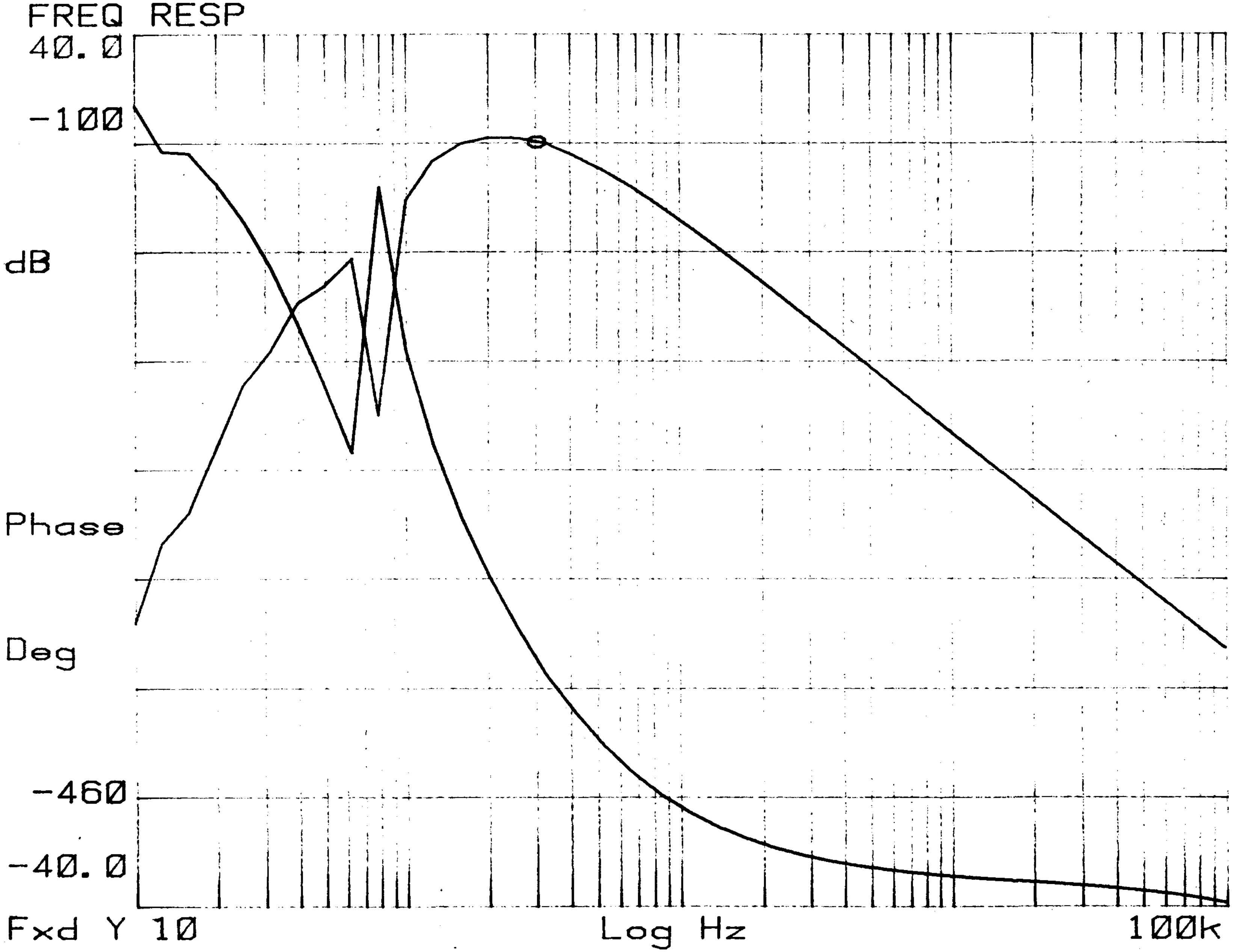
FREQ RESP



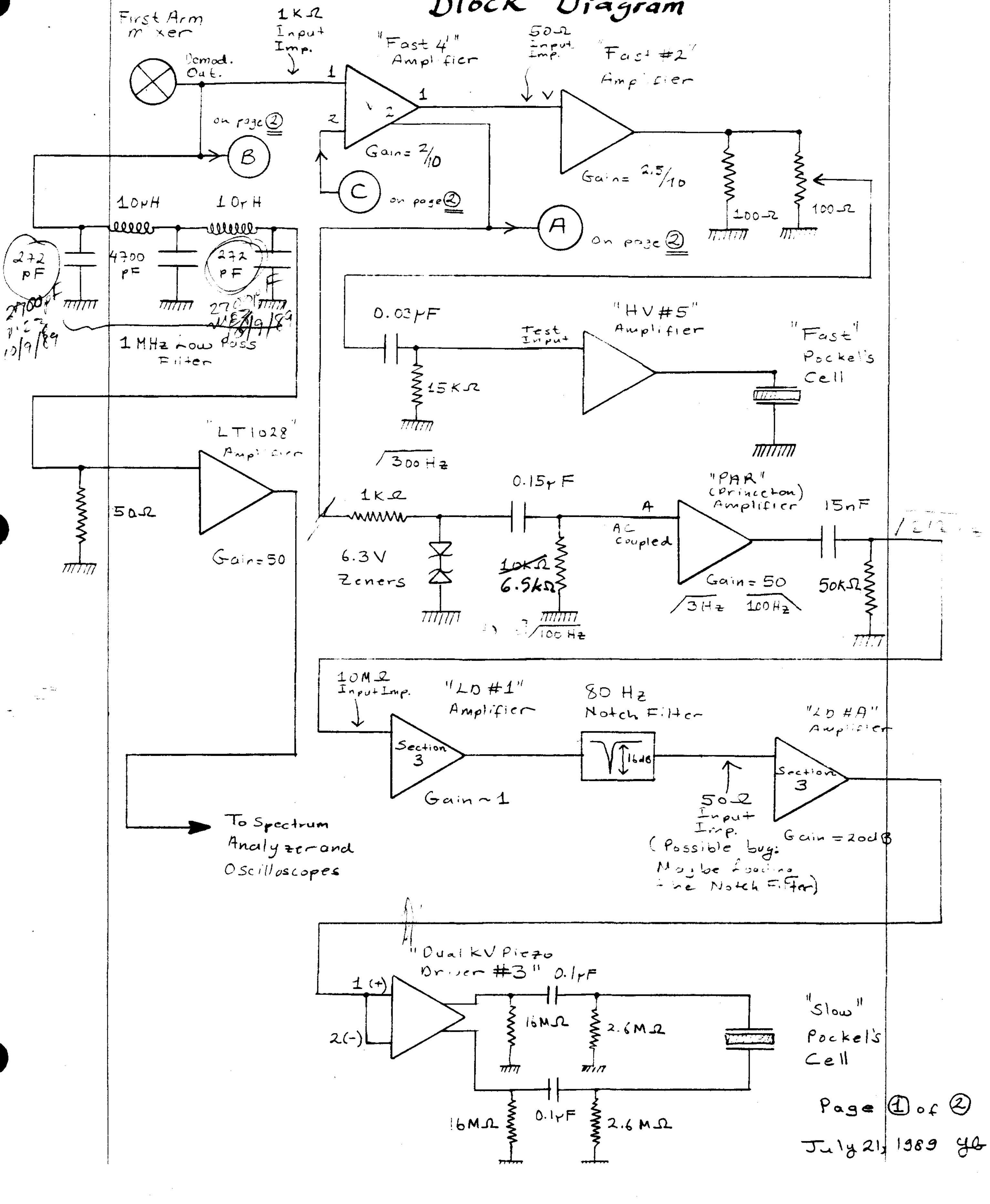
X=302 Hz
Ya=[illegible].2342 dB
FREQ RESP

New Kirst Arm[illegible] Servo loop
Slow Pockel's Cell Drive Filter / Preamp

P91016/[illegible]:52



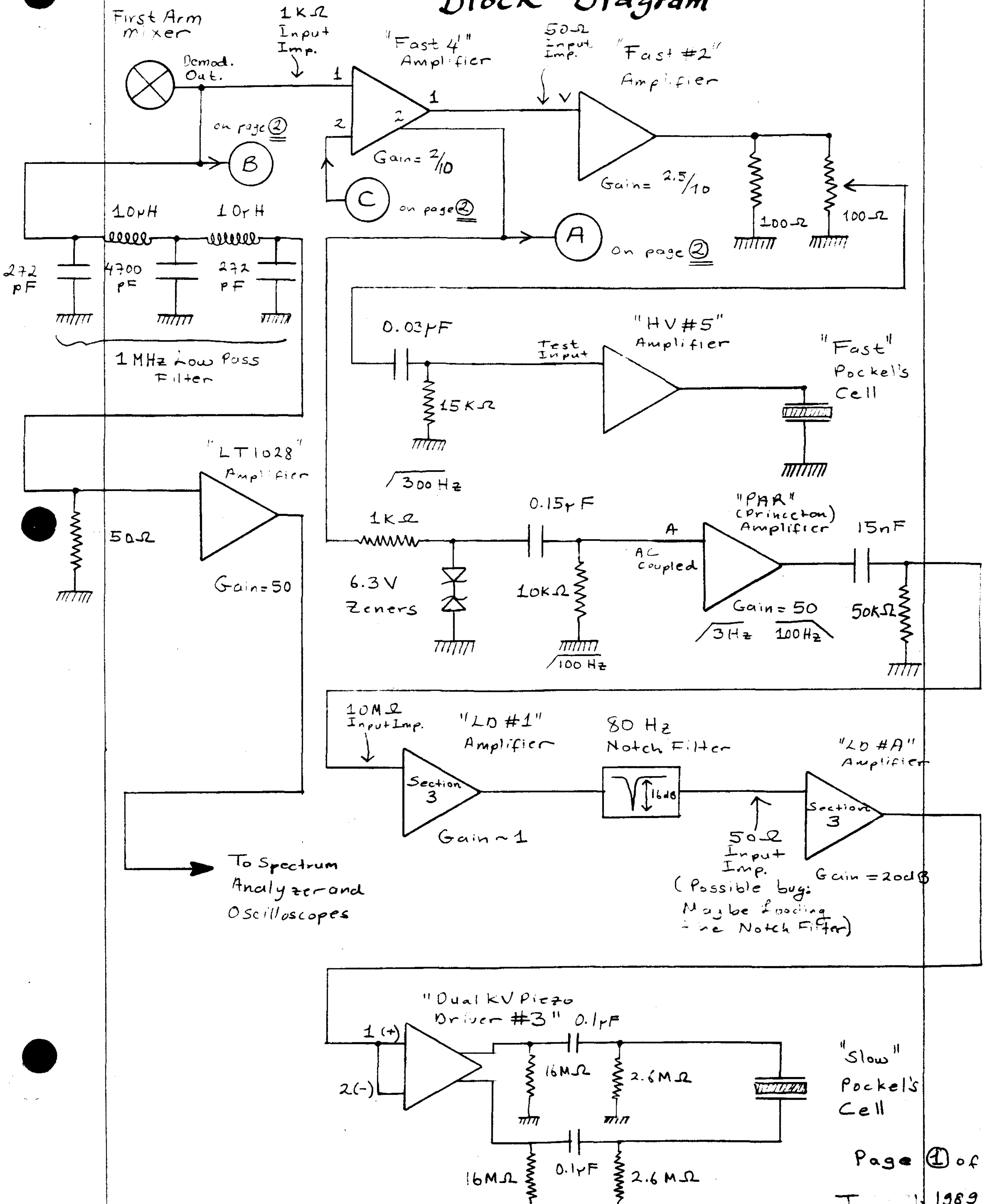
First Arm Servo Loop
Block Diagram



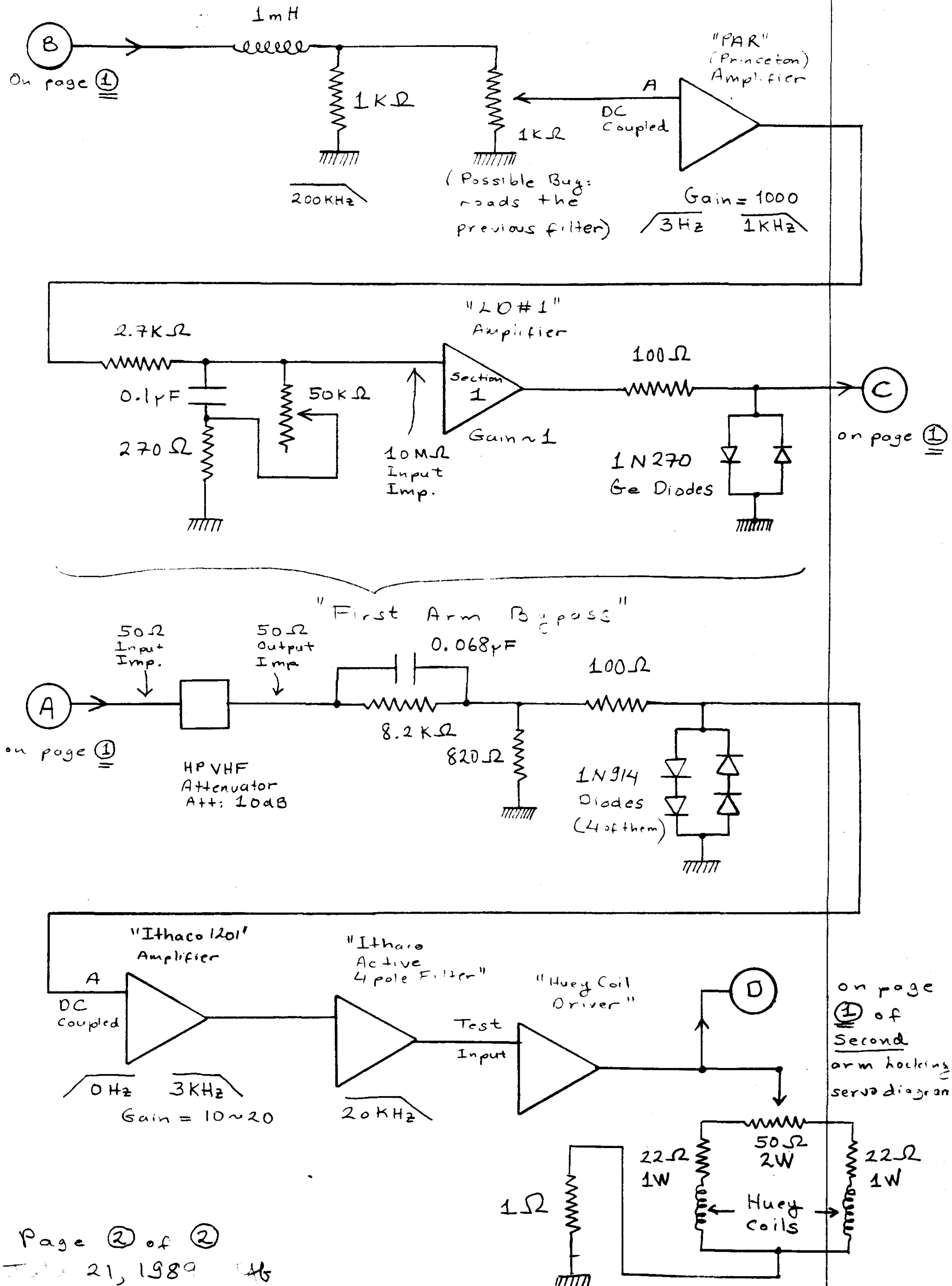
July 21, 1989 YG

OBSOLETE

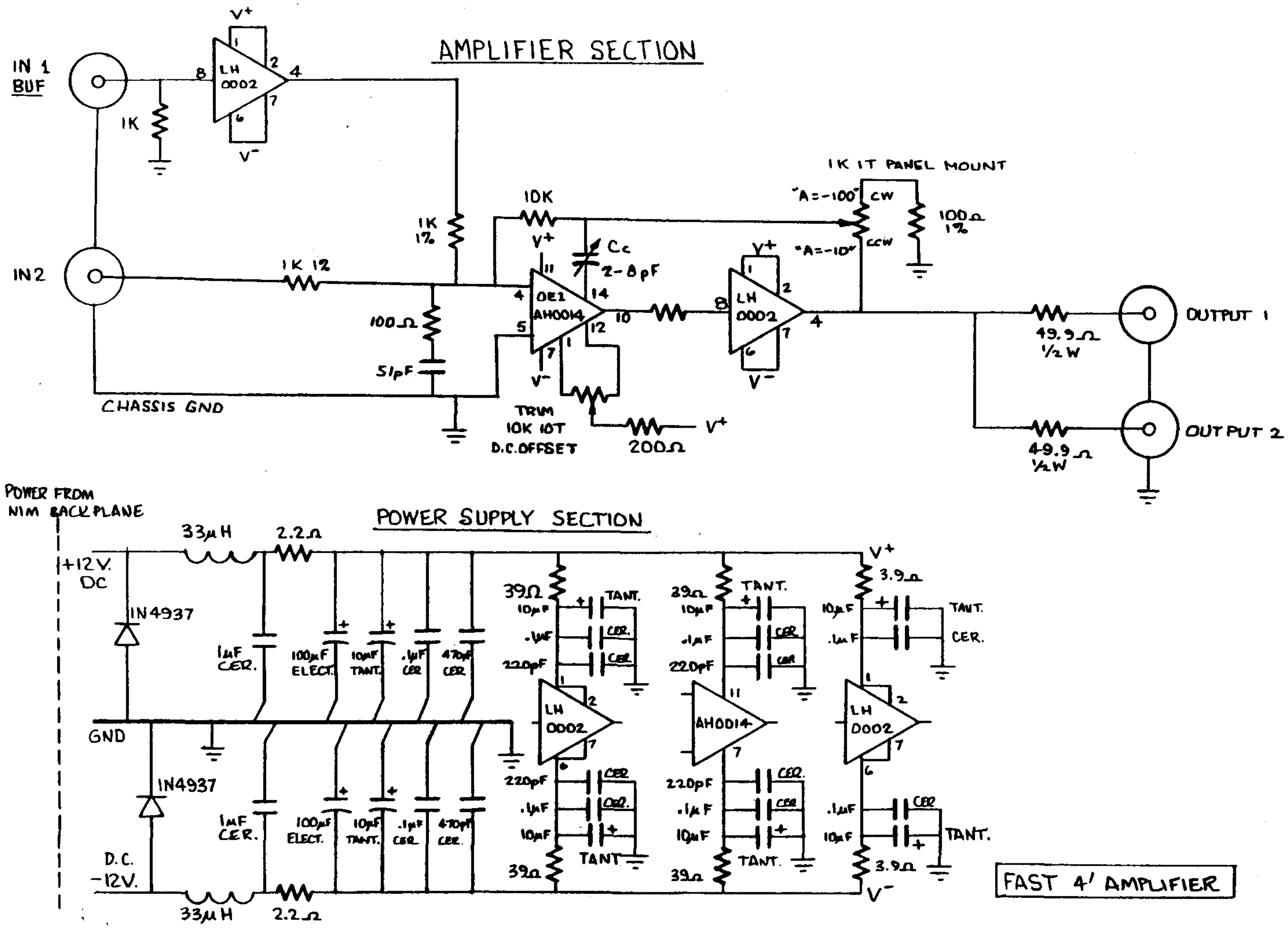
First Arm Servo Loop
Block Diagram



J... 1989 YG


B
On page 1
1mH
1KΩ
200KHz
1KΩ
(Possible Bug: loads the previous filter)
A
DC Coupled
"PAR" (Princeton) Amplifier
Gain = 1000
3Hz
1KHz
2.7KΩ
0.1μF
270Ω
50KΩ
10MΩ Input Imp.
"LO#1" Amplifier
Section 1
Gain ~ 1
100Ω
1N270 Ge Diodes
C
on page 1
"First Arm Bypass"
A
on page 1
50Ω Input Imp.
50Ω Output Imp.
HP VHF Attenuator Att: 10dB
0.068μF
8.2KΩ
820Ω
100Ω
1N914 Diodes (4 of them)
"Ithaco 1201" Amplifier
A
DC Coupled
0Hz
3KHz
Gain = 10~20
"Ithaco Active 4 pole Filter"
20KHz
Test Input
"Huey Coil Driver"
D
on page 1 of Second arm locking servo diagram
50Ω 2W
22Ω 1W
22Ω 1W
Huey Coils
1Ω

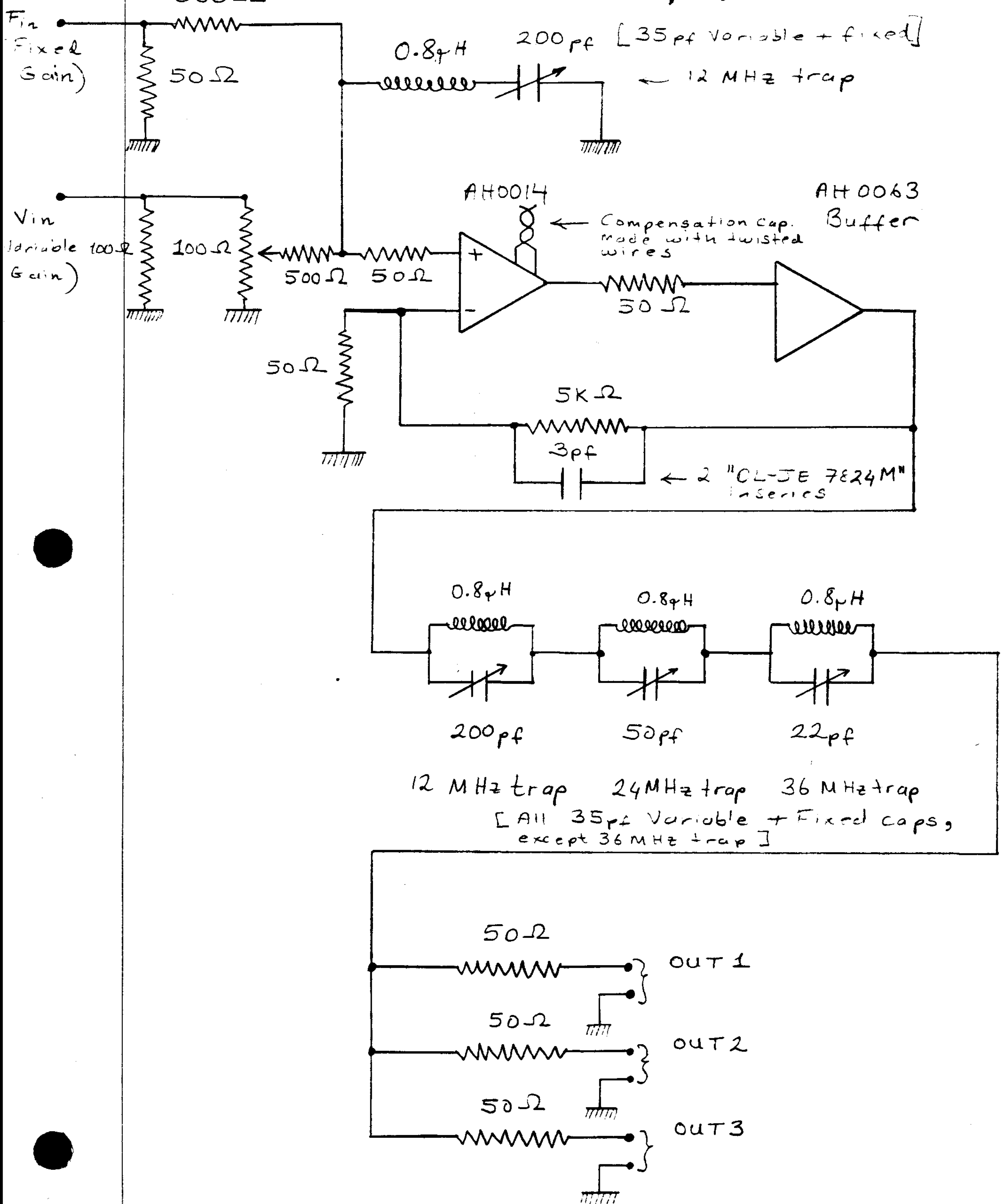
21, 1989



CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
FAST 4' AMPLIFIER 9-22-88 MEZ		
DRAWN BY B.T.	DATE 9-29-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

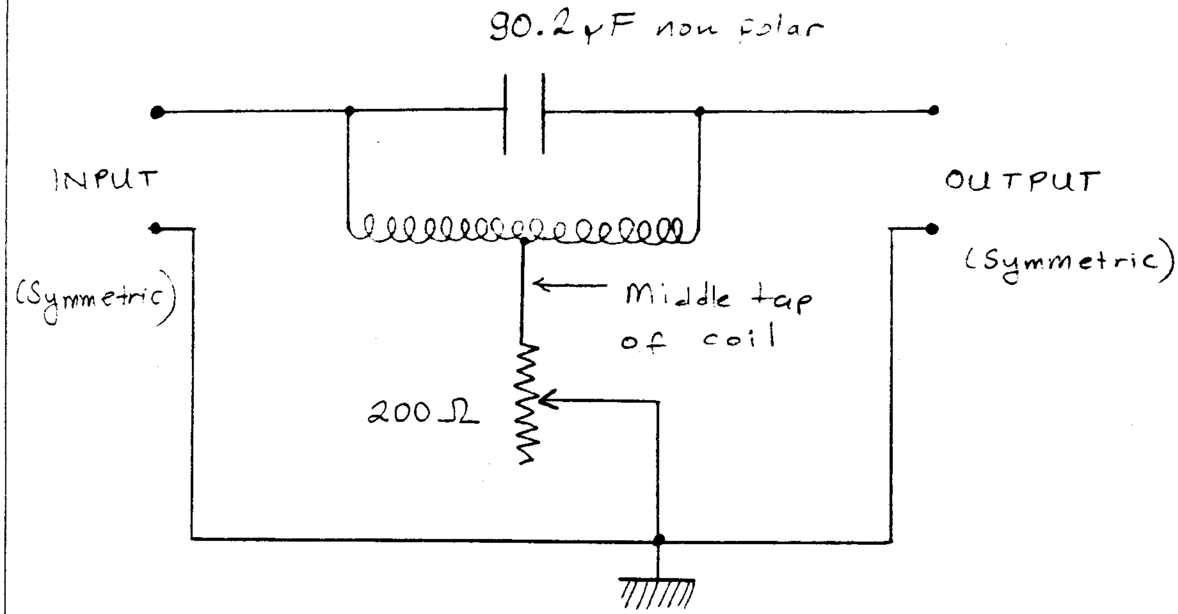
88-0929-1

'Fast 2" Amplifier:



July 24, 1989
YE

80 Hz Notch Filter:



The coil is chosen in such a way that the resonance of the LC combination is 80 ∓ 1 Hz.

July 24, 1989 YB

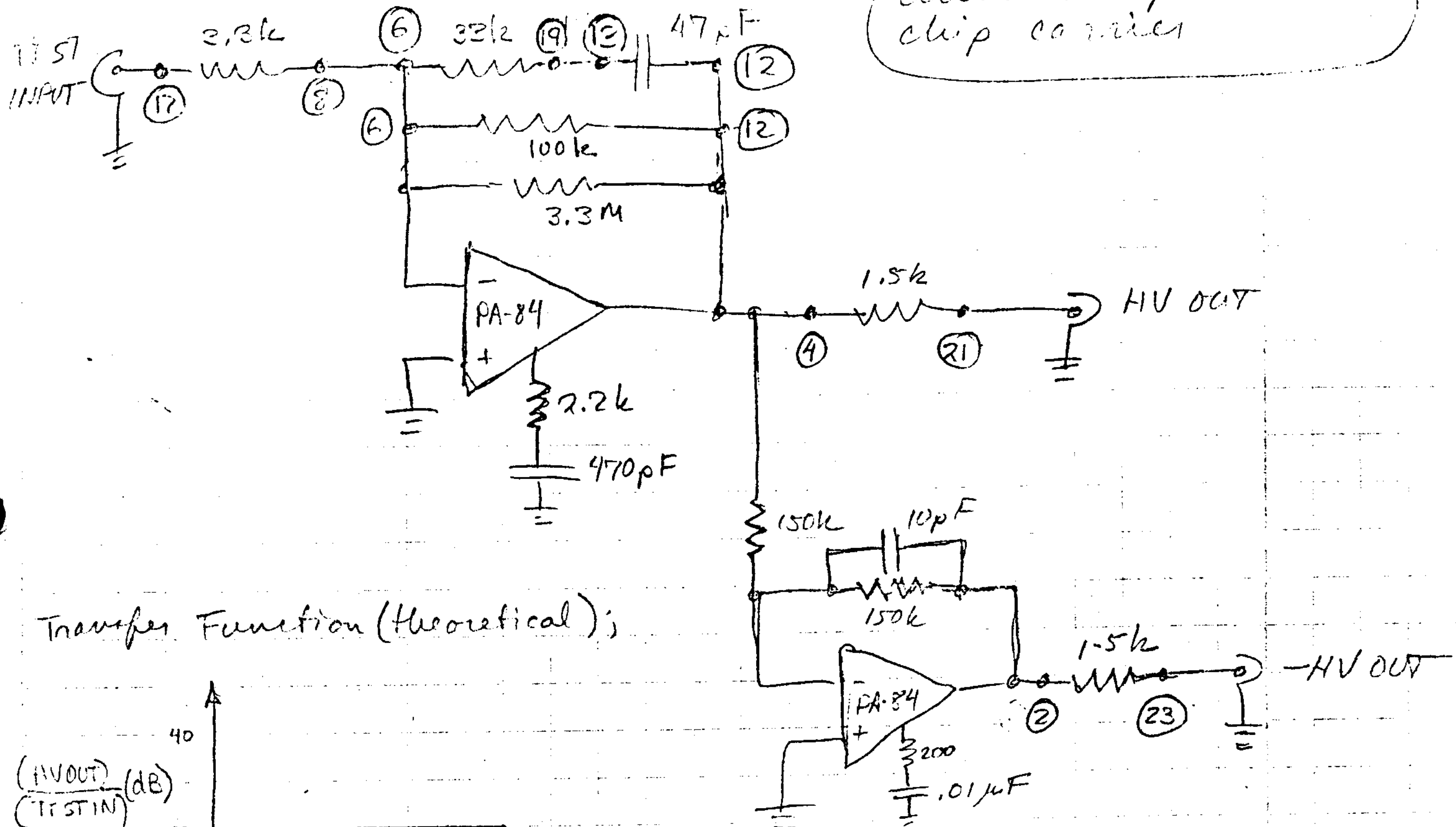
2/24/98

→ LABELED "Y"

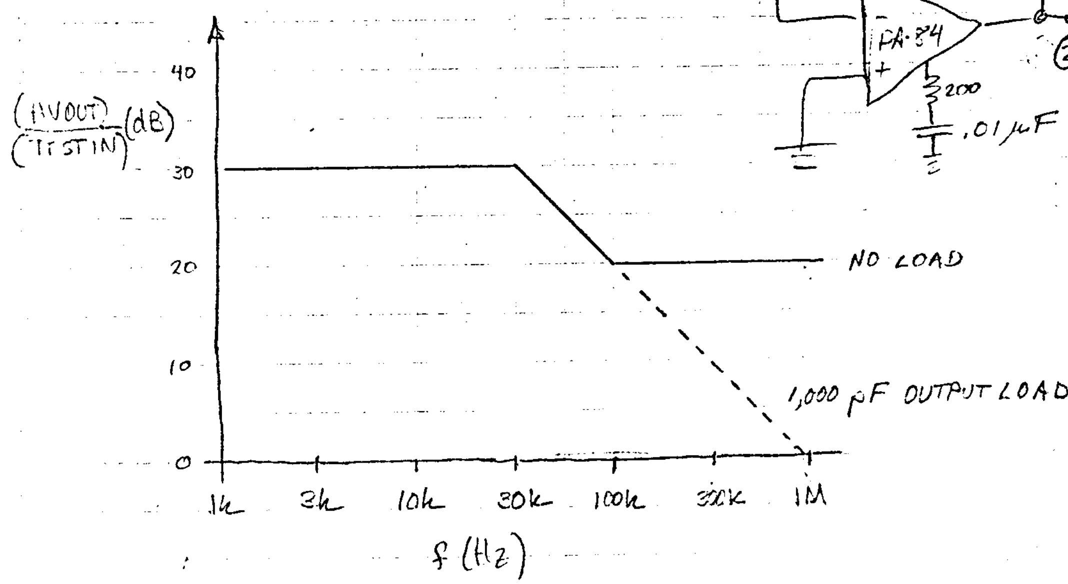
Another H.V. amp has been modified for use in phase correcting loop (to replace/supplement "push" amplifier used for fast m.c. in previous notebooks).

Relevant parts of circuit;

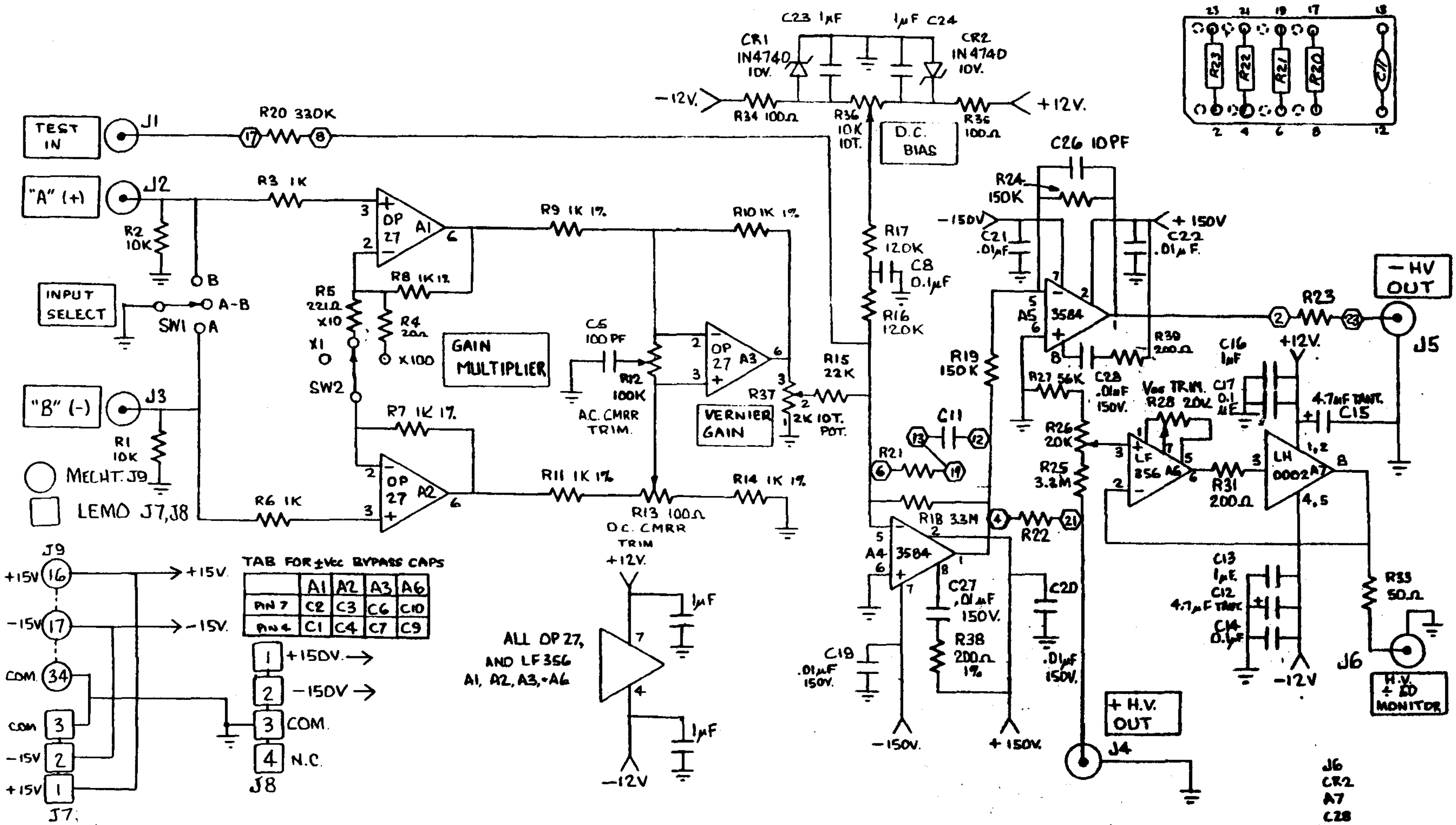
circled #'s = pin # on chip carrier



Transfer Function (theoretical);



Actual transfer function very close to theoretical, but peaky at ~2MHz



LAST: J6, CR2, A7, C28, R39

NO'S SKIPPED: C25, C18, R32, R30, R29

SMARTWRK FILE C:\SMARTWRK HVAMP.PCB
DRAWN FROM E. LINDELEF OF 9-1-87 PRO HVAMP.PL
ADDED COMP CARRIER PIN NO's TO DWG.

REPLACES 87-0901-1

2. J7, J8, and J9 ARE ALL MOUNTED ON BACK PANEL.

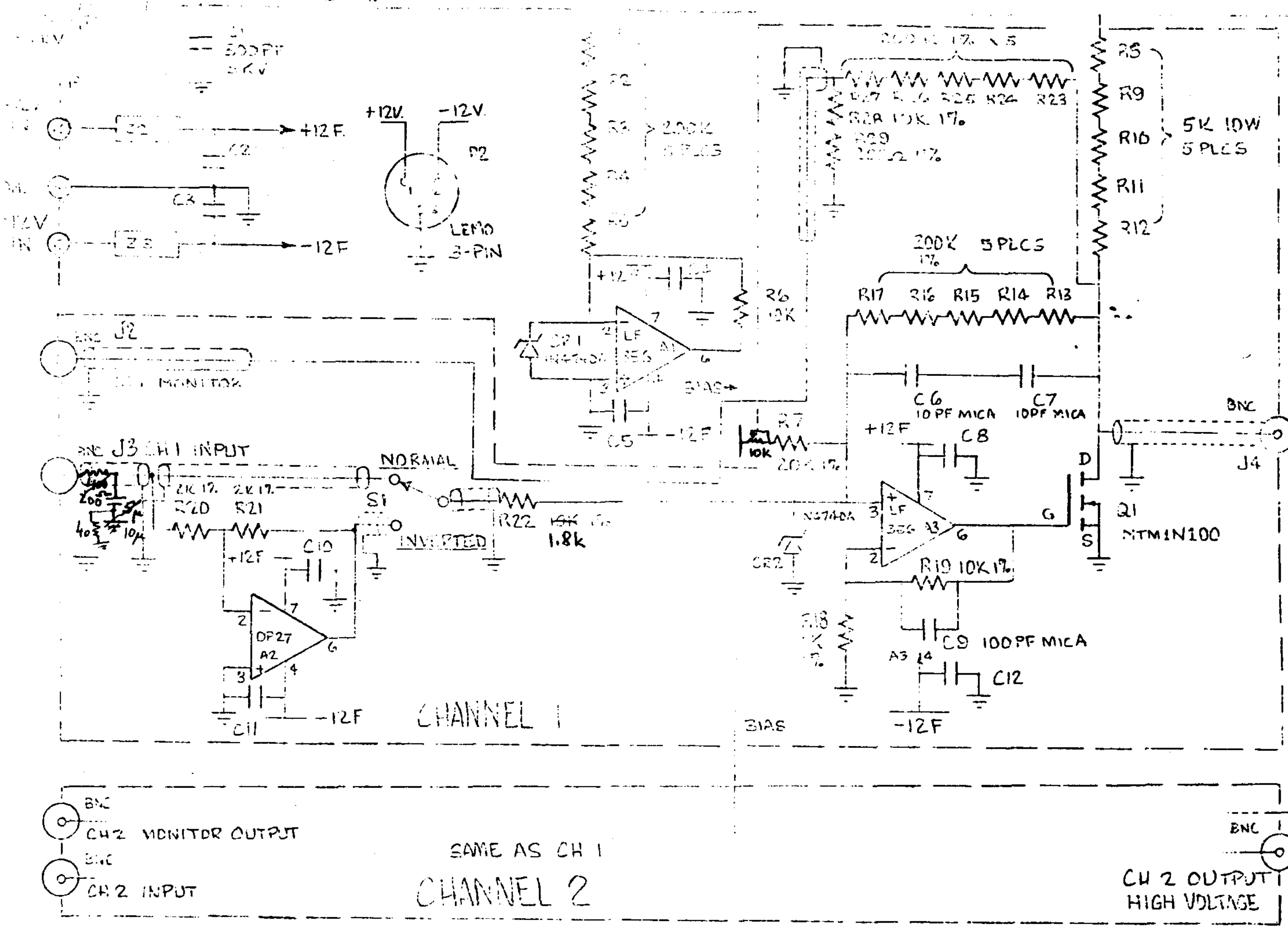
NOTES 1. ┌J┐ INDICATES JUMPER TO SHORT.

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

HV AMPLIFIER ± 150V.

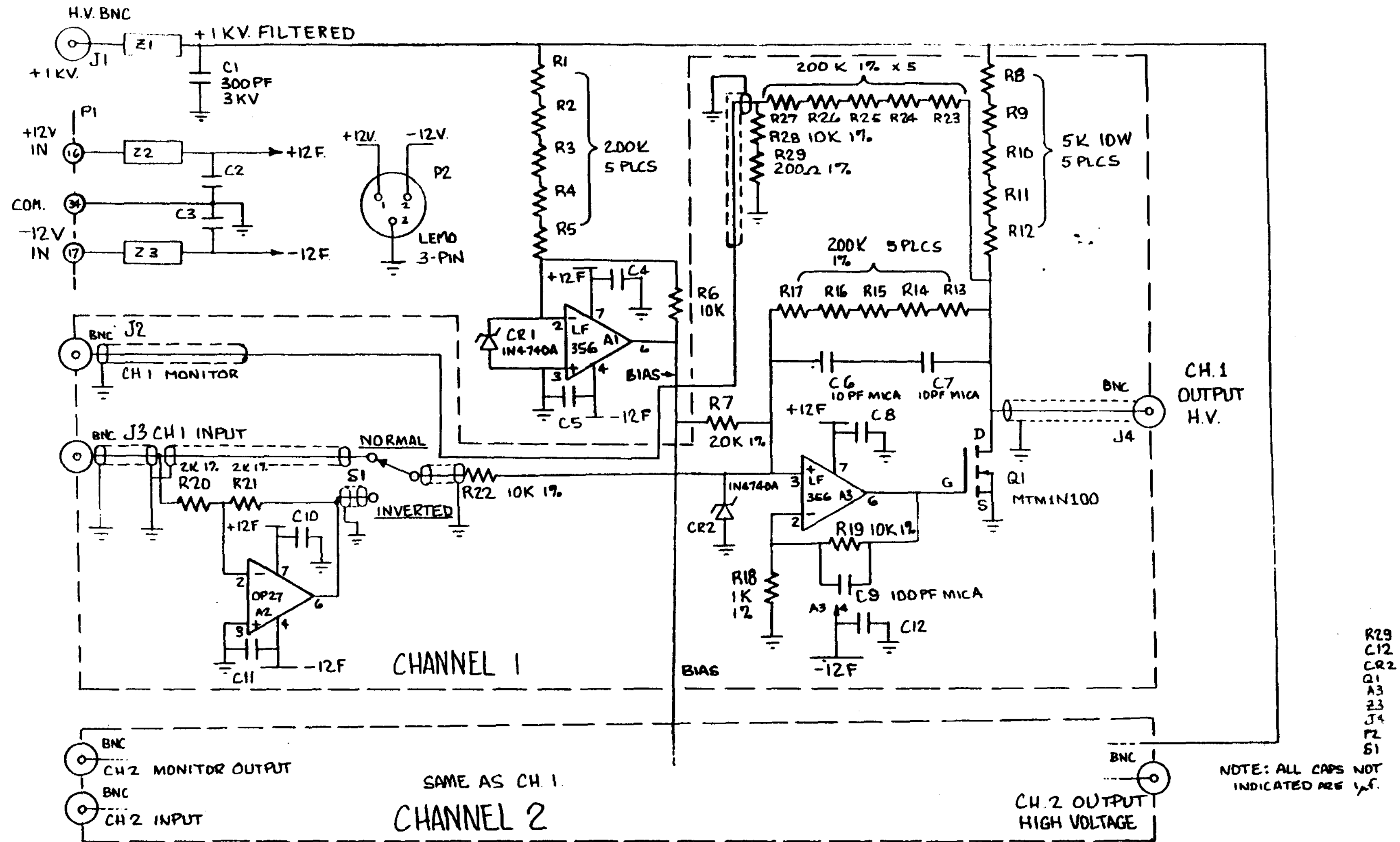
DRAWN BY B. TINKER	DATE 3-4-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

88-0304



HV amplifier modified for use with phase correcting Pockels cell.

3-MARCH



UPDATE TO 2/26/88

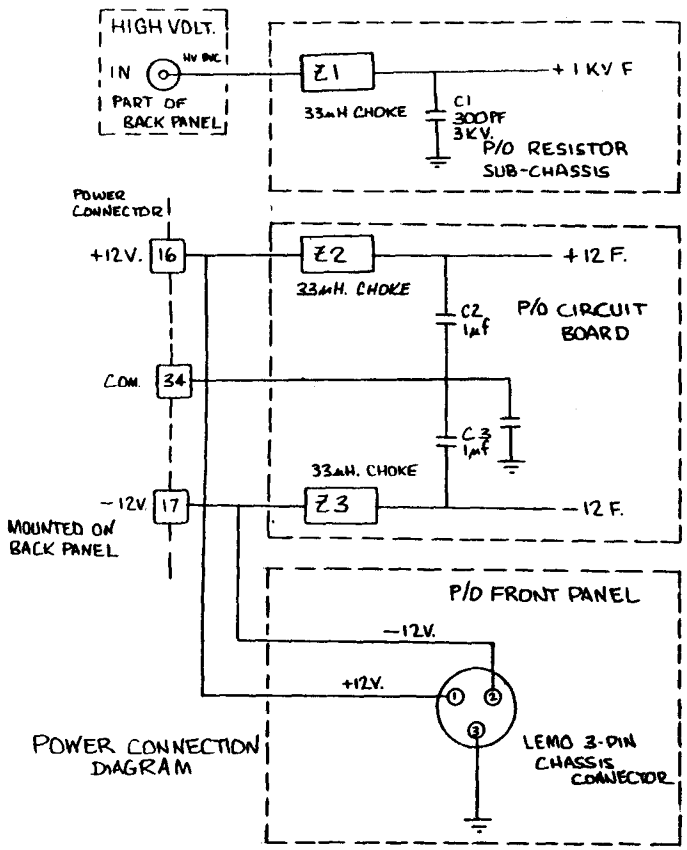
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

DUAL KILOVOLT PIEZO DRIVER

DRAWN BY B. Tinker	DATE 11/24/87	DRAWING NO.
CHECKED BY	SCALE	-1
APPROVED BY	W.O.	

WARNING: CIRCUITS MAY CARRY UP TO 1KV.

87-1124-1



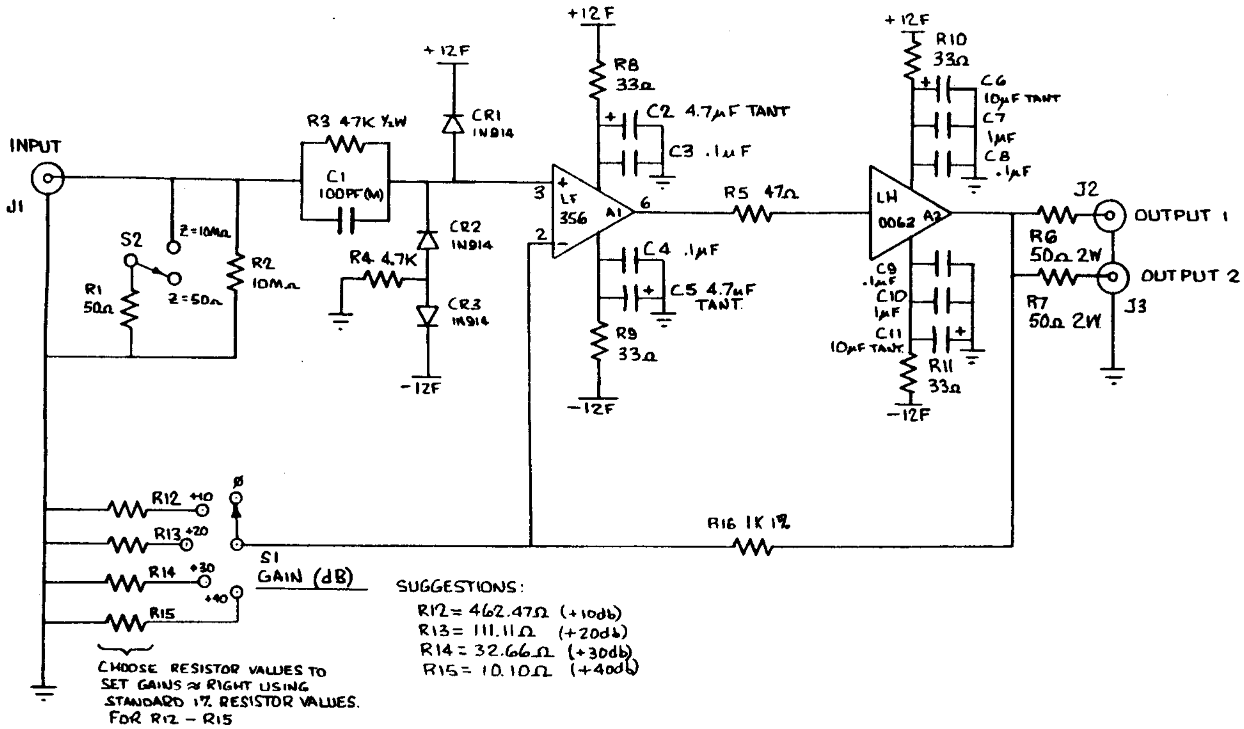
POWER CONNECTION DIAGRAM

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

DUAL KILOVOLT PIEZO DRIVER

DRAWN BY B. TINKER	DATE 2-2-88	DRAWING NO.
CHECKED BY	SCALE	-2
APPROVED BY	W.O.	

87-1124-2



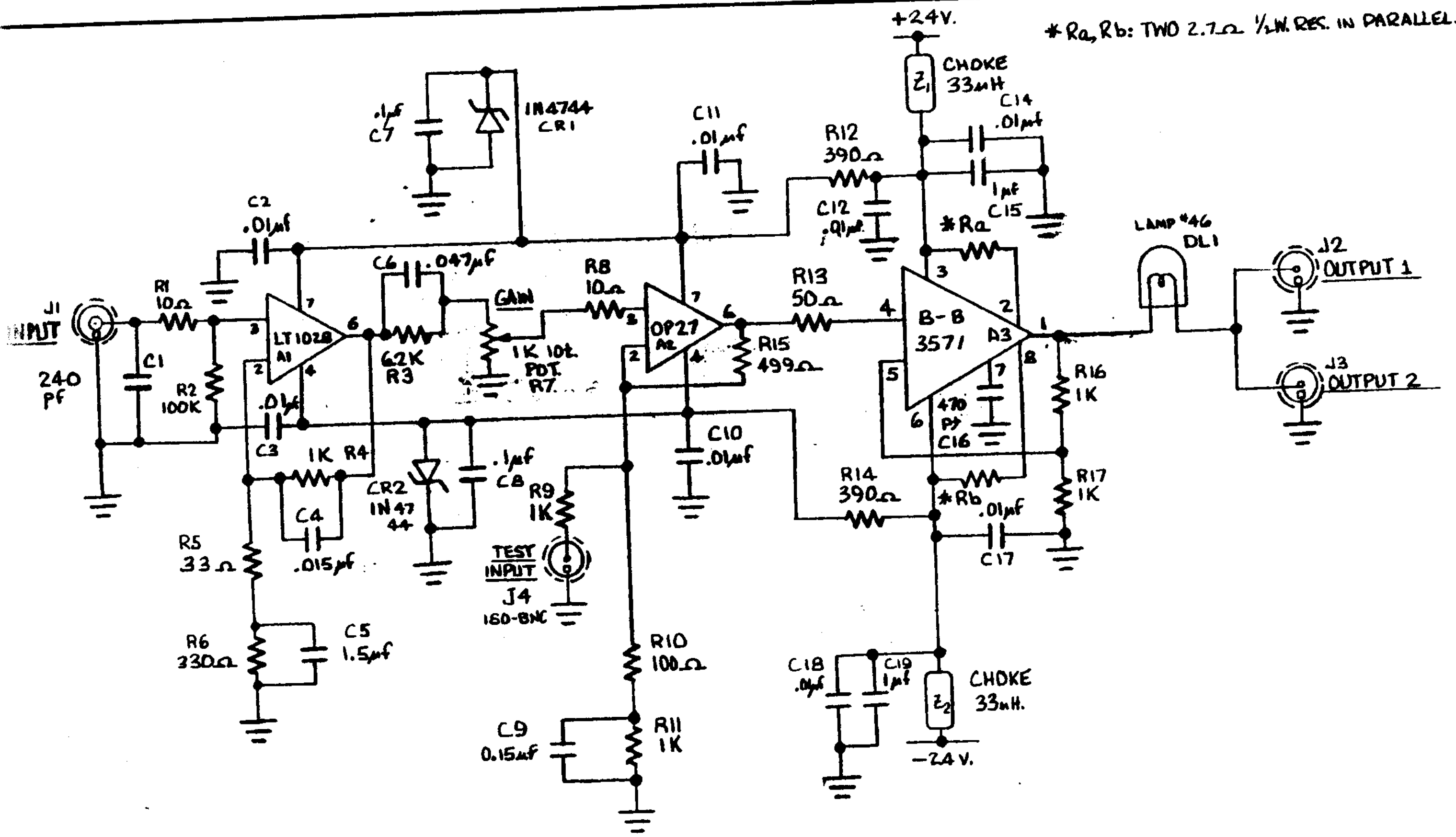
A 2
CR3
S2
J3
R16
LAST C

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

LINE DRIVER

DRAWN BY B.T.	DATE 6-13-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

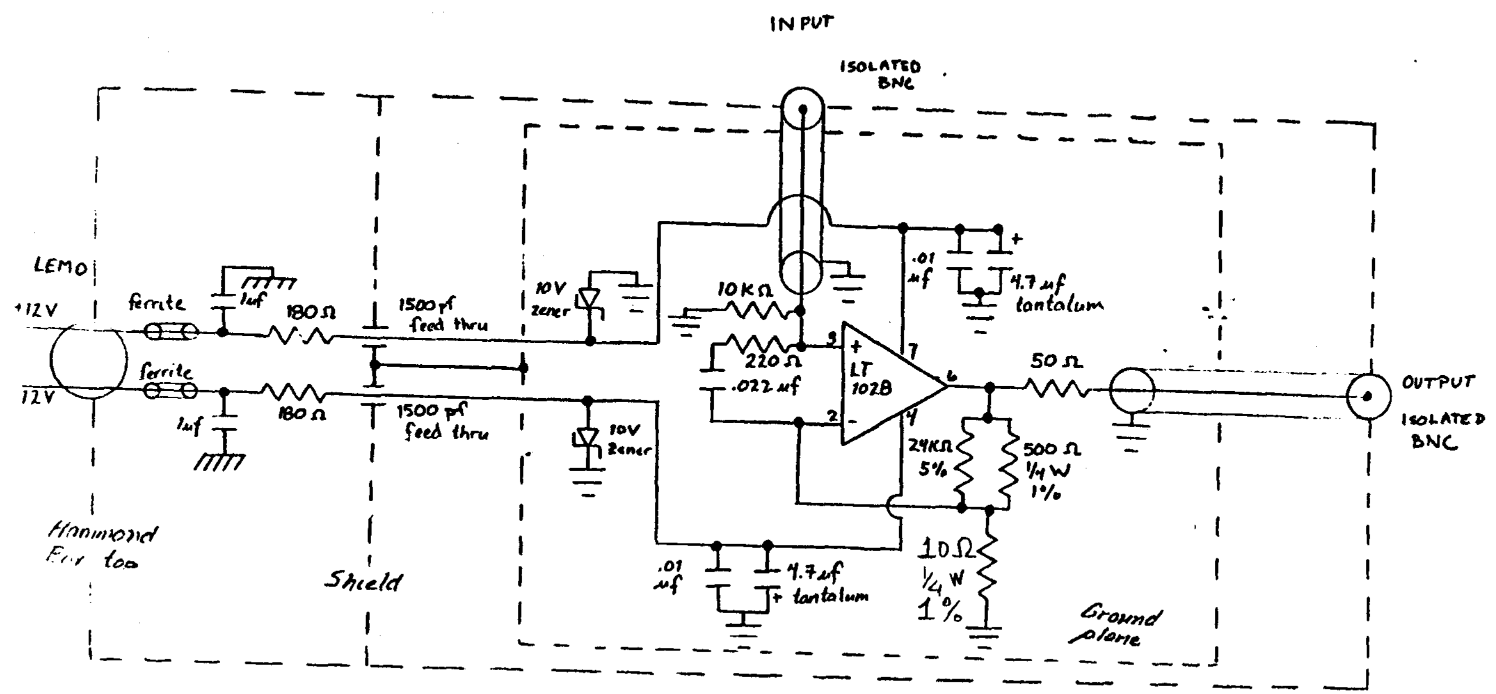
88-0613-1



3-1-88 R15 MOVED: 1K TO 500Ω
1-28-88 C16 FROM 220pf TO 470pf
UPDATE TO 9-8-78

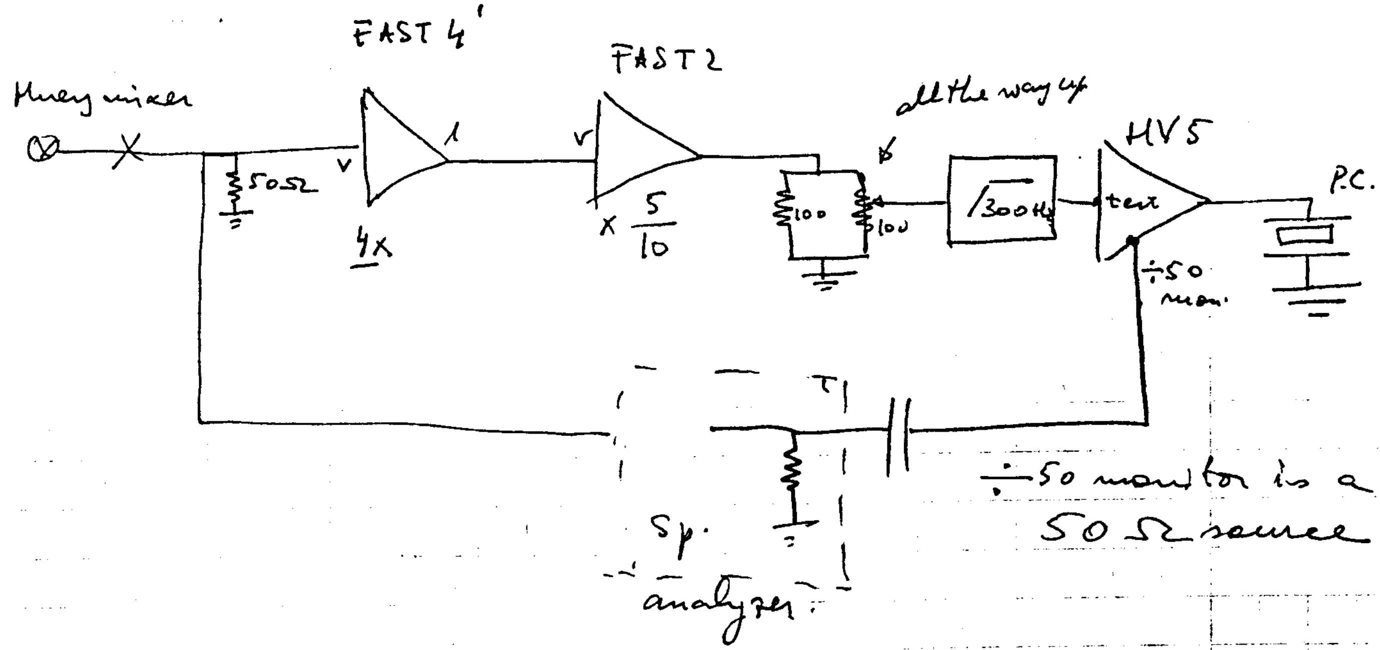
CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
COIL DRIVER HIGH CURRENT		
DRAWN BY B.T.	DATE 9-2-87	DRAWING NO.
CHECKED BY	SCALE	-1
APPROVED BY	W.O.	

87-0902-1

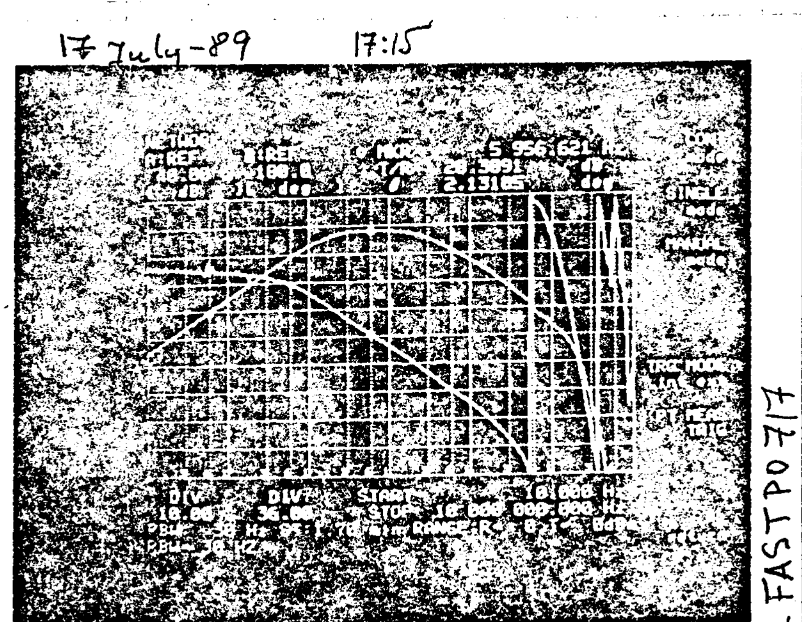


LOW NOISE BUFFER
8-21-97

1st arm (phase correction) servo : fast Pockels cell loop



÷50 monitor is a 50 Ω source

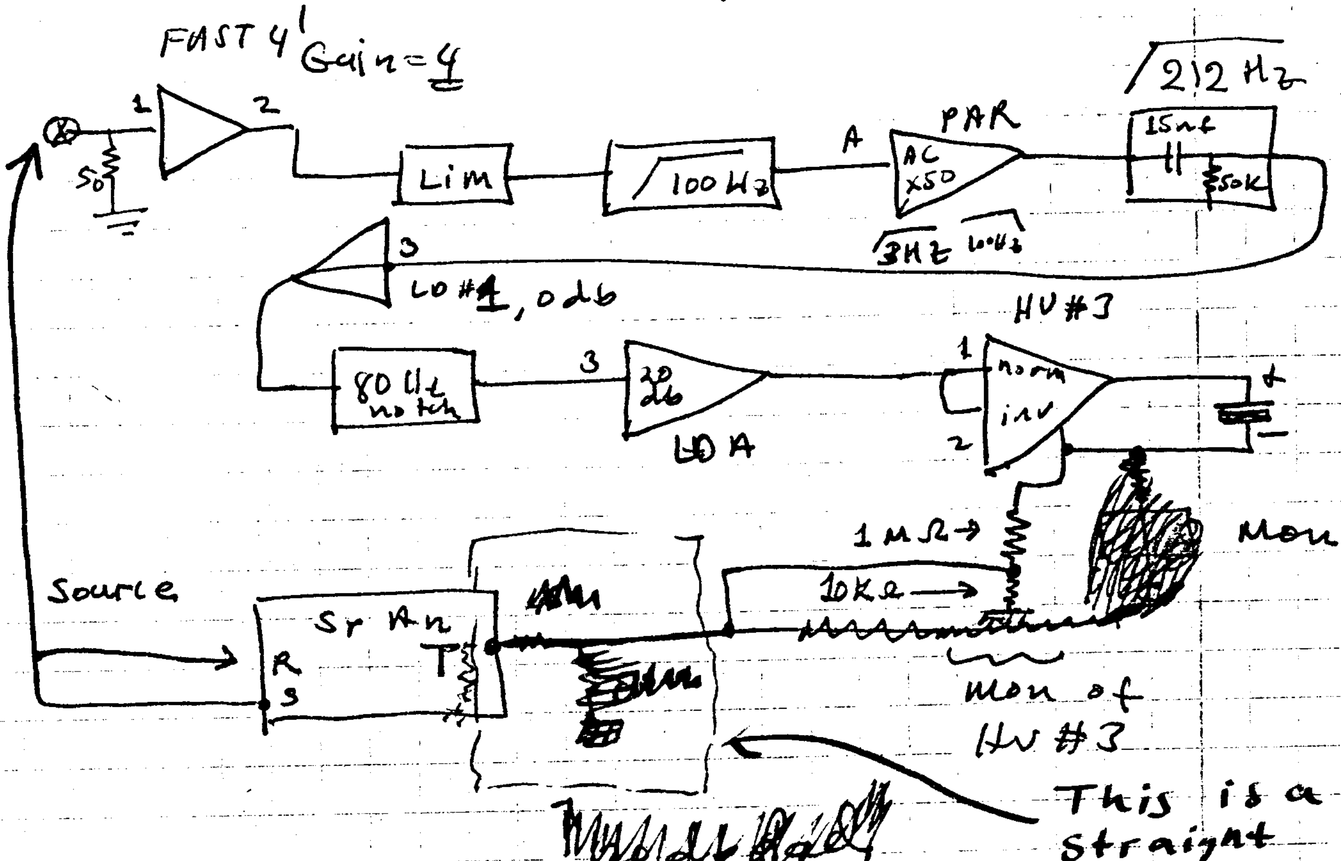


Fast P.C. loop transf. function, 50 Ω at inp of Fast 4

July 17, 1989
Jly, AA, SH

Servo block frequency and phase response:

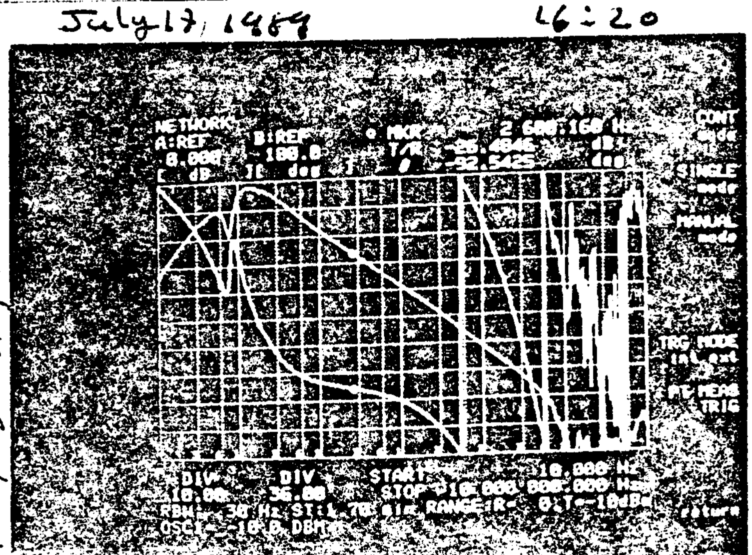
1st arm: Slow pockel's cell loop:



This is a straight connection, not a 20dB pad.

July 17, 1989   16:20

FAST 4' gain: 4



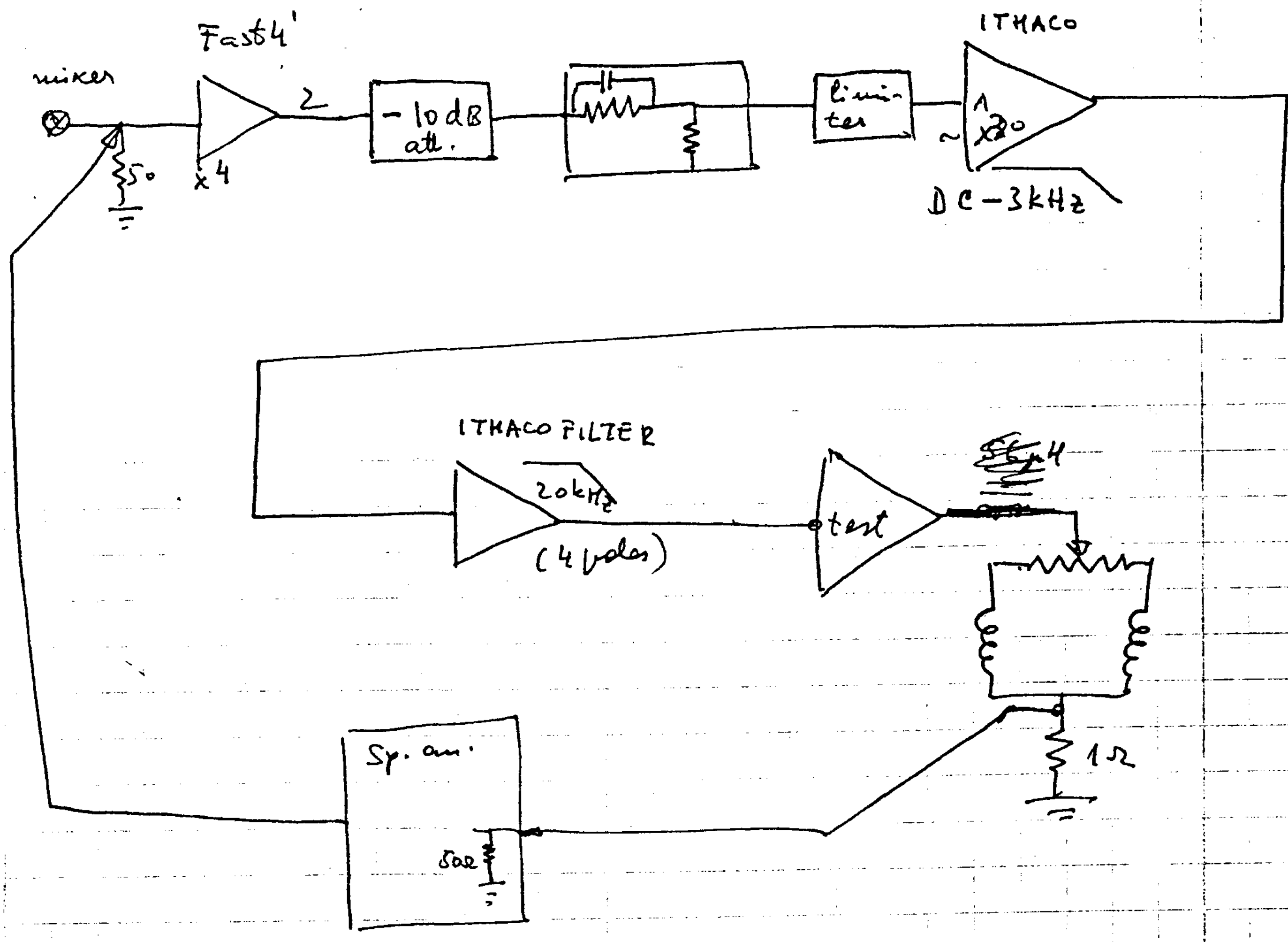
SLOP0717

← real gain: add 92dB (see dividers on sketch above)

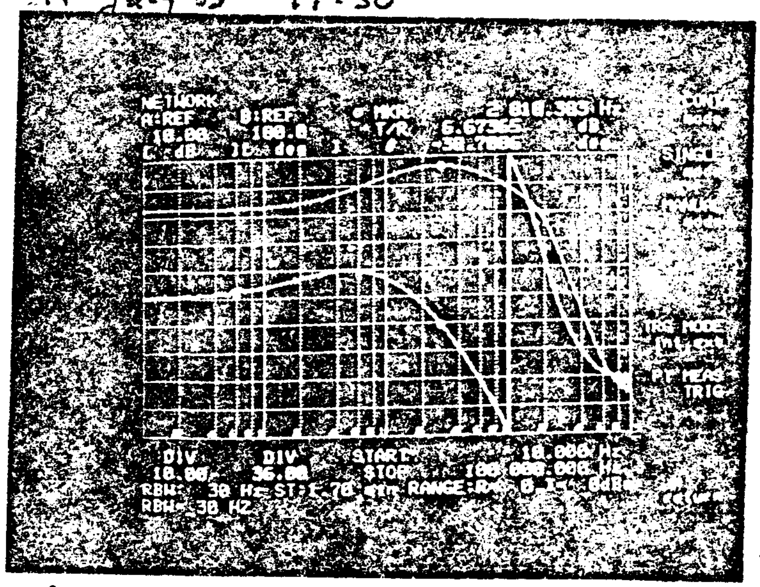
← 50 Ω term at Fast 4 ampl.

slow pockel's cell branch of 1st arm servo loop.

1st arm (phase correcting) servo; coil driver leg



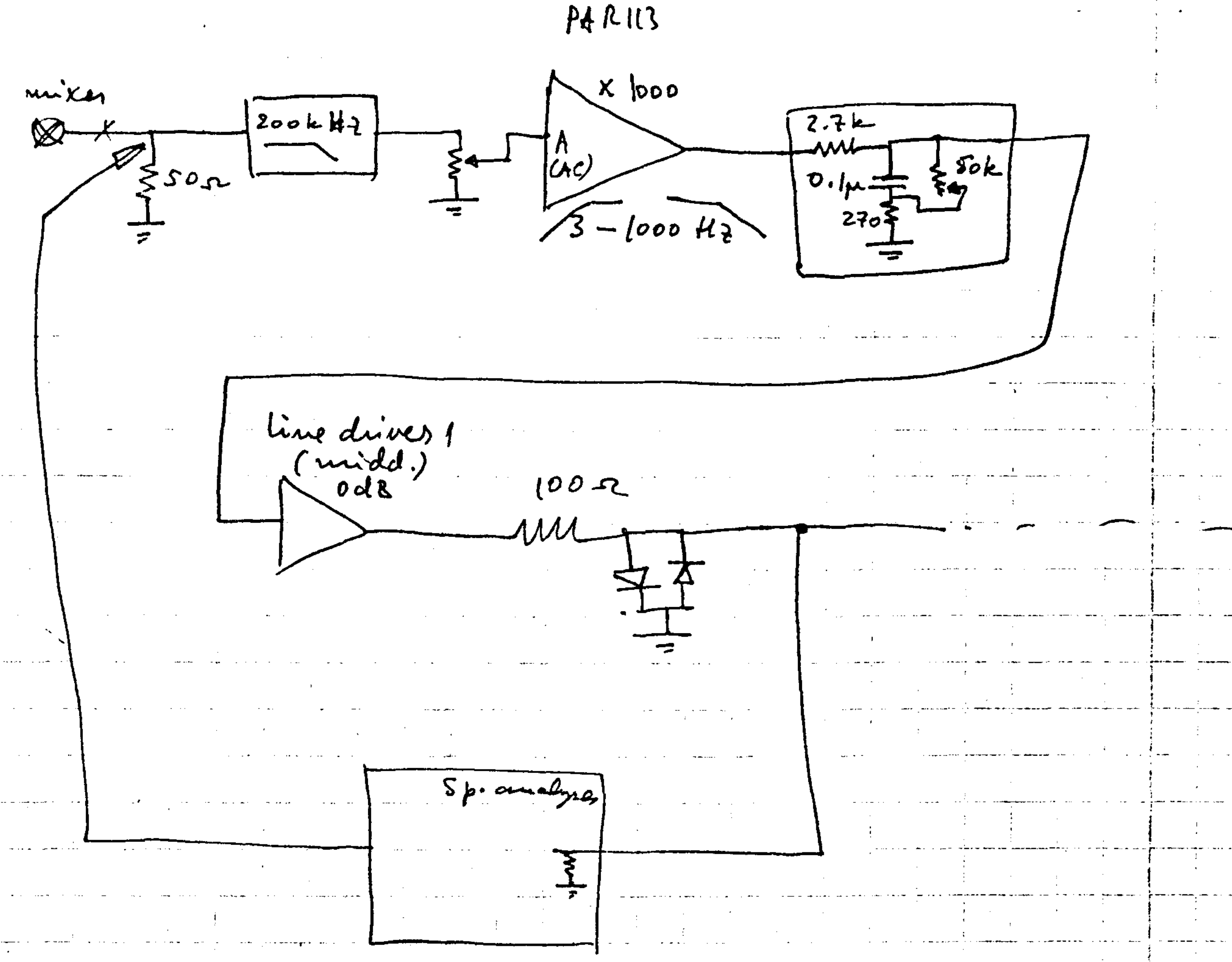
17 July 89 17:30



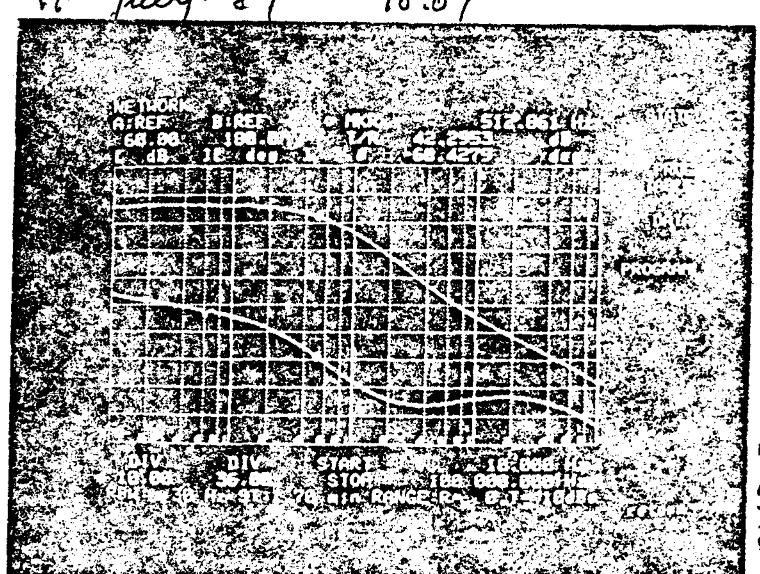
COIL105

Coil leg response, 50Ω at inp of FAST4'

1st arm locking (phase correction) servo: bypass



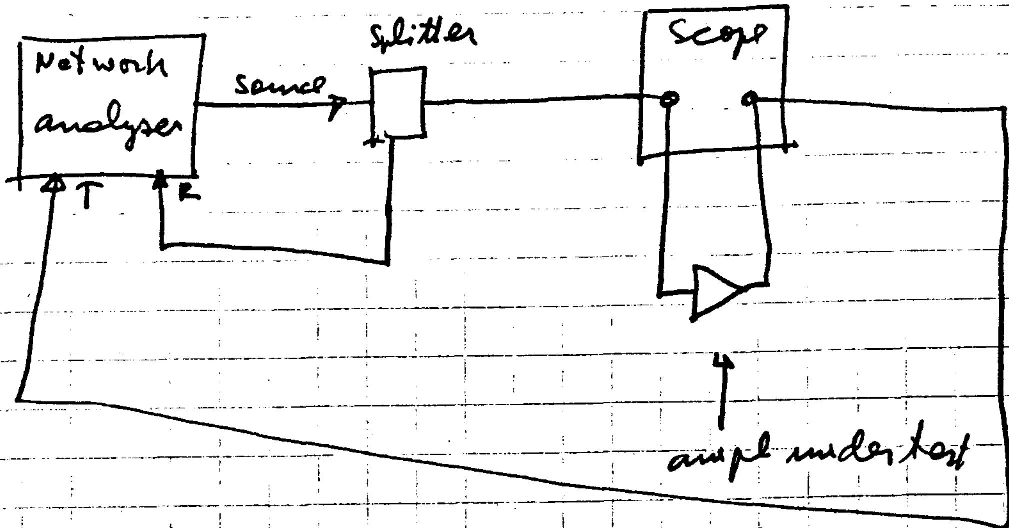
17-July-89 18:09



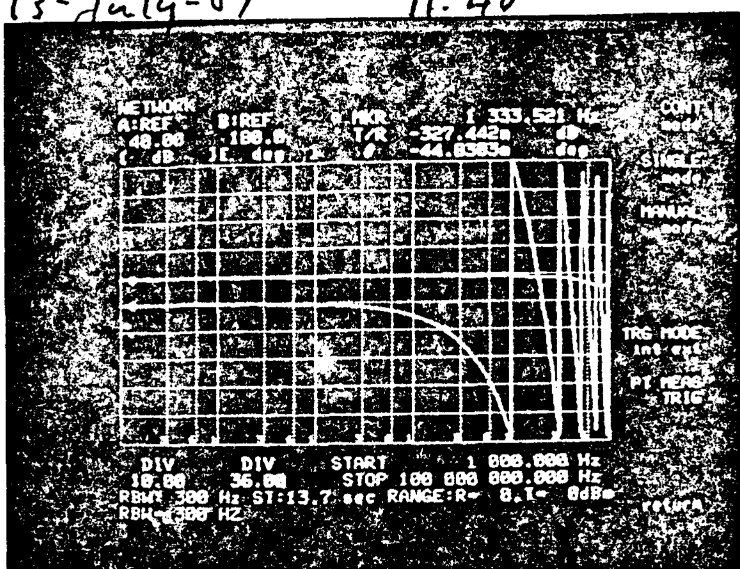
1st arm bypass response

BYP 717

Since ~30' of cables were used to connect the amplifier under test (see diagram below), we took the response of the cables themselves (trace at 11:40)



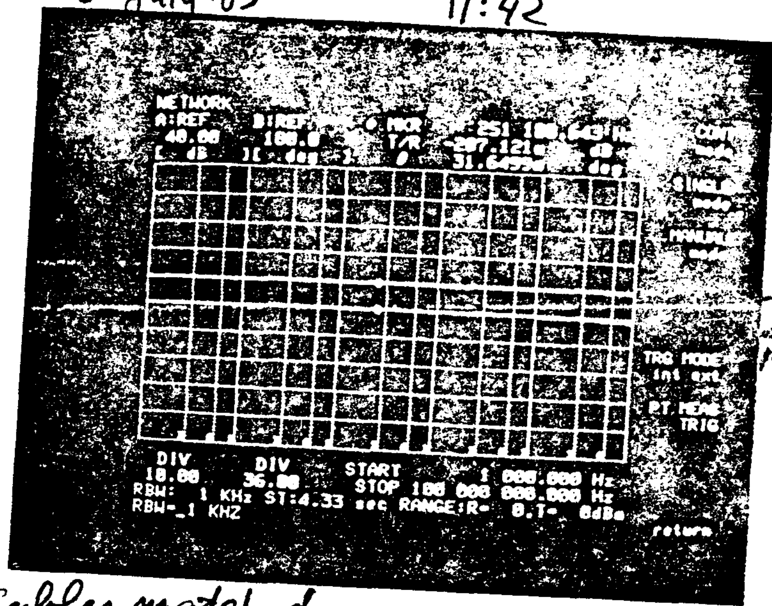
13-July-89 11:40



TR. FUNCTION OF CABLES – they are badly imbalanced

- It turns out that at 250 kHz the cables alone show a phase shift of 5°.
- Therefore, the ~3' cable from splitter to R input was replaced with a long cable, matched to the one in the test path. See traces overleaf

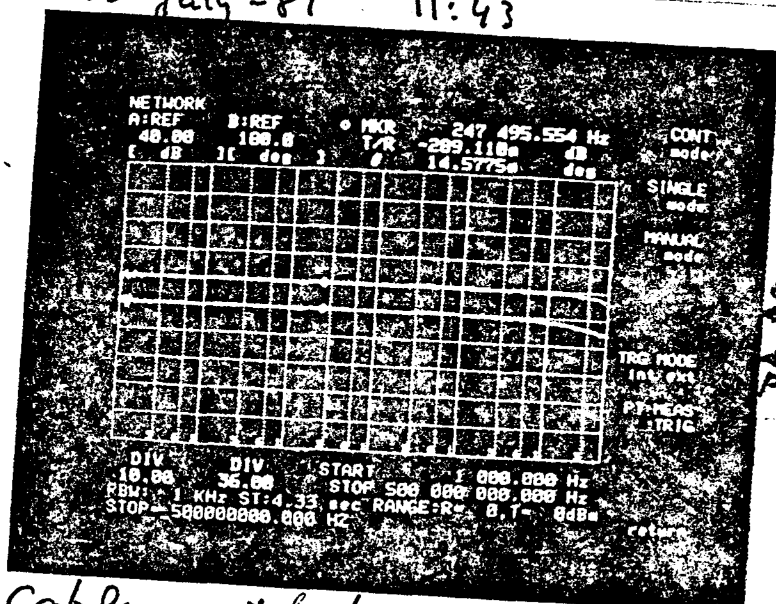
13-July-89 11:42



G
ph

Cables matched

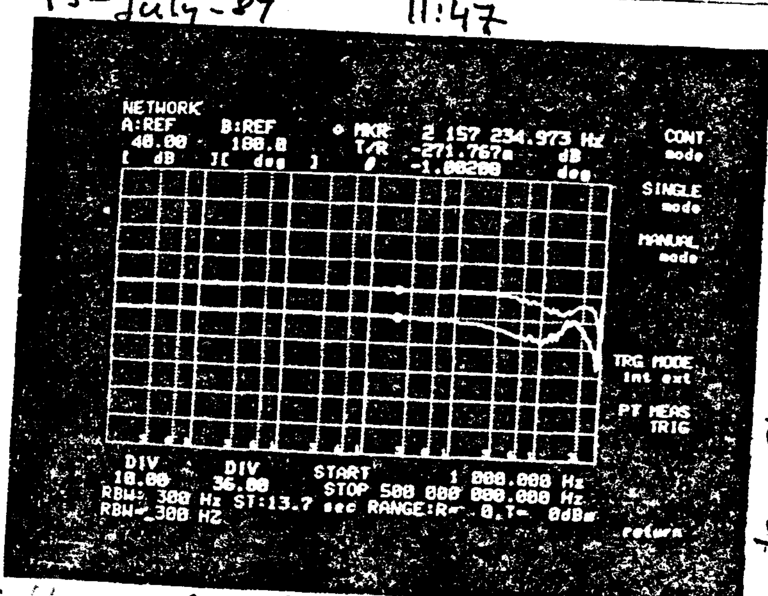
13-July-89 11:43



G
ph

Cables matched

13-July-89 11:47



to scope

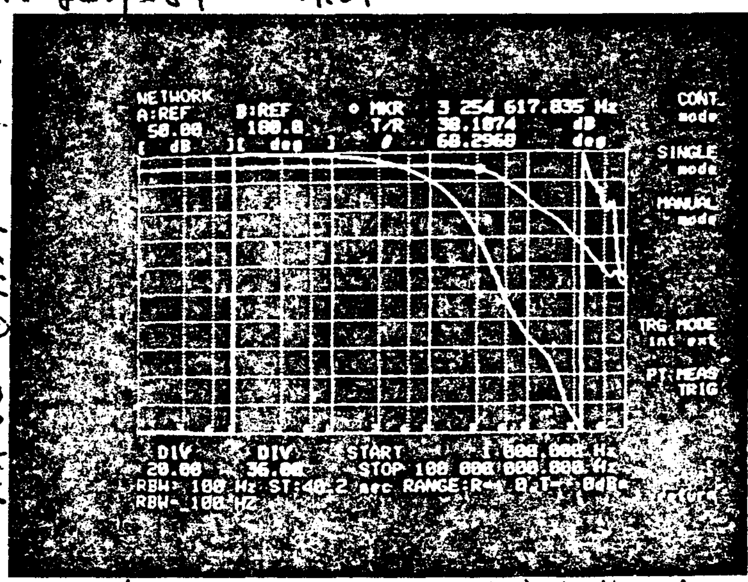
Cables matched, going through T's connected

To obtain the correct phase response of the amplifiers in the 40 m system servos. we decided to measure their response again, this time with the matched cable.

The two ~~traces~~ transfer function (opposite page) clearly illustrate the difference between using unmatched/matc cables. All the following transfer functions have been measured with match cables (see cab response on p. 70 overleaf)

13-July-89 14:09

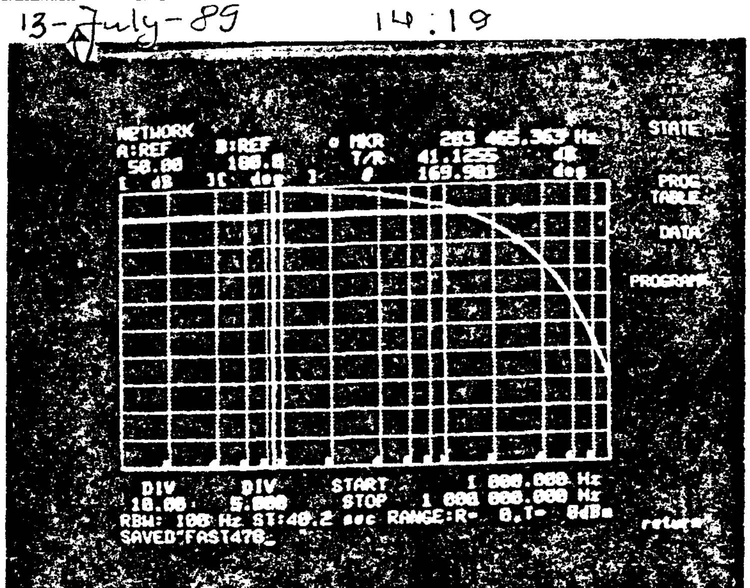
10° phase shift @ 282 kHz



FAST 477

FAST 4', 50 Ω out imp 1 (V) full gain

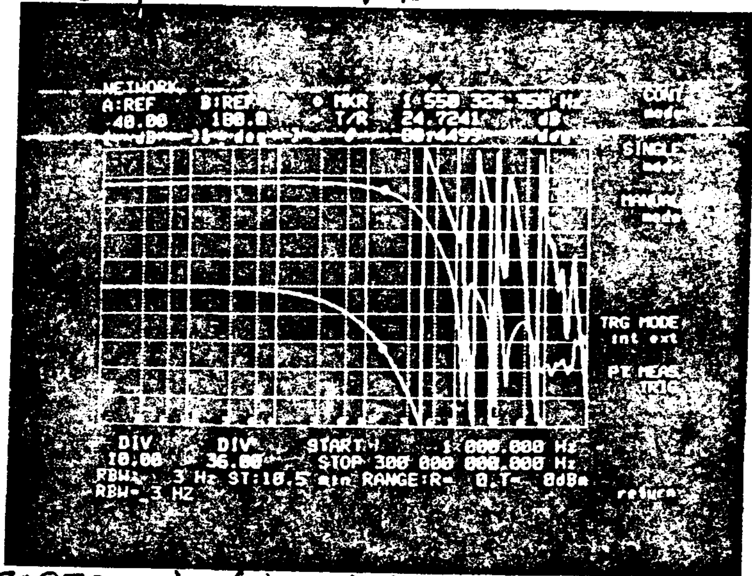
13-July-89 14:19



FAST478

FAST4' imp 1 (V)

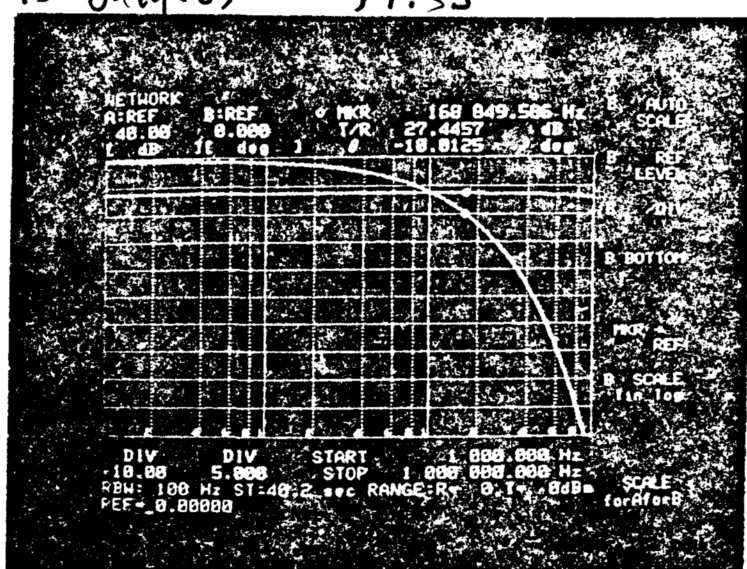
13-July-89 14:45



FAST2 inp(1)V full gain

FAST2 7101

13-July-89 14:35

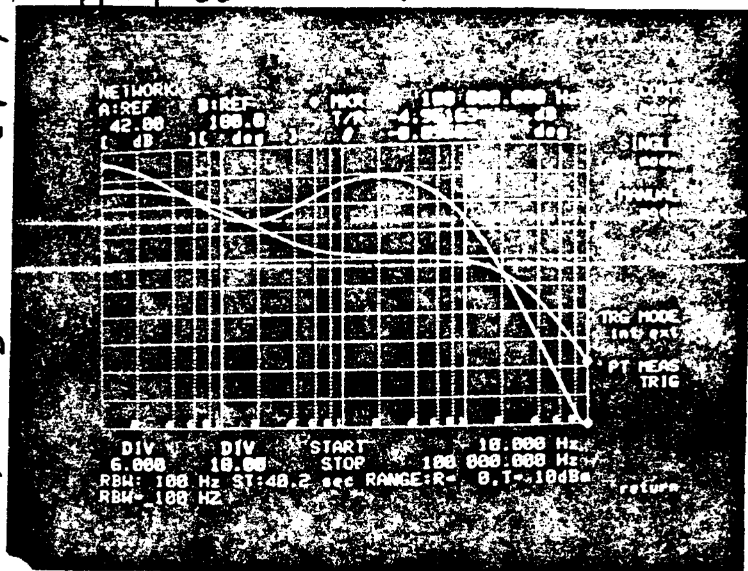


FAST2, inp1(V) full gain

FAST2 7102

13-July-89 15:30

Low Z ITHACO, 50Ω out

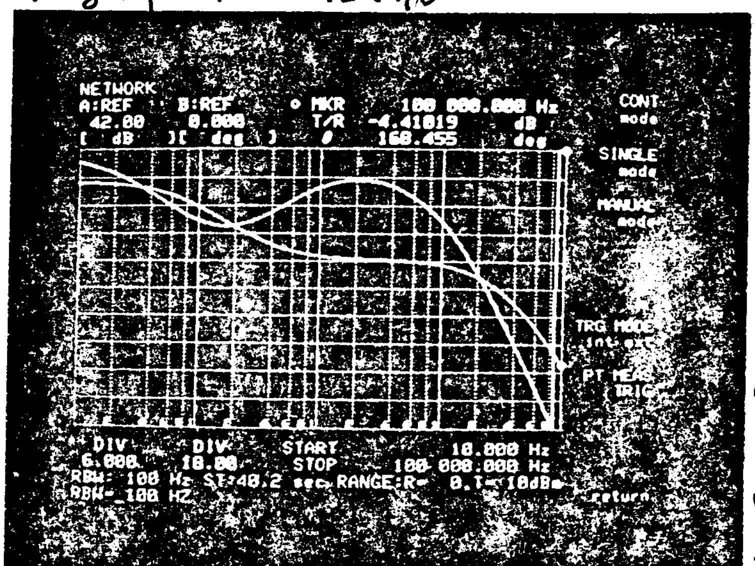


HV3710

wide open

HV3 monitor, left channel, through ITHACOx10

13-July-89 15:40

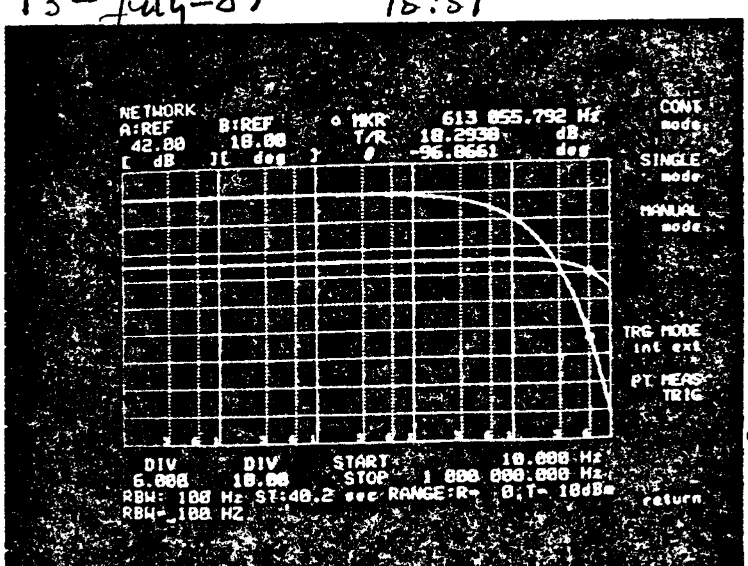


HV3710R

HV3 monitor, as 15:30, right channel

13-July-89 15:51

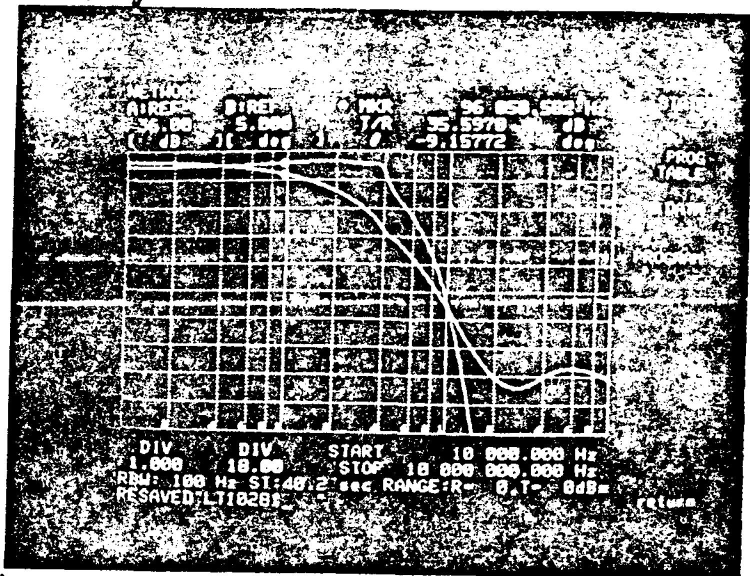
Hi Z in



ITHACO 710

ITHACO x10 Z out, wide open

14-July-89 9:40

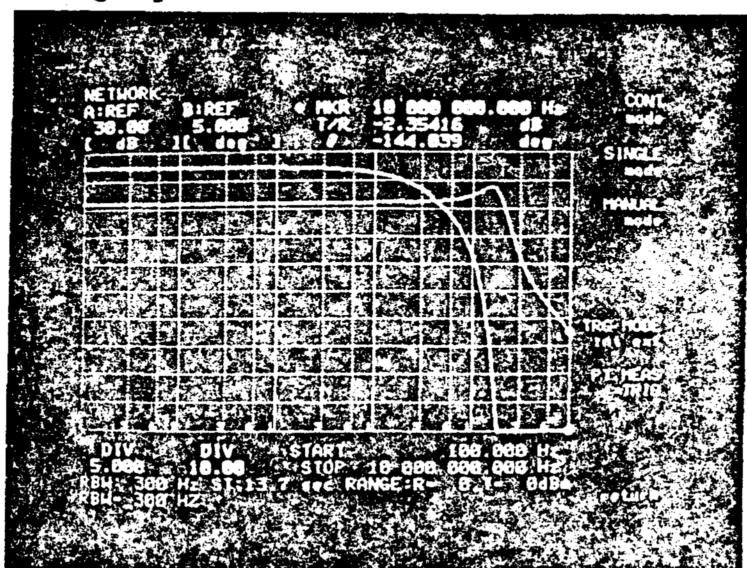


AXES: 10 MHz 36 dB

LT10281

LT 10281 High Z in, 50 out

14-July-89 10:00

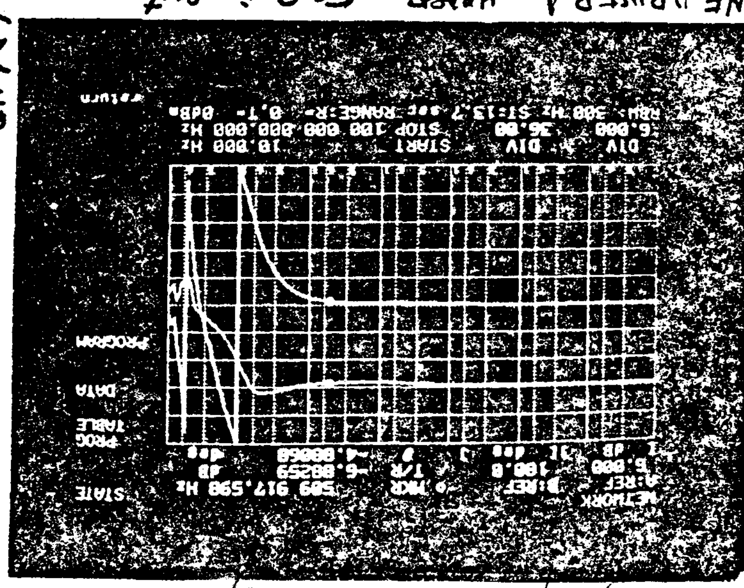


LT10282

LT1028 #2 HiZ in, 50 Ω out

LINE DRIVER 1, 'wafer', 50Ω in/out

LD1UP



GAIN = 0 dB nominal

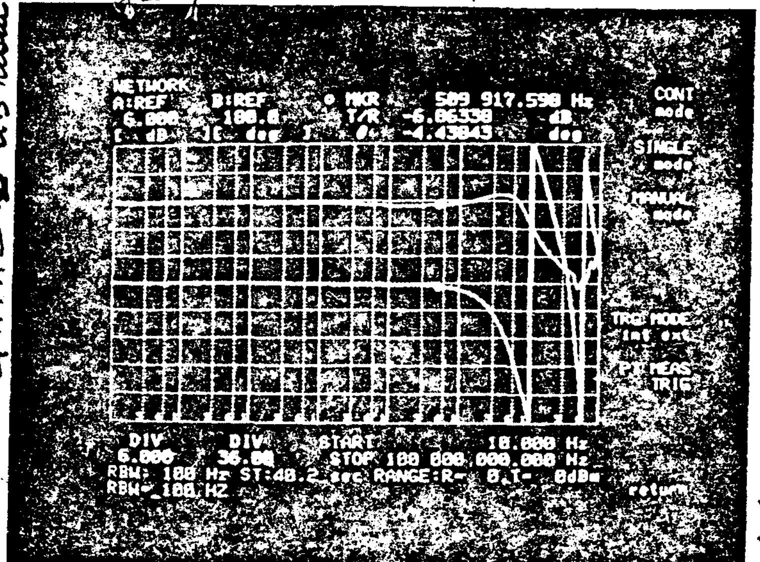
14-July-89 10:1[illegible]

14-July-89

More transfer functions taken

14-July-89 10:17

GAIN = 0 dB nominal

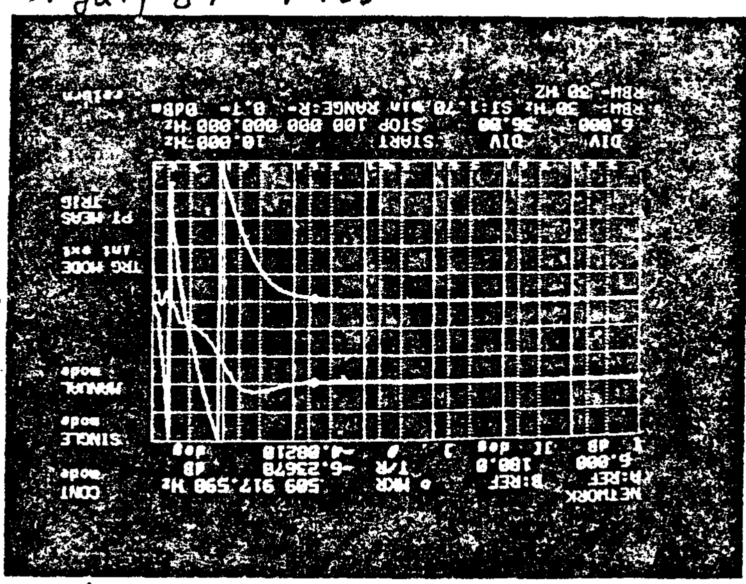


LD1 MID

LINE DRIVER 1, Middle, 50Ω in, out

14-July-89 10:25

GAIN = 0 dB nominal

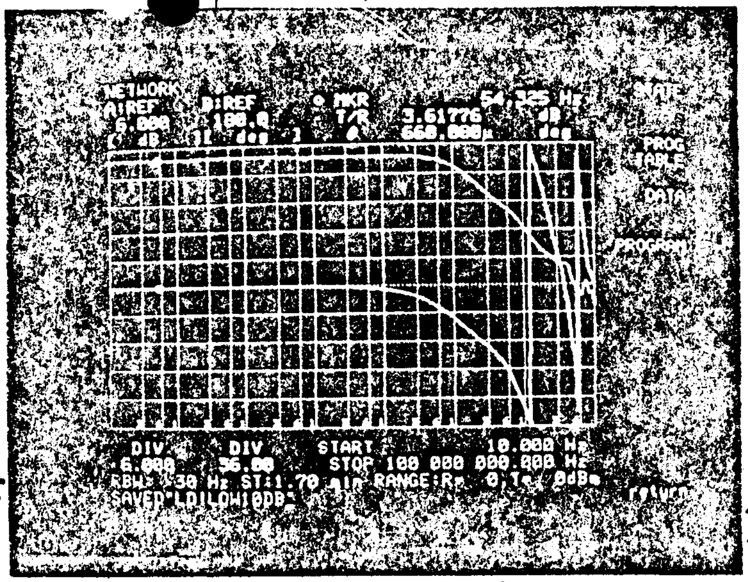


LD1 Low

Line driver 1, Lower, 50Ω in out

14-July-89 10:34

GAIN : 1x10dB nominal

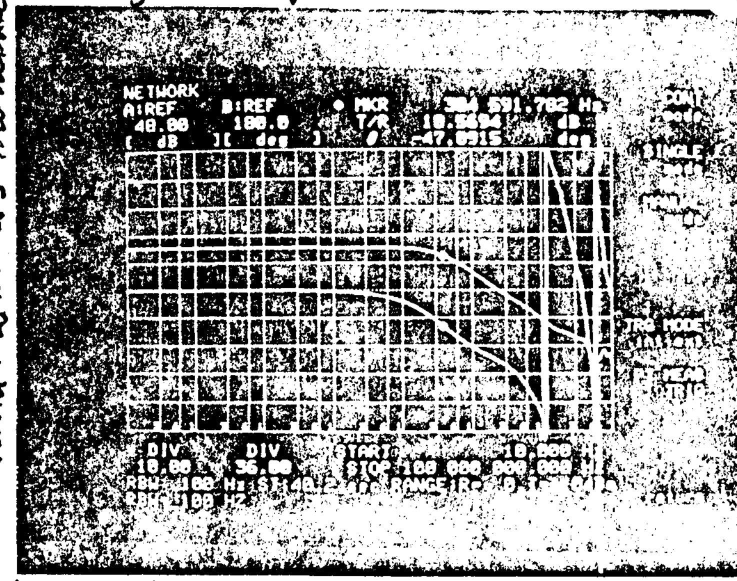


LD1LOW10dB

Line dr. 1 lower, 50Ω in out

14-July-89 10:36

Gain: 2x10dB nominal

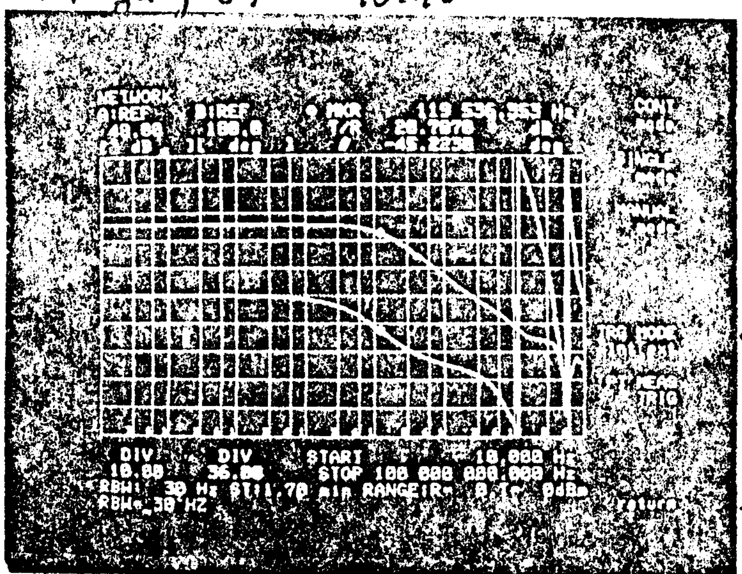


LD1LOW20dB

Line driver 1, lower, 50Ω in, out

14-July-89 10:40

GAIN: 3x10 dB nominal

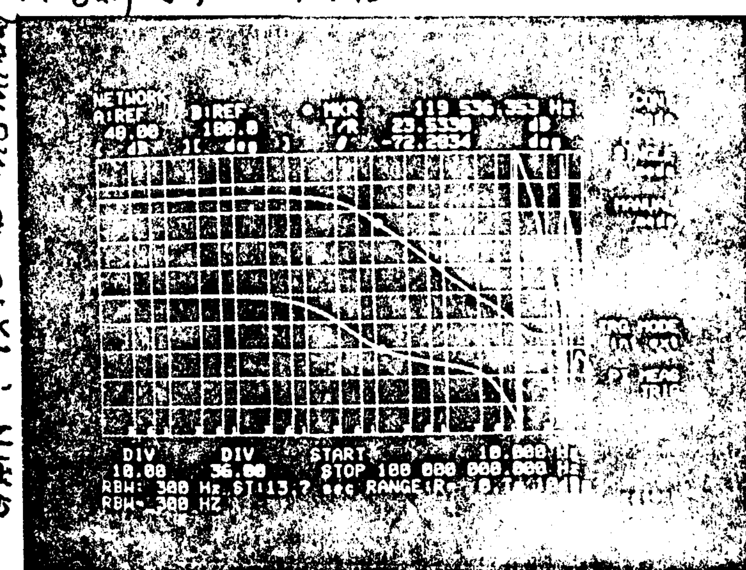


LD1LOW30dB

Line driver 1, lower, 50Ω in, out

14-July-89 10:45

GAIN : 4x10 dB nominal

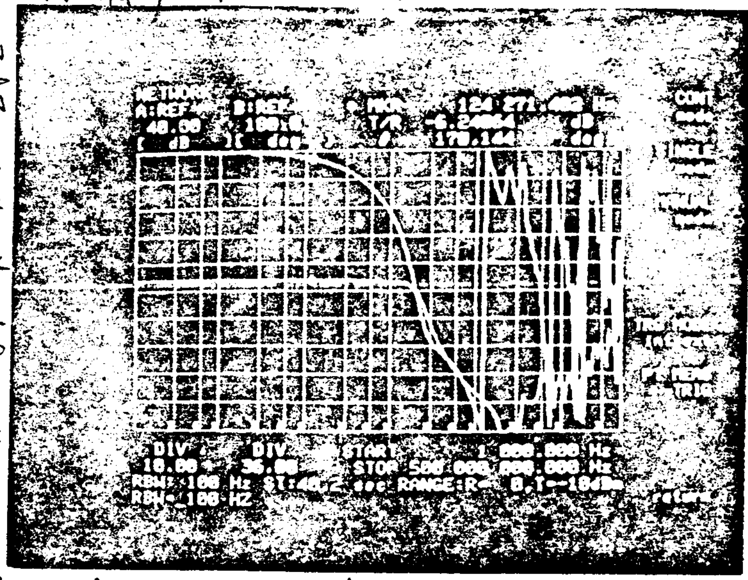


LD1LOW40dB

Line driver 1, lower, 50Ω in,

17 July 89 13:35

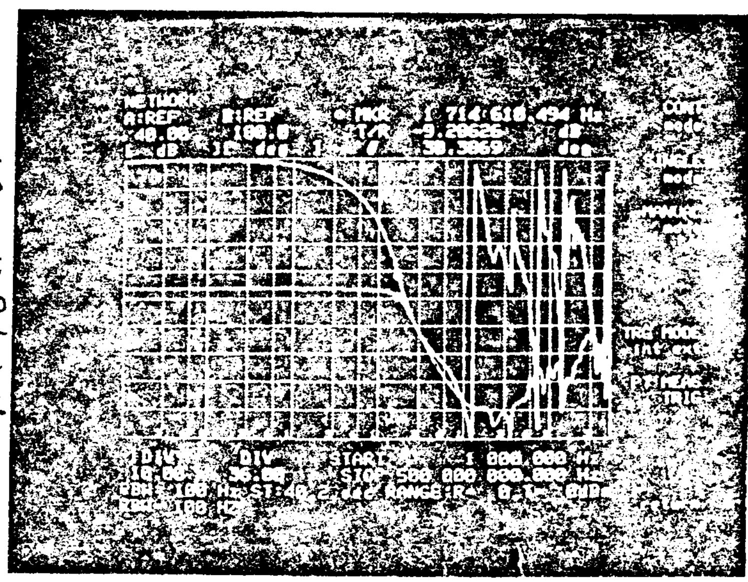
3dB point at: 1.955MHz



LDA MID ØDB

Line driver A, mid, 0dB, 50Ω out.

10° : 128.4 kHz

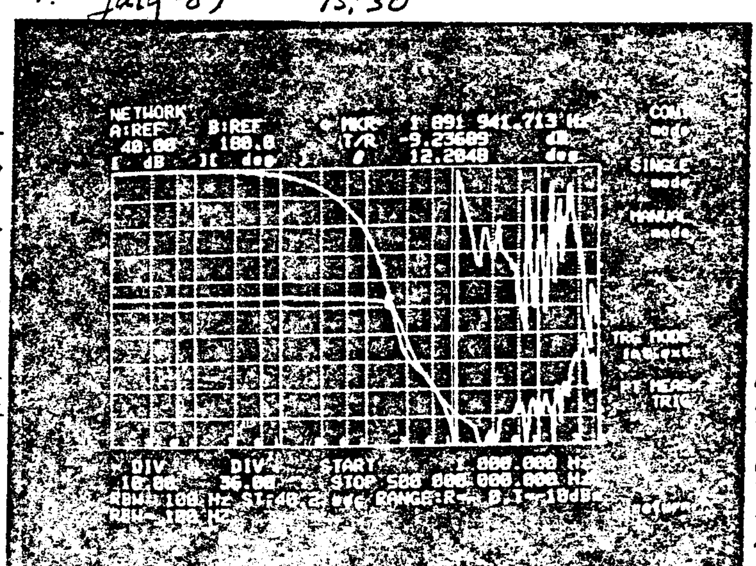


LDA LOW

Linedriver A lower, 50Ω out, 0dB

17 July-89 13:30

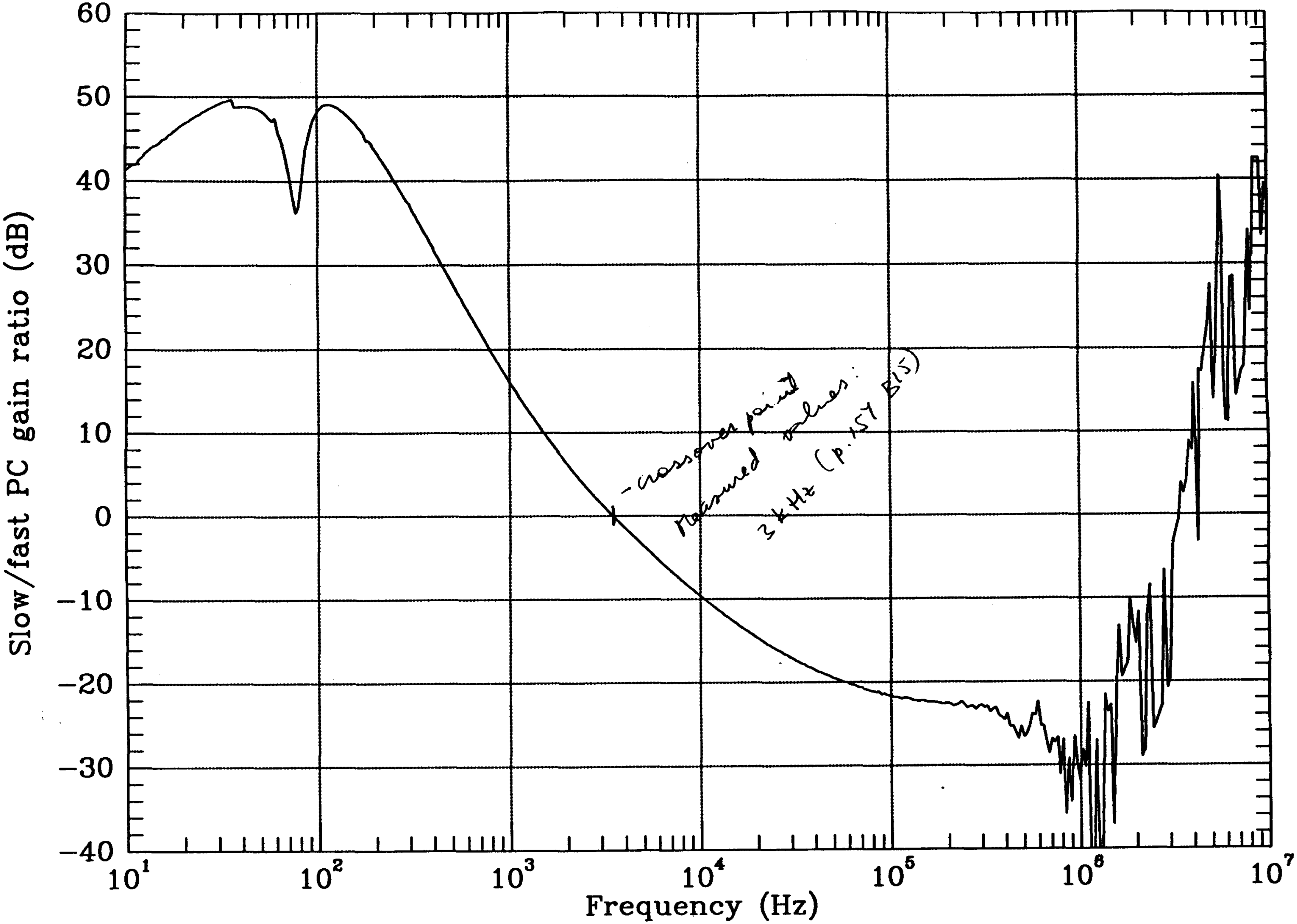
10° at: 124 kHz



LDA UP 0DB

-driver A 0 dB 50Ω out

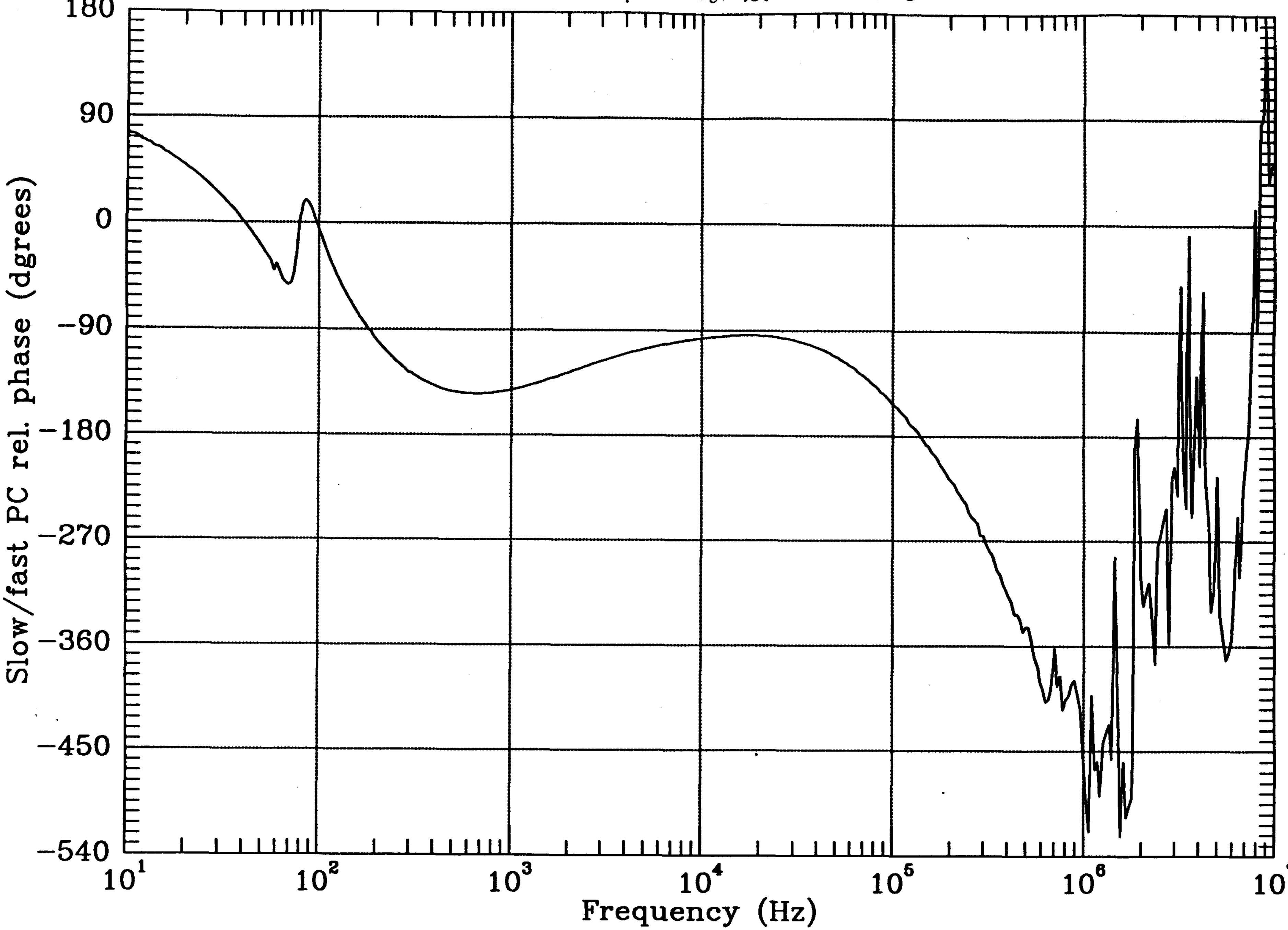
1st arm servo



21-July-89

AA, YG
measured
processed
by AA

1st arm servo

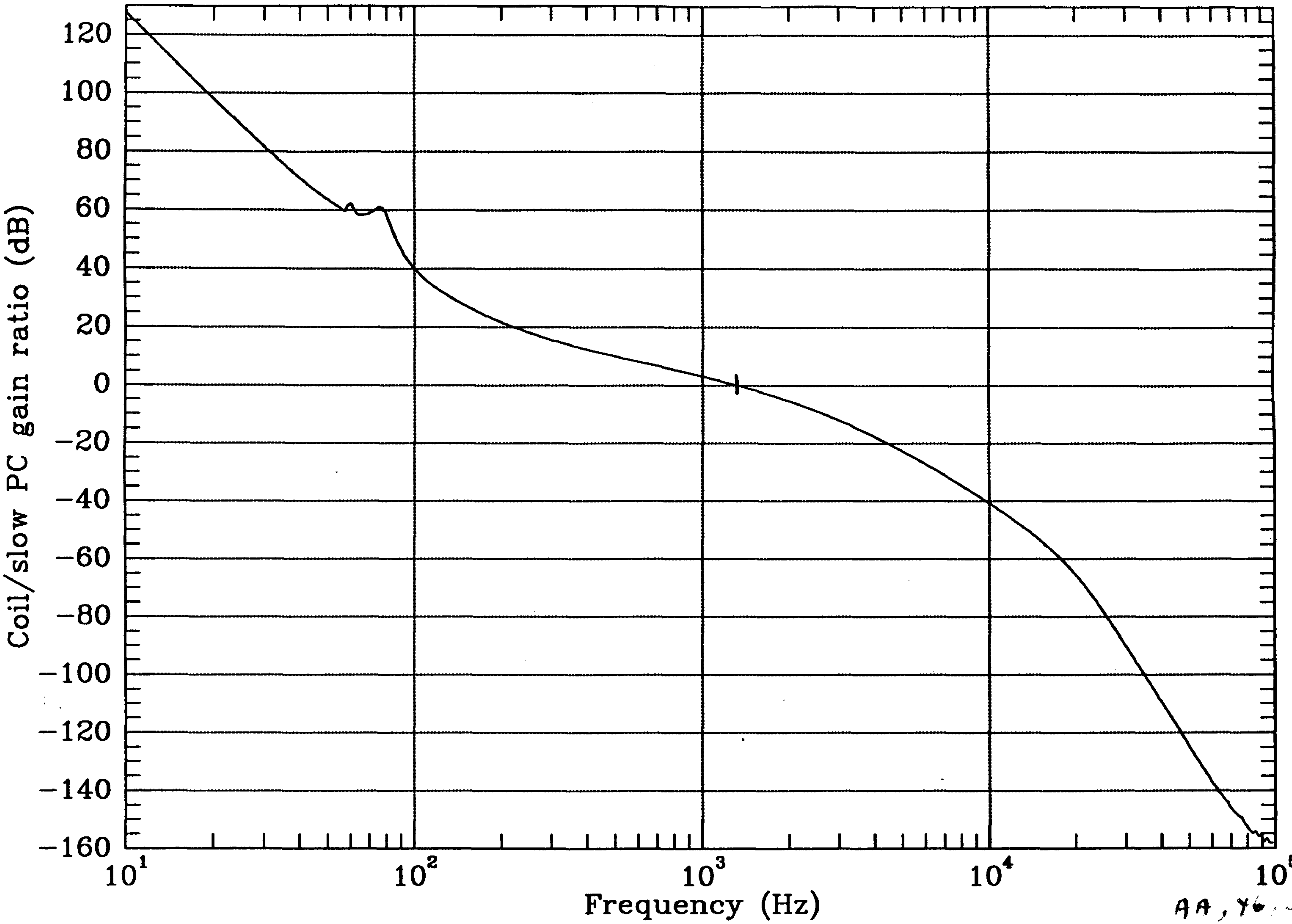


USES FILES: SLOP0721
FASTP0 1

21-July-89

4A, Y6,
measureme
processe
by 4A

1st arm servo

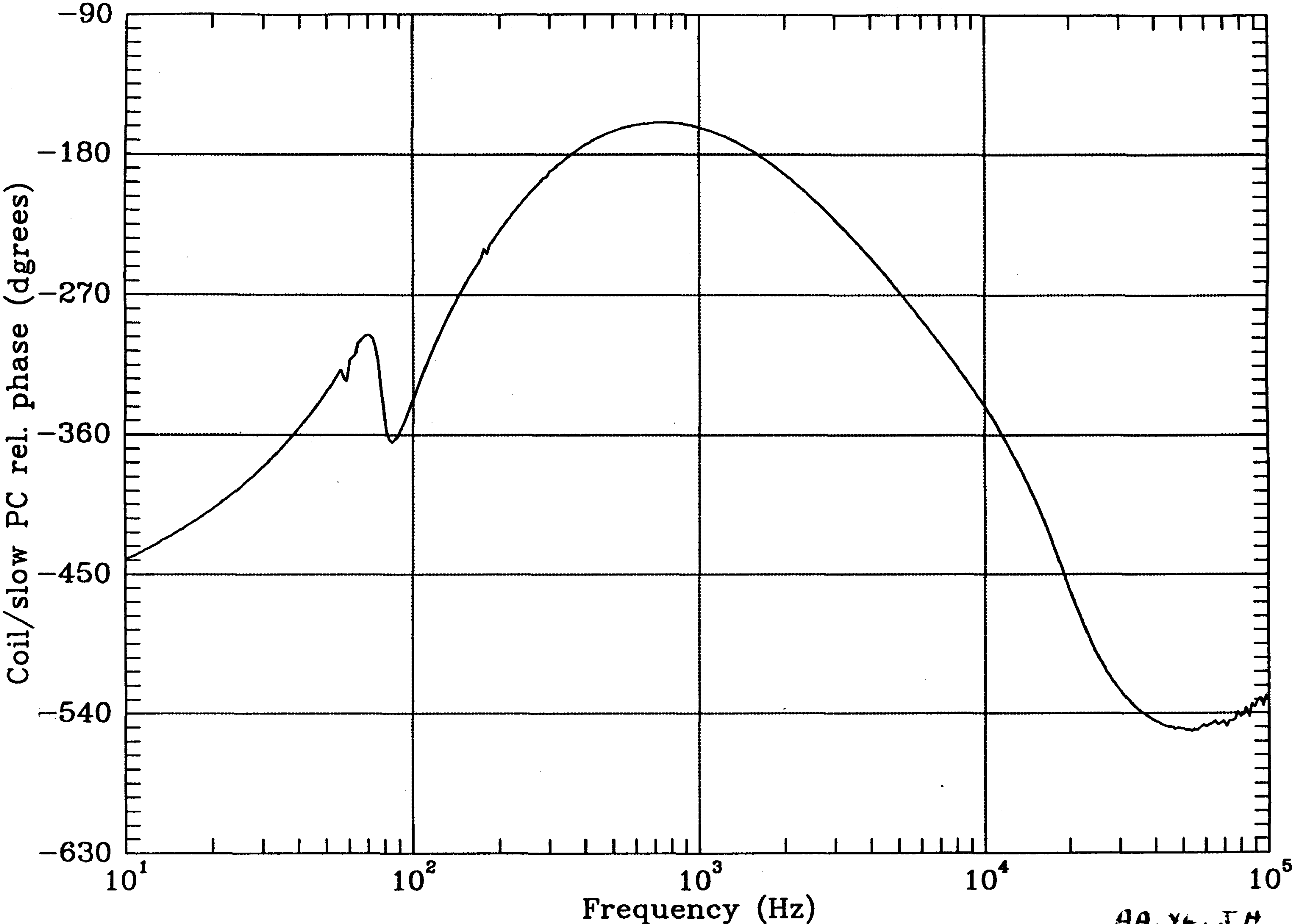


AA, YG, J
measurement
processed by A.

21-J[illegible]-89

uses coil, c.f, coilpc.pl

1st arm servo



AA, YG, JH
measurements
processed by AA

uses coil[illegible] ', coilpcpl1

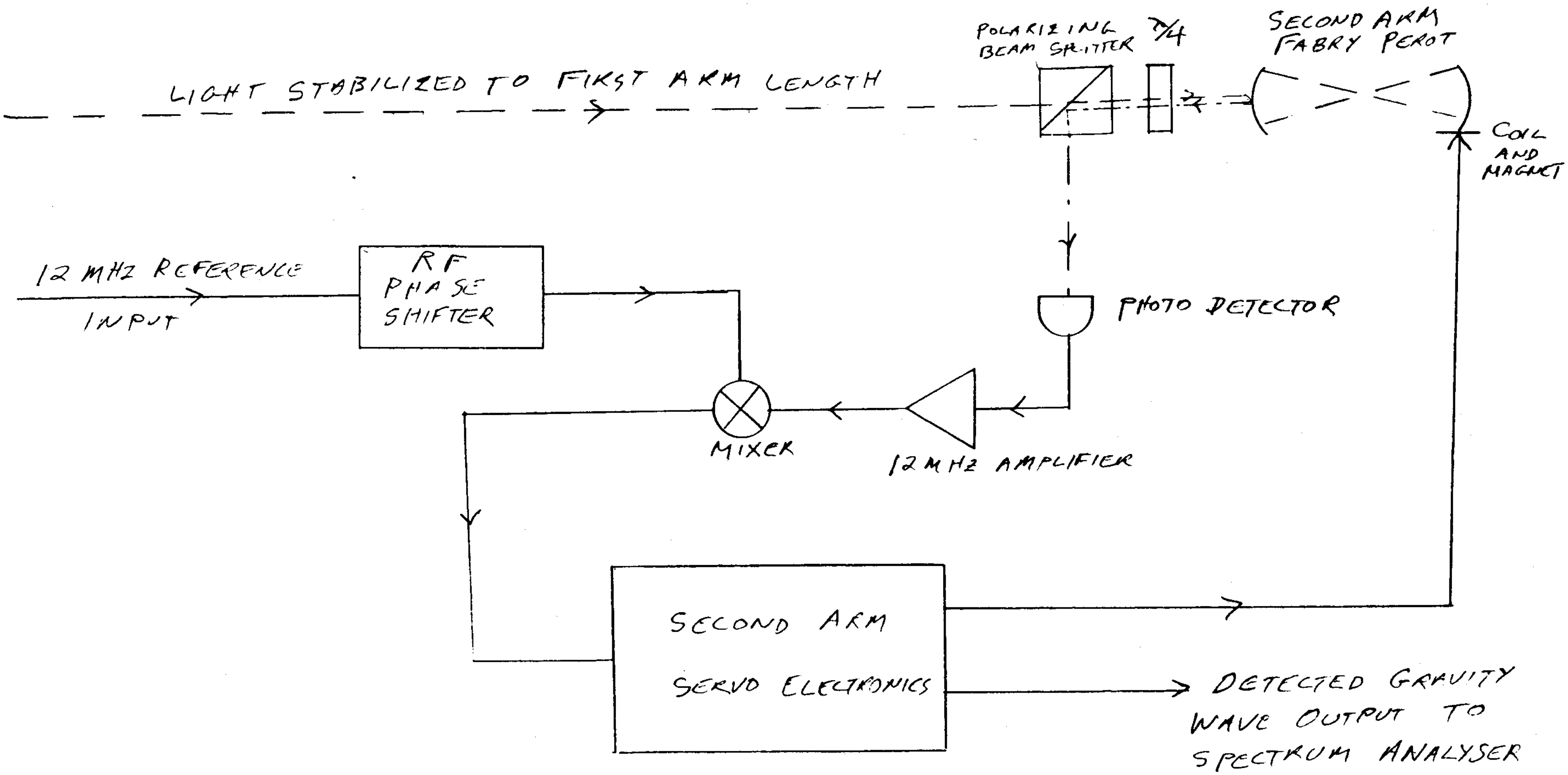
24[illegible] ly-89

BATCH
START

Second Arm

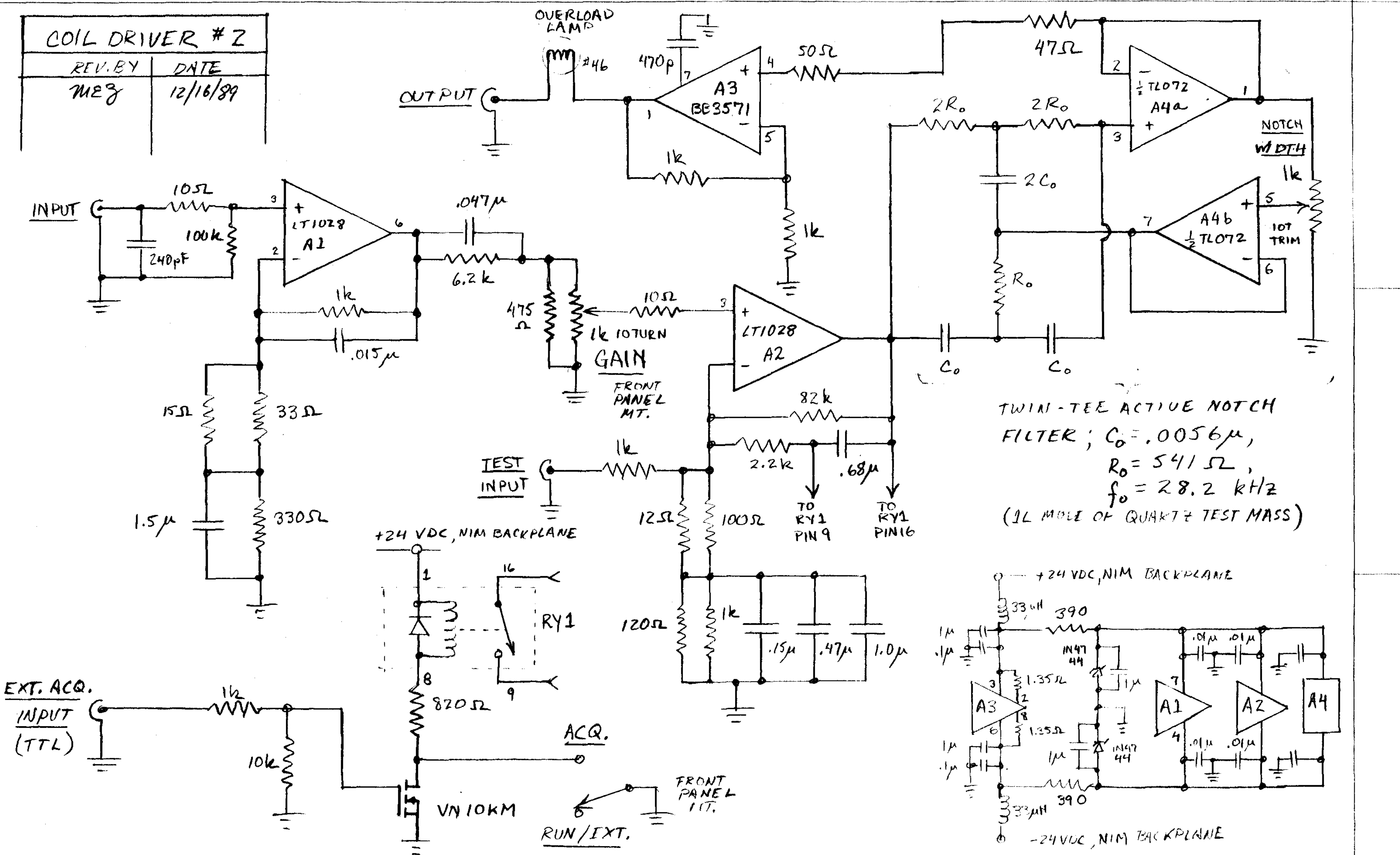
STAPLE
OR
DIVIDER

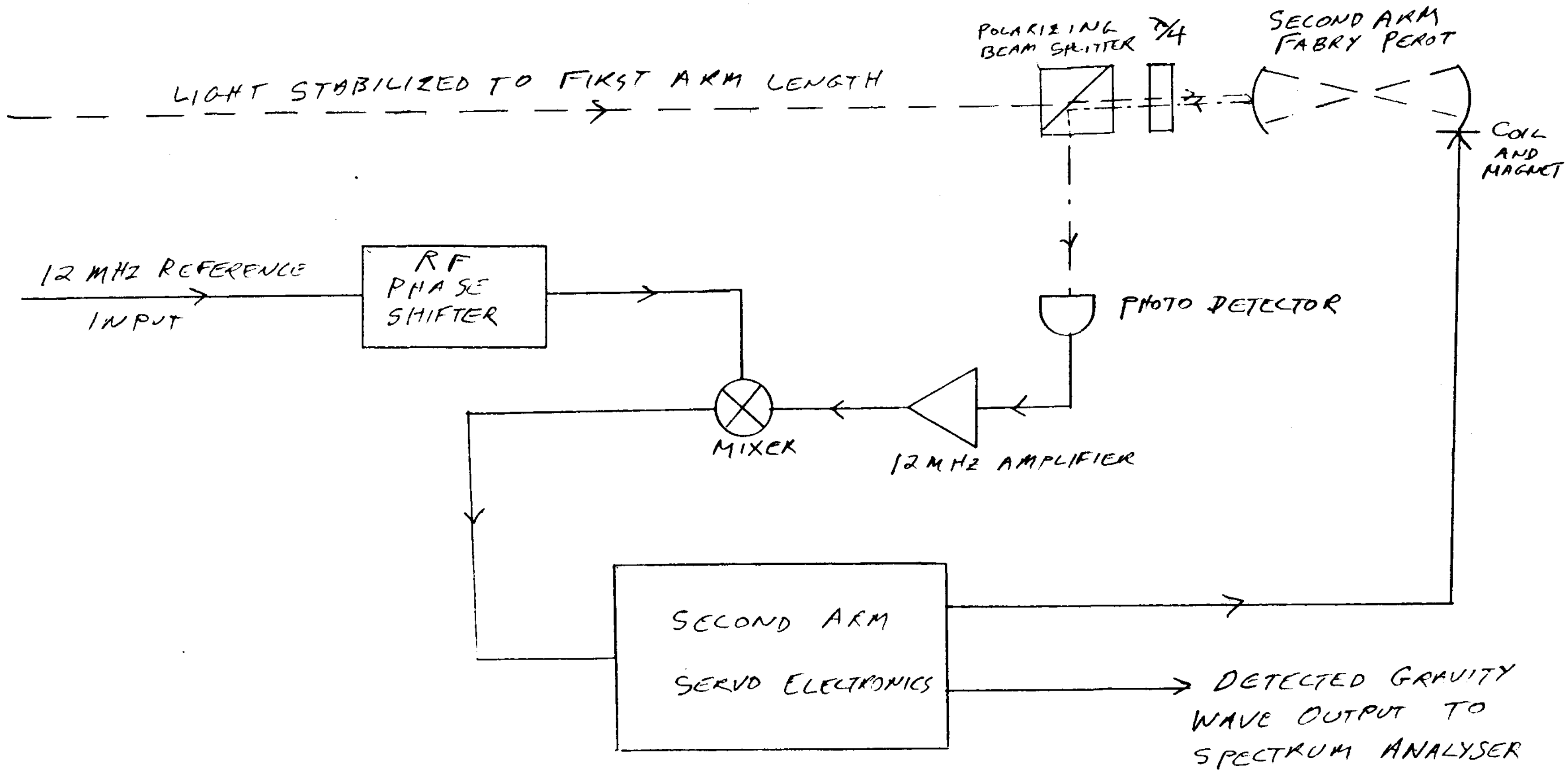
2ND ARM SERVO ADDITIONS



SECOND ARM (GRAVITY WAVE DETECTING) SERVO

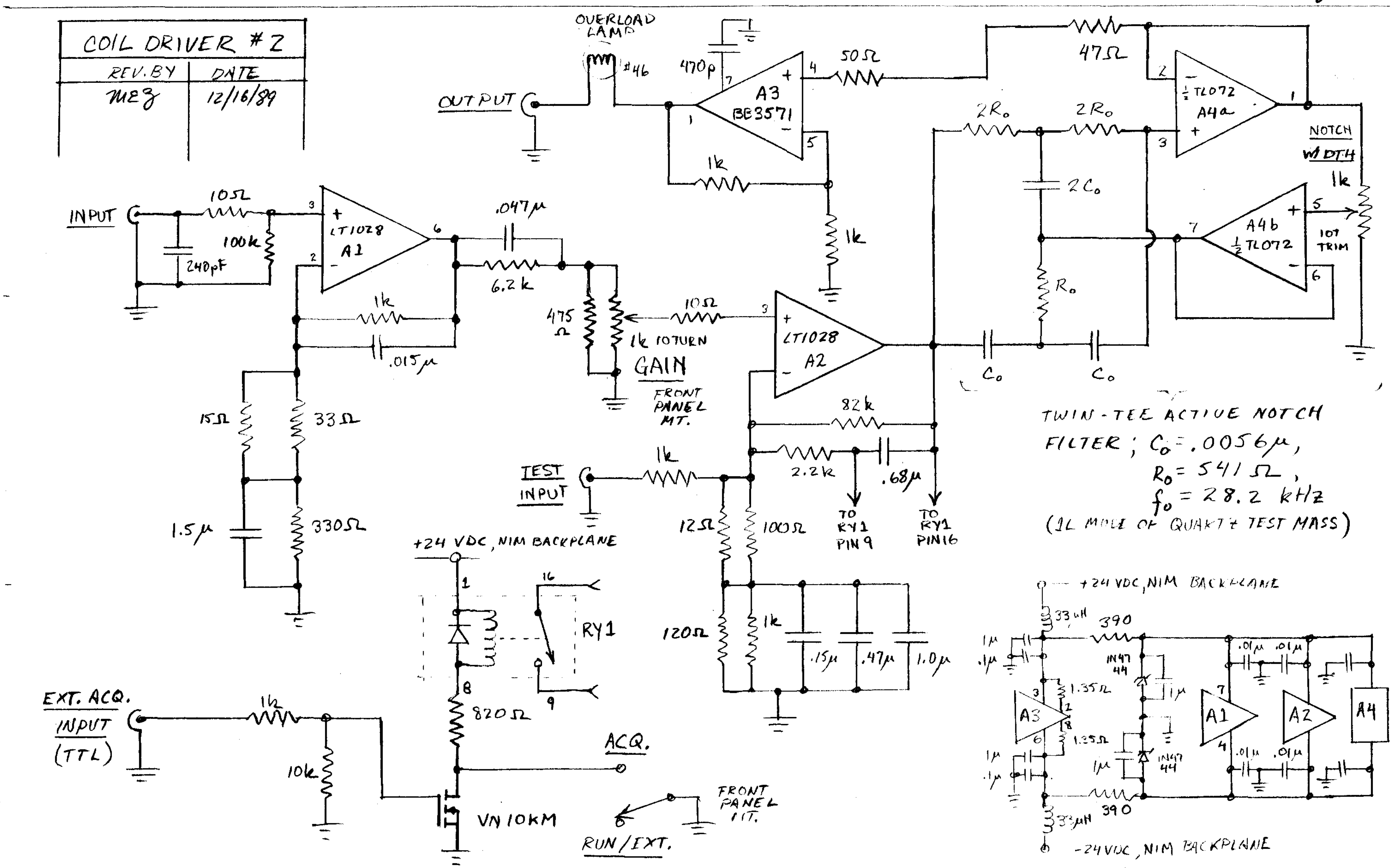
12/16/89 MEZ


COIL DRIVER # 2
REV. BY
DATE
MEZ
12/16/89
OVERLOAD LAMP
#46
470p
A3
BE3571
50Ω
47Ω
OUTPUT
1k
2R₀
2R₀
½ TL072
A4a
NOTCH WIDTH
1k
10T TRIM
2C₀
A4b
½ TL072
R₀
INPUT
10Ω
100k
240pF
LT1028
A1
.047μ
6.2k
1k
.015μ
475 Ω
1k 10TURN
GAIN
FRONT PANEL MT.
10Ω
LT1028
A2
C₀
C₀
82k
2.2k
.68μ
TO RY1 PIN 9
TO RY1 PIN16
TWIN-TEE ACTIVE NOTCH FILTER; C₀ = .0056μ, R₀ = 541 Ω, f₀ = 28.2 kHz
(1L MOLE OF QUARTZ TEST MASS)
15Ω
33Ω
1.5μ
330Ω
TEST INPUT
1k
12Ω
100Ω
120Ω
1k
.15μ
.47μ
1.0μ
+24 VDC, NIM BACKPLANE
RY1
820Ω
EXT. ACQ. INPUT (TTL)
1k
10k
VN10KM
ACQ.
RUN/EXT.
FRONT PANEL MT.
+24 VDC, NIM BACKPLANE
33μH
390
1N4744
1.35Ω
A3
A1
A2
A4
390
33μH
-24 VDC, NIM BACKPLANE



SECOND ARM (GRAVITY WAVE DETECTING) SERVO

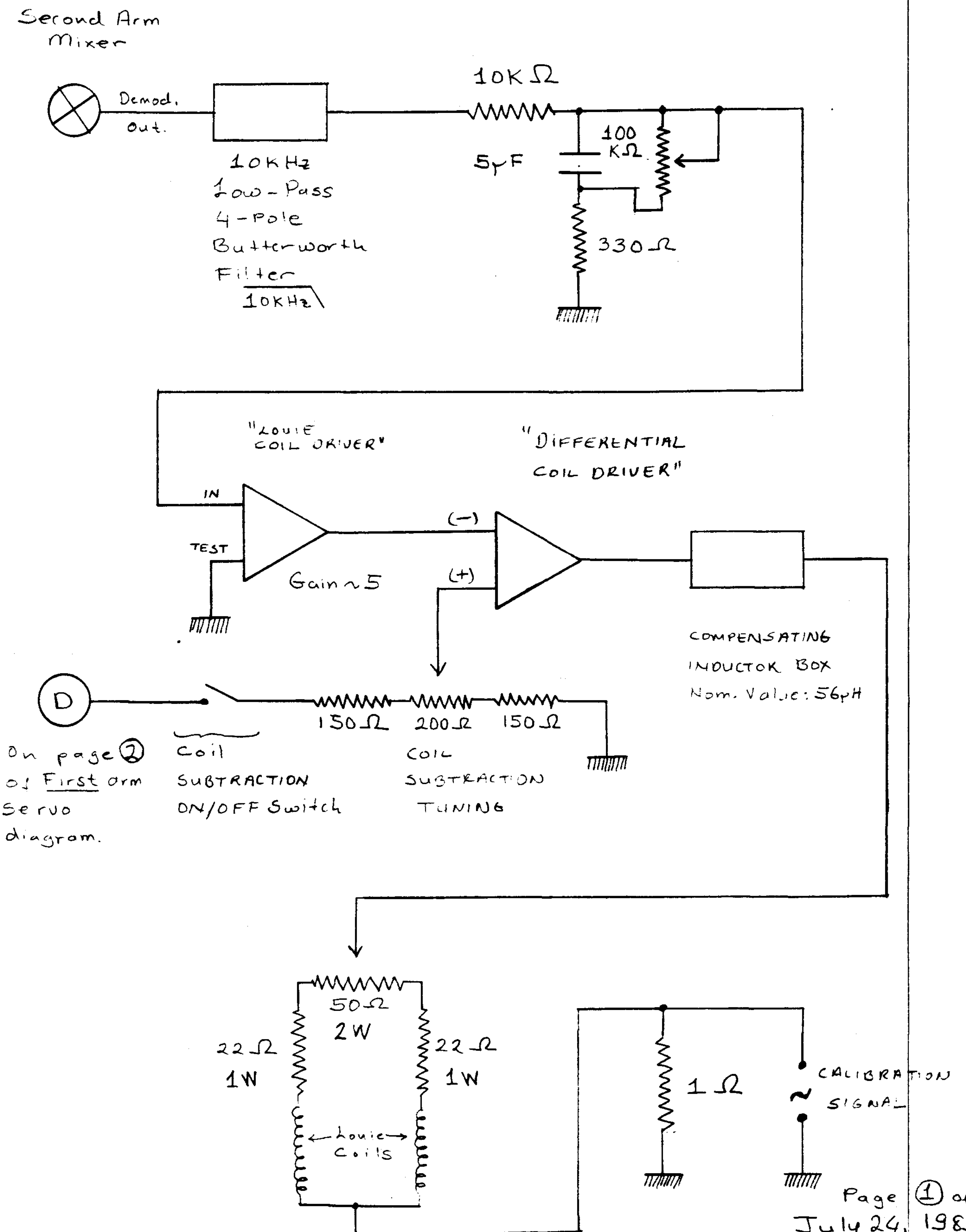
12/16/89 MEZ



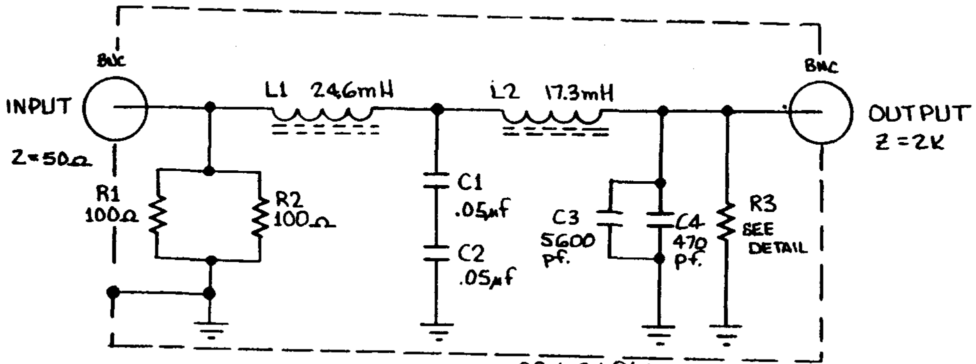
COIL DRIVER #2
REV. BY
DATE
MEZ
12/16/89
INPUT
10Ω
100k
240pF
LT1028
A1
.047μ
6.2k
1k
.015μ
15Ω
33Ω
1.5μ
330Ω
475 Ω
1k 10TURN
GAIN
FRONT PANEL MT.
OVERLOAD LAMP
#46
OUTPUT
470p
A3
BE3571
1k
1k
50Ω
47Ω
½ TL072
A4a
2R₀
2R₀
2C₀
R₀
C₀
C₀
A4b
½ TL072
NOTCH WIDTH
1k
10T TRIM
10Ω
LT1028
A2
82k
2.2k
.68μ
TO RY1 PIN 9
TO RY1 PIN16
TEST INPUT
1k
12Ω
100Ω
120Ω
1k
.15μ
.47μ
1.0μ
TWIN-TEE ACTIVE NOTCH FILTER; C₀ = .0056μ, R₀ = 541 Ω, f₀ = 28.2 kHz
(1L MODE OF QUARTZ TEST MASS)
+24 VDC, NIM BACKPLANE
RY1
820Ω
ACQ.
EXT. ACQ. INPUT (TTL)
1k
10k
VN10KM
FRONT PANEL MT.
RUN/EXT.
+24 VDC, NIM BACKPLANE
33μH
390
1μ
.1μ
1.35Ω
1N4744
A3
A1
A2
A4
.01μ
33μH
390
-24VDC, NIM BACKPLANE

OBSOLETE

Second Arm Servo Loop
Block Diagram:



July 24, 1989 YL

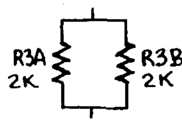


C3+C4 ≅ 6070pf
C1 AND C2 = .025μf.

L1— WIND 248t. ON BOBBIN. USE CORE G-42213-40 AND MTG. CLIP. 24.6mH.
L2— WIND 208t. ON BOBBIN. SAME CORE AS L1. 17.3mH.
(WIRE IS #32 INSULATED COPPER)

NOTE: ALL CAPS. ARE MYLAR OR MICA.

R3 DETAIL



1. FOR 1K OUTPUT Z 2K RES IN PARALLEL
2. CUT ONE RESISTOR FOR 2K OUTPUT Z.

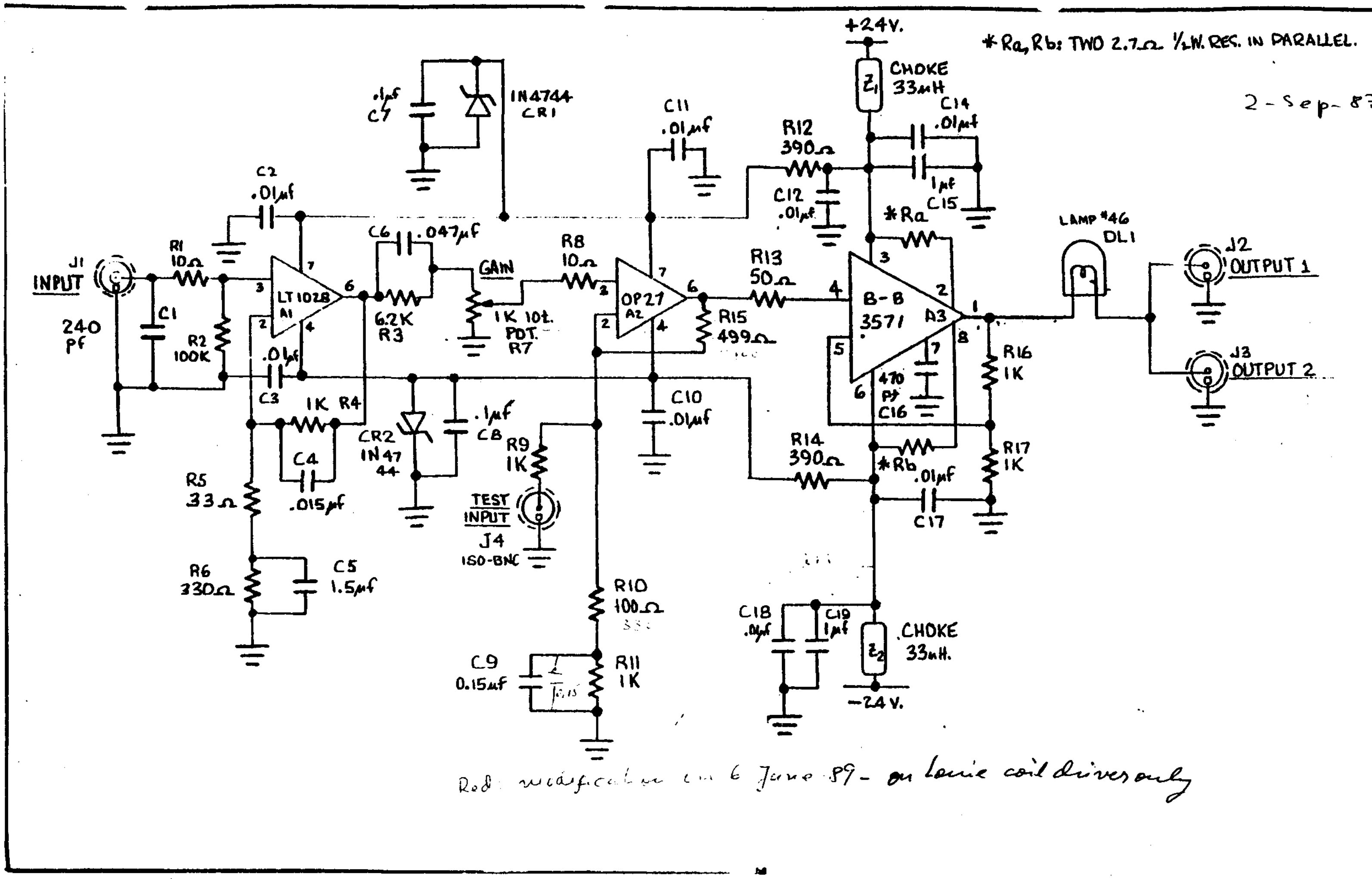
Cut-off = 10 KHz at 3db POINT

Obsolete

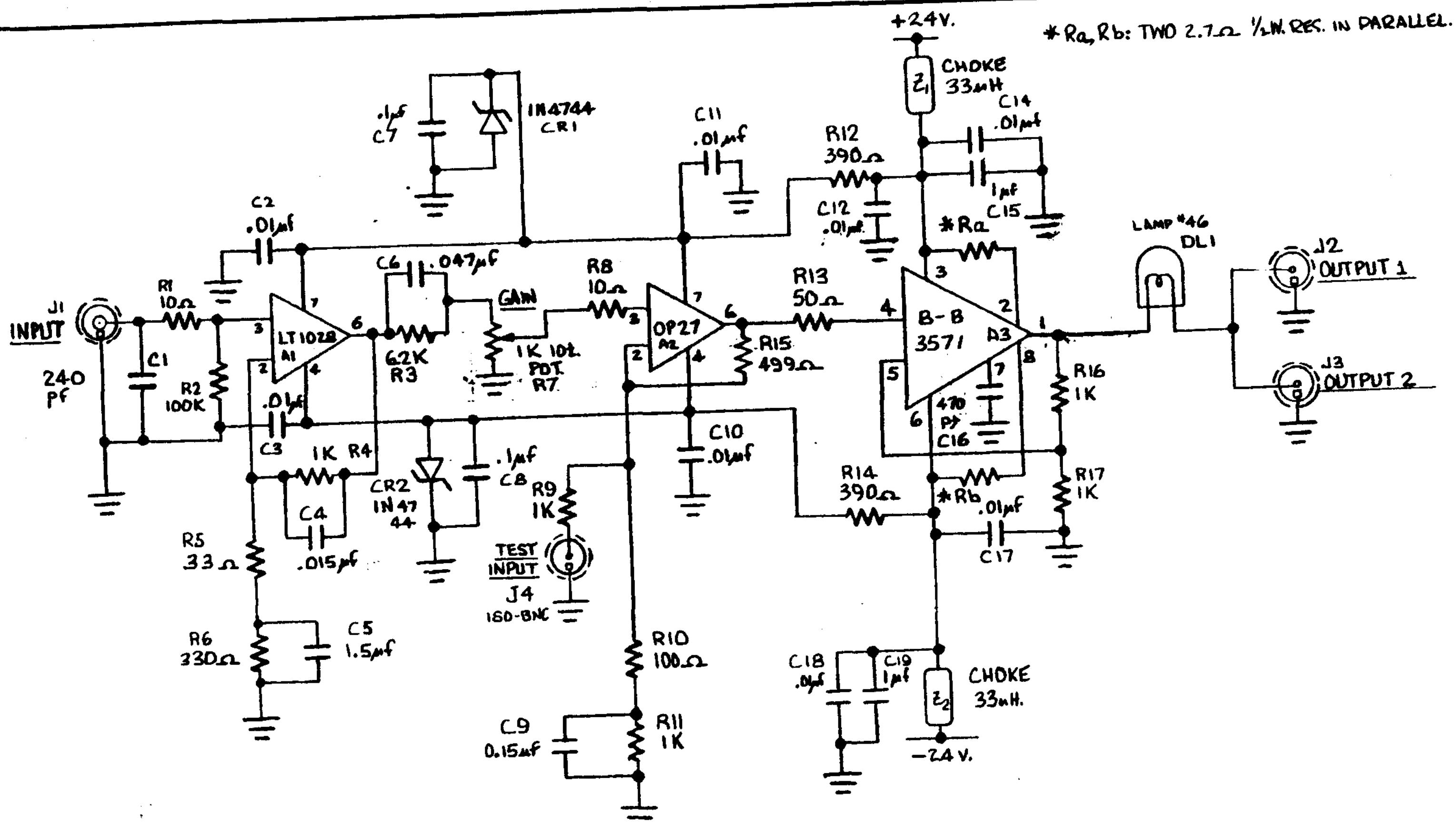
2-29-88 ADD R3 DETAIL

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
FOUR-POLE BUTTERWORTH FILTER		
DRAWN BY B. Tinker	DATE 08-11-87	DRAWING NO. -1
CHECKED BY	SCALE	
APPROVED BY	W.O.	

87-0811-1



*Ra, Rb: TWO 2.7Ω ½W. RES. IN PARALLEL.
2-Sep-87
+24V.
CHOKE 33mH
Z1
C14 .01µf
C15 1µf
R12 390Ω
C12 .01µf
C11 .01µf
.1µf C7
1N4744 CR1
C2 .01µf
C6 .047µf
GAIN
R8 10Ω
*Ra
LAMP #46 DL1
J2 OUTPUT 1
J3 OUTPUT 2
J1 INPUT
240 pf
R1 10Ω
C1
R2 100K
LT1028 A1
6.2K R3
1K 10t. POT. R7
OP27 A2
R13 50Ω
R15 499Ω
B-B 3571 A3
470 pf C16
R16 1K
R17 1K
C3 .01µf
1K R4
C4 .015µf
CR2 1N4744
.1µf C8
R9 1K
TEST INPUT J4
150-BNC
C10 .01µf
R14 390Ω
*Rb
.01µf C17
R5 33Ω
R6 330Ω
C5 1.5µf
R10 100Ω
C9 0.15µf
R11 1K
C18 .01µf
C19 1µf
CHOKE 33mH.
Z2
-24V.



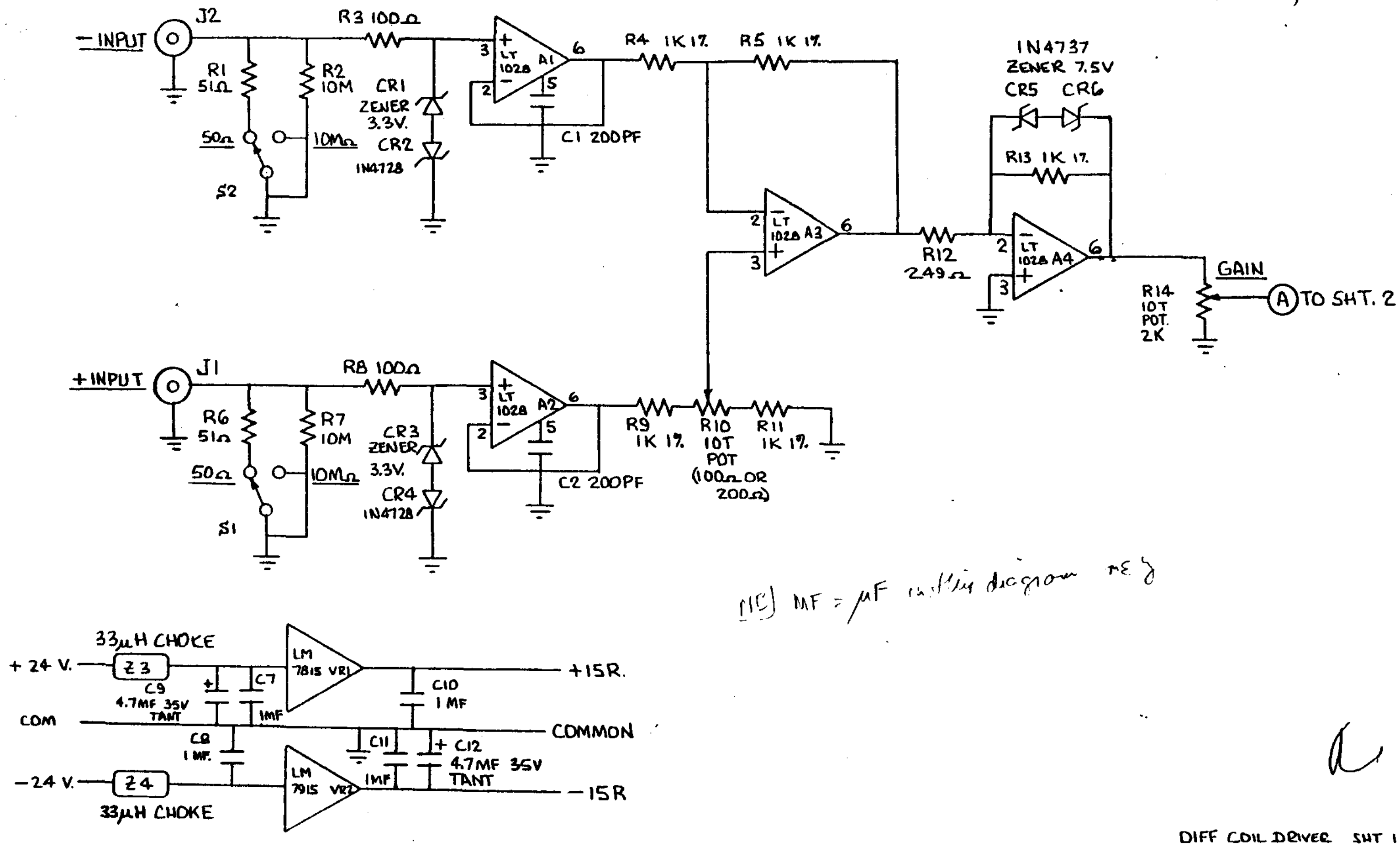
OBSOLETE

3-1-88 R15 MOVED: 1K TO 500Ω
1-28-88 C16 FROM 220pf TO 470pf
UPDATE TO 9-8-78

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
COIL DRIVER HIGH CURRENT		
DRAWN BY B.T.	DATE 9-2-87	DRAWING NO. -1
CHECKED BY	SCALE	
APPROVED BY	W.O.	

87-0902-1

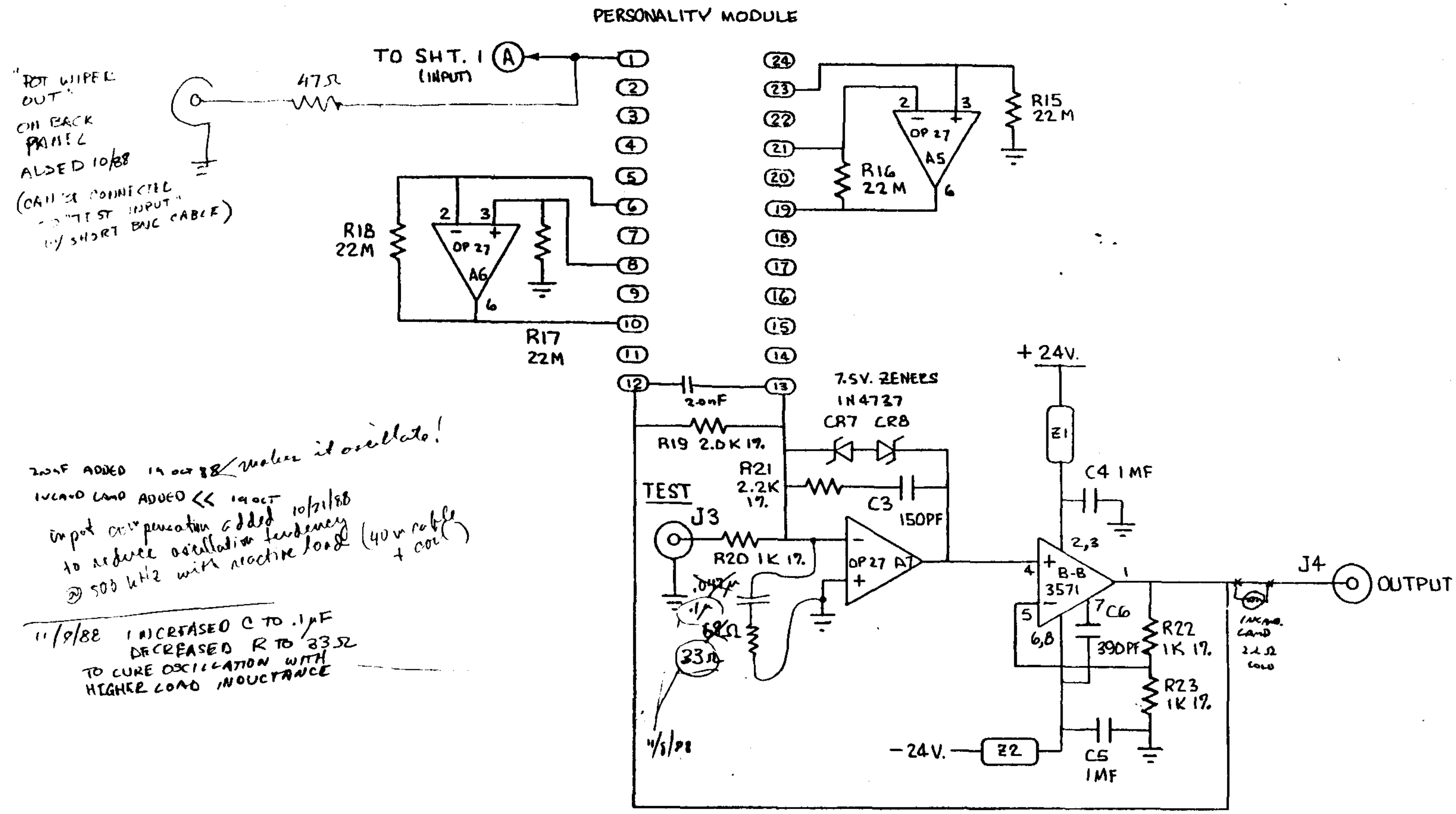
High current, programable, differential coil drive (MK II)

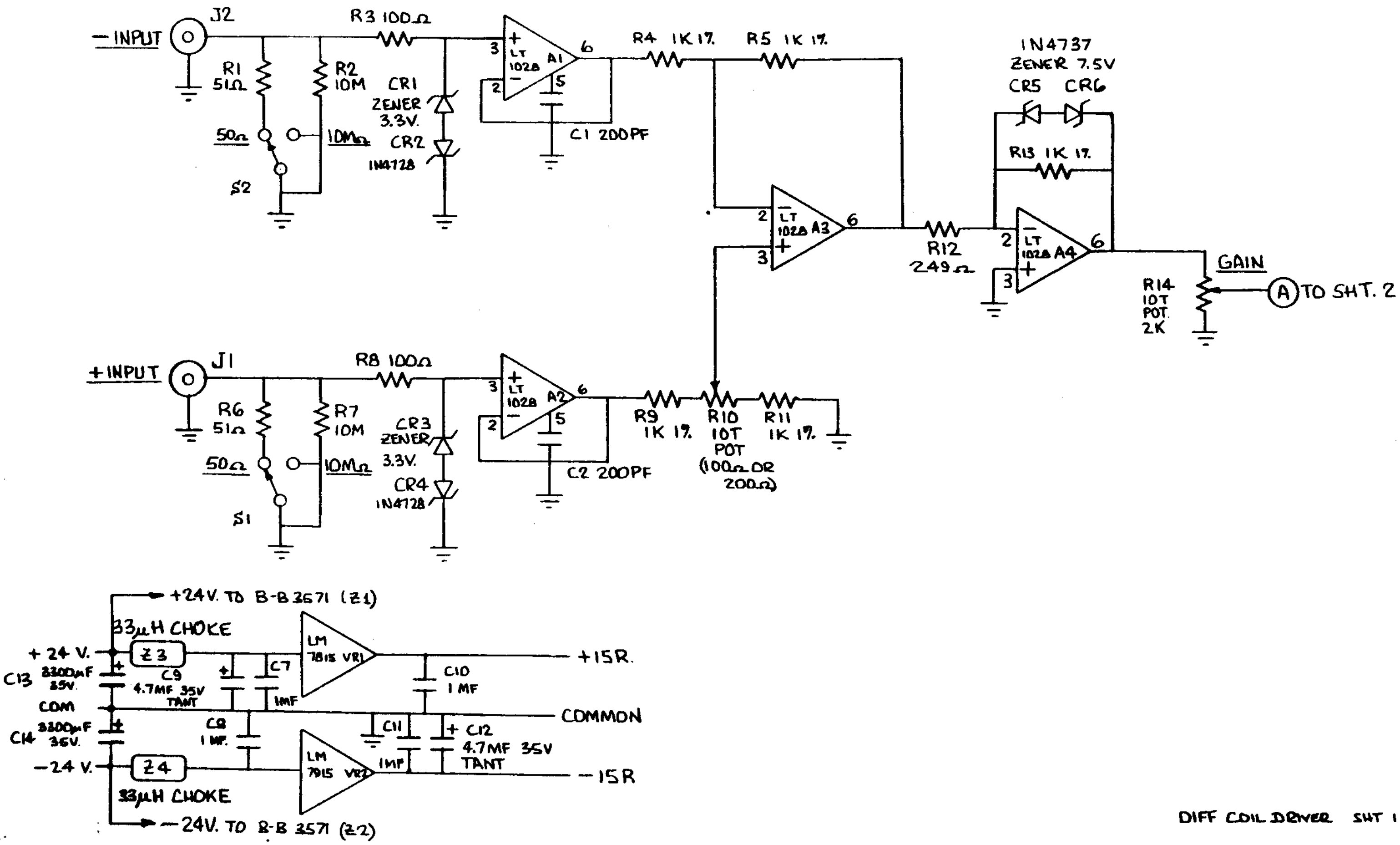


(NB) MF = µF in this diagram ref

DIFF COIL DRIVER SHT 1

CALIFORNIA


PERSONALITY MODULE
TO SHT. 1 (A)
(INPUT)
47Ω
"POT WIPER OUT" ON BACK PANEL ADDED 10/88
(CAN BE CONNECTED TO "TEST INPUT" W/ SHORT BNC CABLE)
R18 22M
OP 27 A6
R17 22M
R15 22M
R16 22M
OP 27 A5
20nF
R19 2.0K 1%
7.5V. ZENERS 1N4737
CR7 CR8
R21 2.2K 1%
C3 150PF
TEST
J3
R20 1K 1%
OP27 A7
+24V.
Z1
C4 1MF
B-B 3571
C6 390PF
R22 1K 1%
R23 1K 1%
−24V.
Z2
C5 1MF
J4
OUTPUT
INCAND. LAMP
.047µ
.1µ
68Ω
33Ω
11/3/88
20nF ADDED 14 OCT 88 ← makes it oscillate!
INCAND LAMP ADDED ← 14 OCT
input compensation added 10/21/88 to reduce oscillation tendency @ 500 kHz with reactive load (40 m cable + coil)
11/9/88 INCREASED C TO .1µF
DECREASED R TO 33Ω
TO CURE OSCILLATION WITH HIGHER LOAD INDUCTANCE

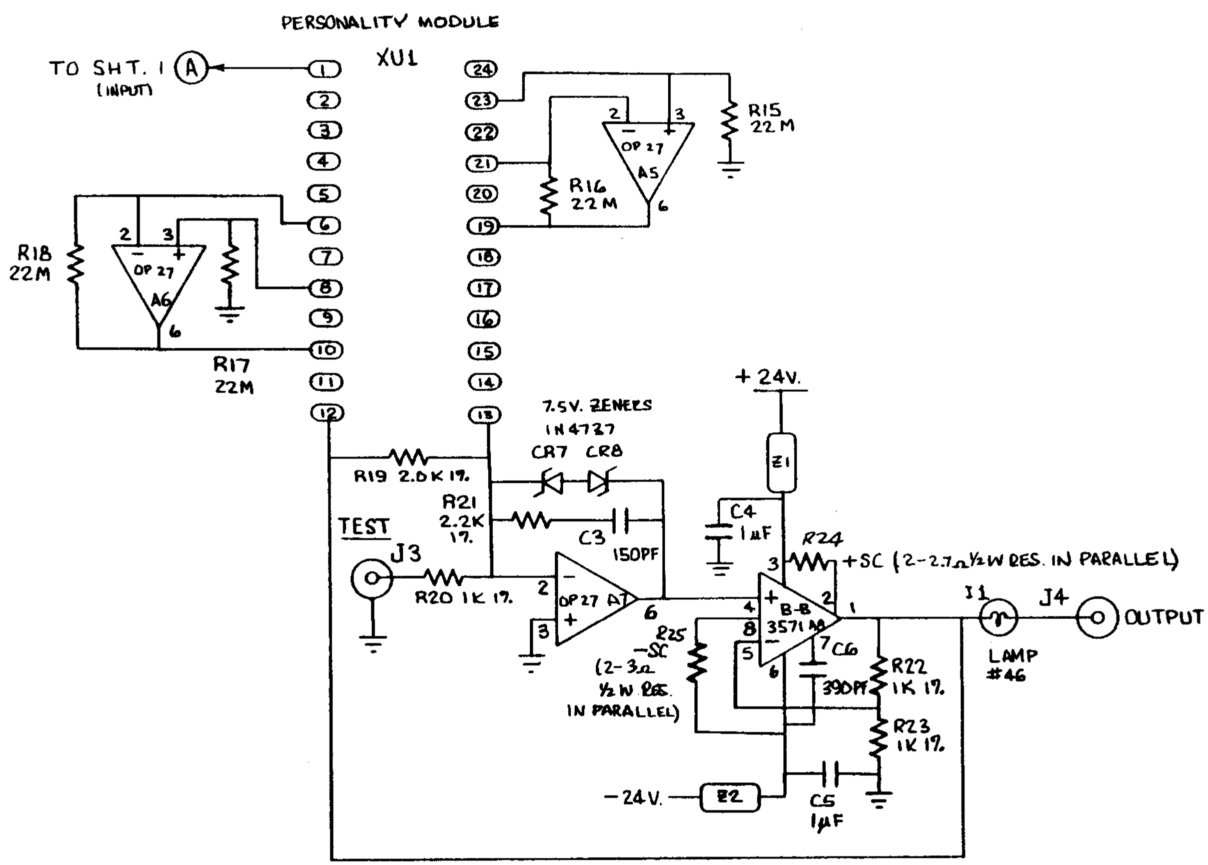


DIFF COIL DRIVER SHT 1

UPDATE 10/4/88 B.

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
PROG. DIFF. COIL DRIVER		SHT. 1
DRAWN BY B.T.	DATE 4-29-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

88-0429-1

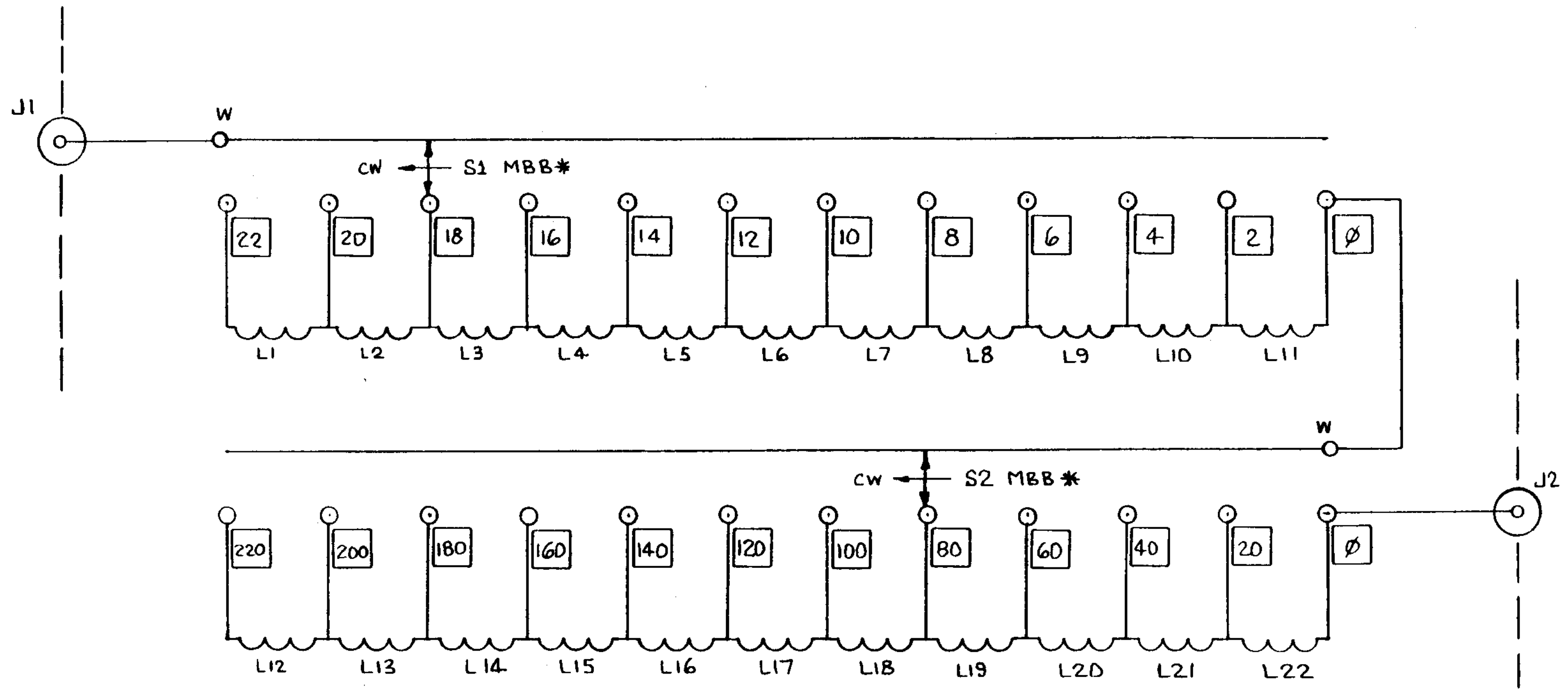


DIFF COIL DRIVER SHT 2

UPDATE 10/4/88

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
PROG. DIFF. COIL DRIVER		SHT. 2
DRAWN BY B.T.	DATE 4-29-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

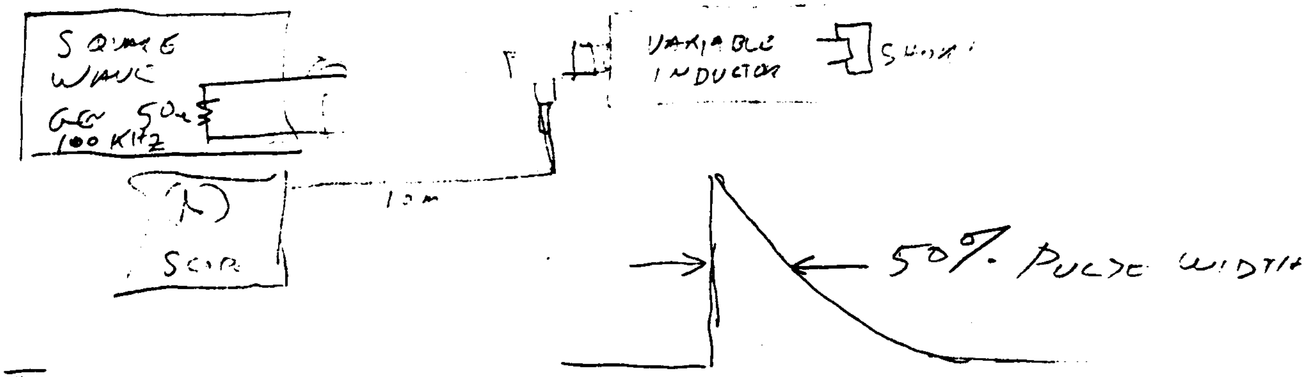
88-0429-2



4. *S1 & S2 ARE MAKE-BEFORE-BREAK, 12-POSITION SWITCHES.
3. VALUES IN BOXES ARE IN μH.
2 L12-L22 = 20μH
1. L1-L11 = 2μH
NOTES:

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
INDUCTANCE BOX: GRAVITY PHYSICS RANGE: Ø TO 242μH IN 2μH STEPS		
DRAWN BY R.T.	DATE 5-8-89	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

VARIABLE INDUCTOR [illegible]



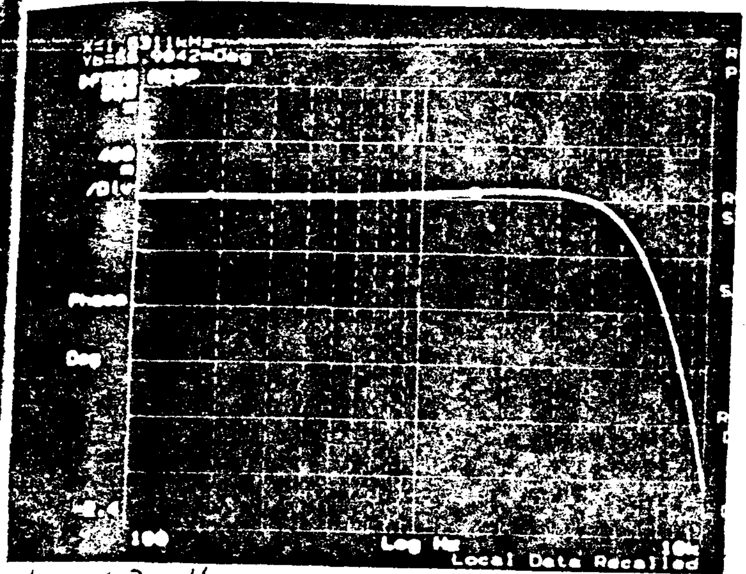
TEST SET UP

INDICATED INDUCTANCE		50% PULSE WIDTH		INDUCTANCE	
0	μHY	10	ns	<.7	μHY
2	"	46	"	3.3	"
4	"	86	"	6.2	"
6	"	112	"	8.1	"
8	"	160	"	11.5	"
VERNIER 10	"	180	"	13.0	"
12	"	220	"	15.9	"
14	"	250	"	18.0	"
16	"	270	"	19.5	"
18	"	290	"	20.9	"
20	"	315	"	22.7	"
22	"	350	"	25.2	"
20	"	330	"	23.8	"
40	"	660	"	47.6	"
60	"	960	"	69.2	"
80	"	1240	"	89.4	"
100	"	1520	"	110.0	"
120	"	1840	"	133.0	"
140	"	2150	"	155.0	"
COARSE 160	"	2450	"	177.0	"
180	"	2700	"	195.0	"
200	"	3000	"	216.0	"
220	"	3250	"	234.0	"

INDUCTANCE BOX TEST

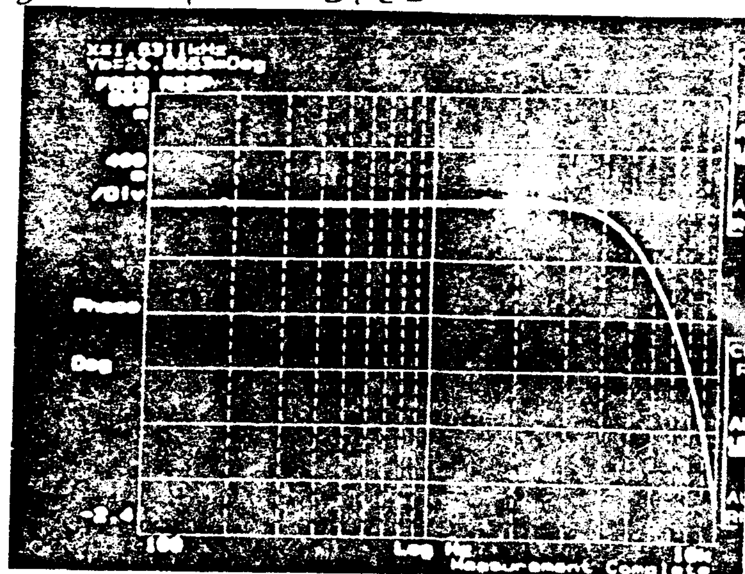
9-MAY-89

9-MAY-89 9:20



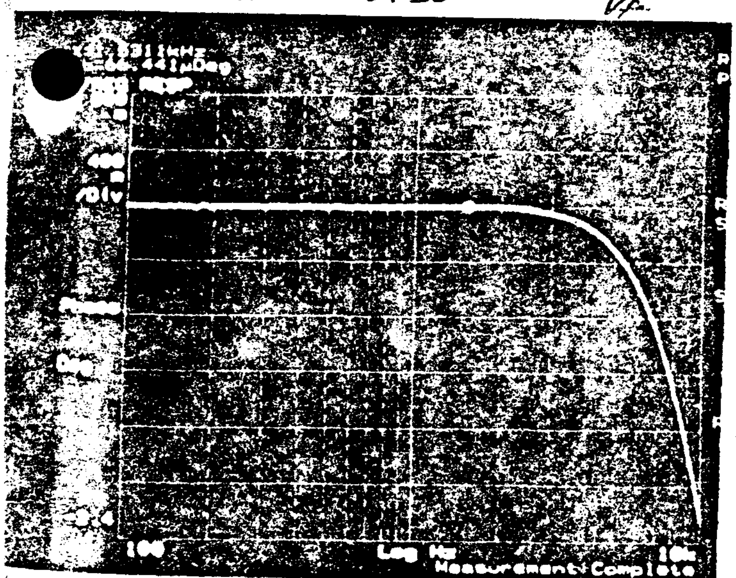
L = 52 μH

9-MAY-89 9:25



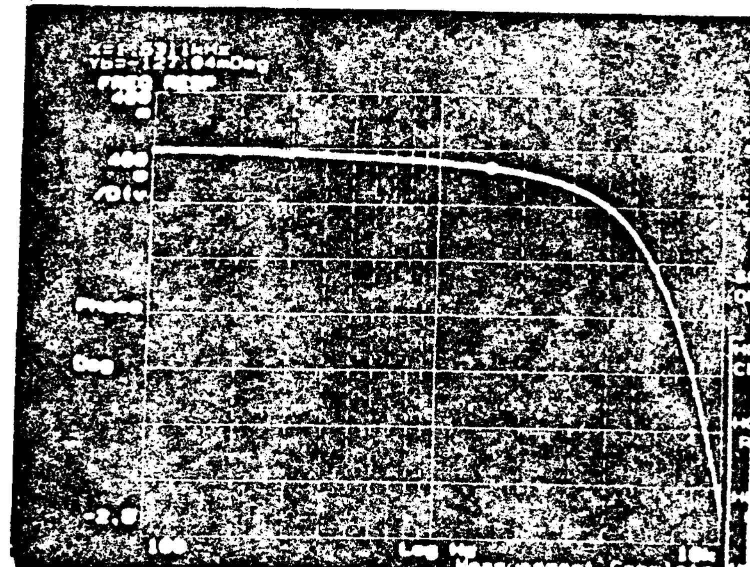
L = 54 μH

9-MAY-89 9:35



L = 56 μH

9-MAY-89 9:00



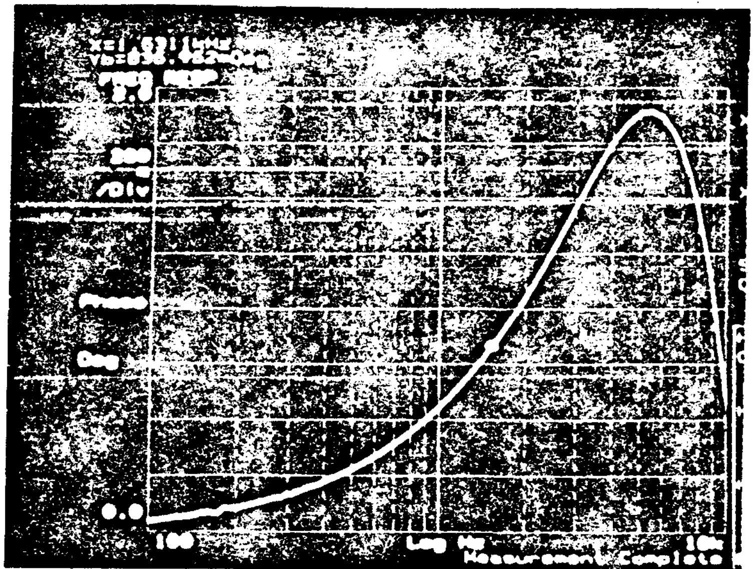
L = 60 μH

Using the new adjustable inductor in series w. Louie coils (instead of the fixed 80 μH one), phase matching of currents in the two coils for Huey, Louie respectively was checked w. the set-up on p. 74. Results are shown in order of increasing L. Best matching: L = 56 μH → if the resulting 66 μdeg were the only limit, a foil subtraction of ~ 10^5 would be possible. Of course, at this level differences in the mass/pendulum (etc) response become the real limits.

npt

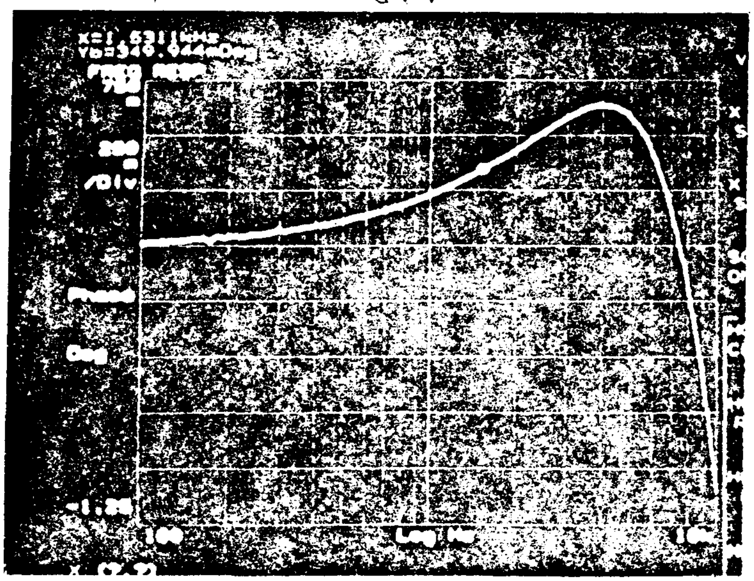
$\frac{dF}{di} =$

9-MAY-89 8:50



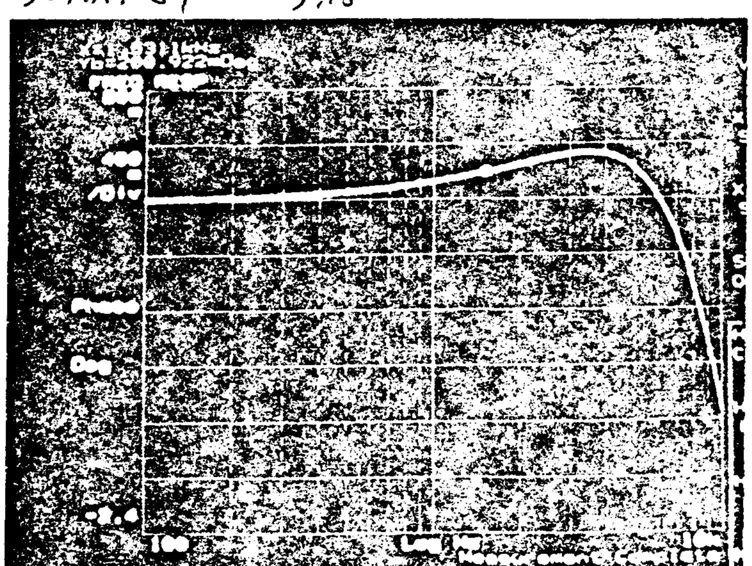
L = 0 μH

9-MAY-89 8:45

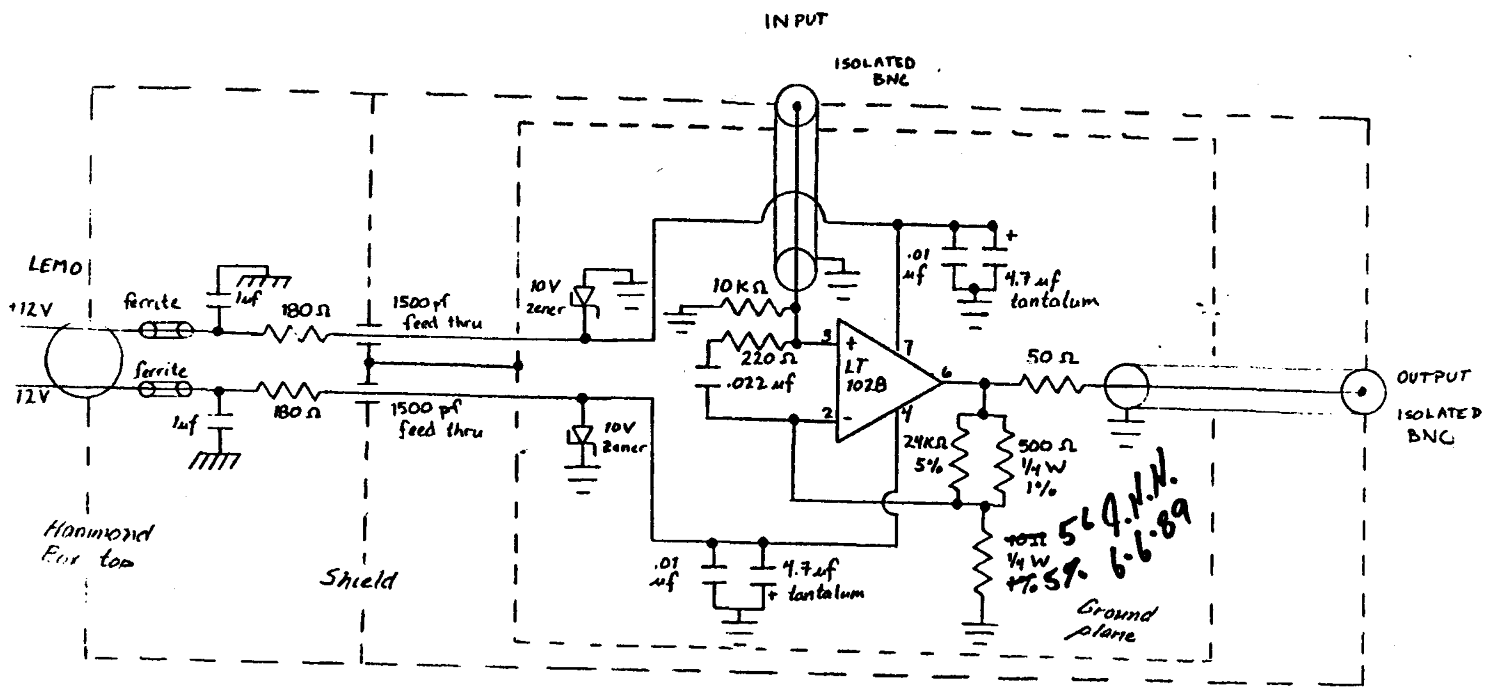


L = 34 μH

9-MAY-89 9:15



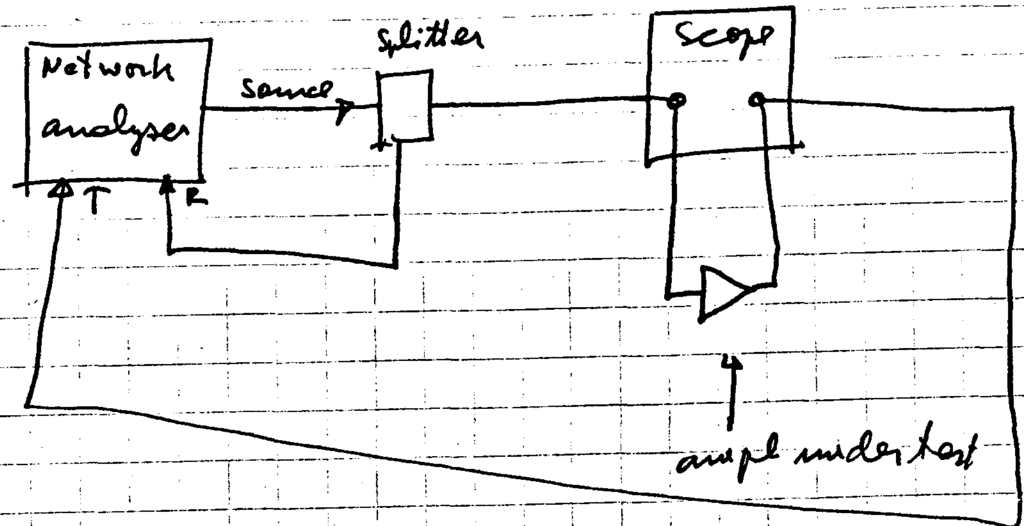
L = 40 μH



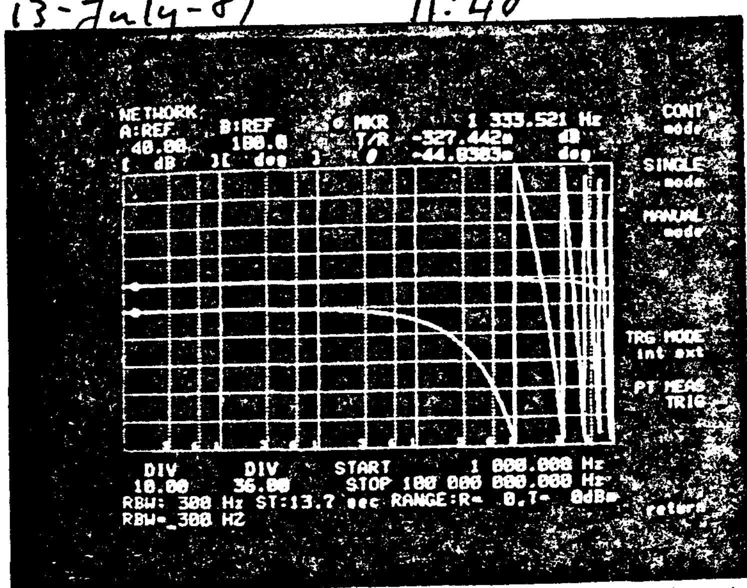
LOW NOISE BUFFER
8-21-87

(13-July-89)

Since ~30' of cables were used to connect the amplifier under test (see diagram below), we took the response of the cables themselves (trace at 11:40)



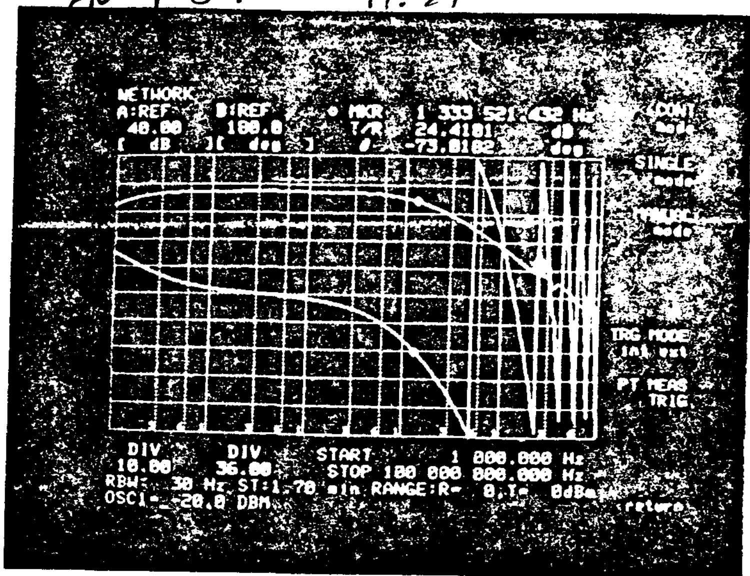
13-July-89 11:40



TR. FUNCTION OF CABLES – they are badly unbalanced

- It turns out that at 250 kHz the cables alone show a phase shift of 5°.
- Therefore, the ~3' cable from splitter to R input was replaced with a long cable, matched to the one in the test path. See traces overleaf

13-July-89 11:21



AXES: 100 MHz 40dB

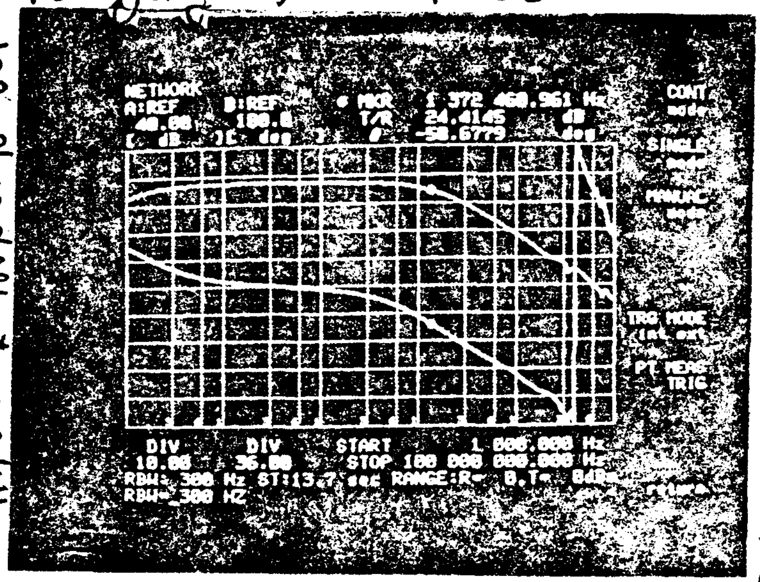
50K 713

← unmatched cables

50K 50 Ω in and out

13-July 89 12:02

10° phase shift at 230 KHz



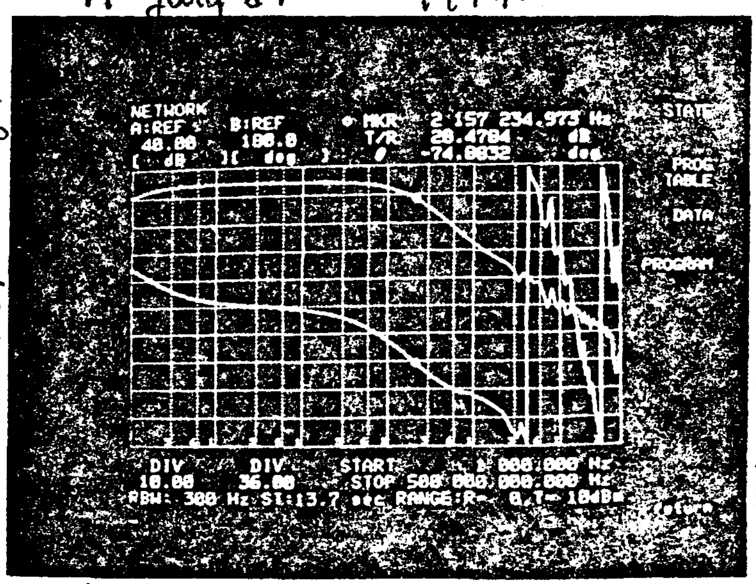
~~50K in and out~~ ~~50K 713~~

← matched cables

50K 50 Ω in and out

14-July 89 17:40

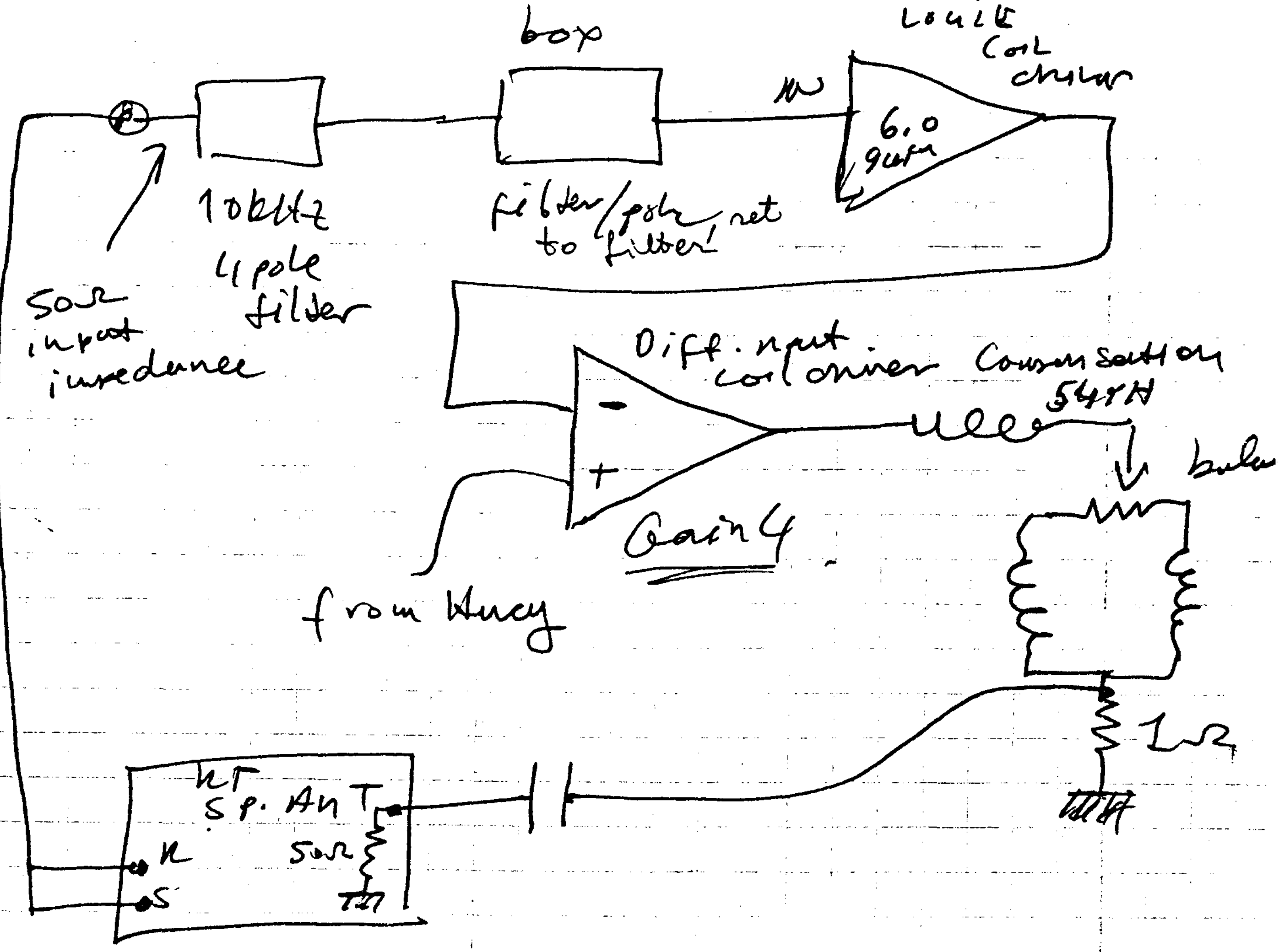
10°: 203 KHz



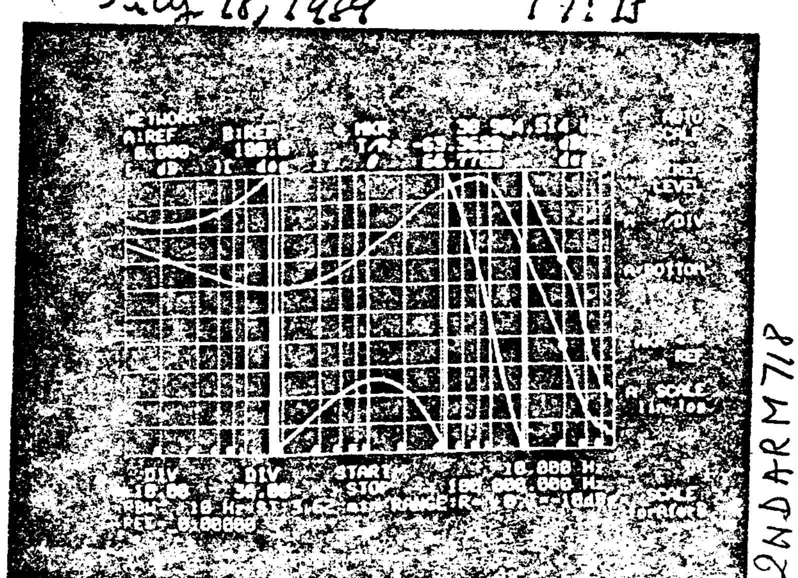
50K 713

50K 50 Ω ~~and~~ out

Second arm chain transfer functions



July 18, 1989 17:15



second arm chain transfer function

BATCH START

Other

STAPLE
OR
DIVIDER

DETECTION PROCESS

PHASE MODULATED LIGHT FROM THE LASER IS REFLECTED FROM THE BACK OF THE MIRROR WHERE THE FABRY PEROT IS EXCITED. (APPROXIMATELY 99.9% OF THE LIGHT IS REFLECTED) ADDED TO THIS LIGHT IS THE LIGHT ESCAPING THROUGH THE SAME MIRROR FROM THE FABRY PEROT. THIS ESCAPING LIGHT HAS BEEN STRIPPED OF ITS SIDEBANDS DUE TO THE NARROW BANDWIDTH OF THE FABRY PEROT. (THE ESCAPING LIGHT IS NEARLY AS INTENSE AS THE INCIDENT LIGHT, SINCE AS IN ANY RESONATOR, THE ENERGY INSIDE BUILDS UP UNTIL THE LOSSES ARE EQUAL TO THE EXCITATION; THIS RATIO IS THE "CONTRAST.") THE INTERFERED BEAM TRAVELLING FROM THE FABRY PEROT INPUT MIRROR TO THE PHOTODIODE IS THUS, TO A FIRST APPROXIMATION:

$$k\left(\sin(\omega_0 t) + k_m[\sin(\omega_0+\omega_m)t - \sin(\omega_0-\omega_m)t]\right)$$

REFLECTED LIGHT WITH SIDEBANDS

$$+ \sin(\omega_0 t + \phi)$$

LIGHT FROM CAVITY

THIS EQUATION IS THE EQUATION OF THE STRENGTH OF THE ELECTRIC (OR MAGNETIC) FIELD. THE PHOTODIODE RESPONDS TO THE POWER IN THE LIGHT, PROPORTIONAL TO THE SQUARE OF THE FIELD. THUS IT SERVES AS A "SQUARE LAW DETECTOR". EXAMINING THE ACTION OF A SQUARE LAW DETECTOR ON THE EQUATION OF THE INTERFERED BEAM WILL SHOW HOW THE PHASE DIFFERENCE IN THE LIGHT IS DETECTED.

DETECTION PROCESS

FOR SIMPLICITY, LET ALL CONSTANTS BE ASSUMED 1,

LET $X_1 = \sin \omega_0 t$

$X_2 = \sin[(\omega_0 + \omega_m)t]$

$X_3 = -\sin[(\omega_0 - \omega_m)t]$

$X_4 = \sin[\omega_0 t + \phi]$

$$(X_1 + X_2 + X_3 + X_4)^2 = X_1^2 + X_2^2 + X_3^2 + X_4^2 + 2X_1X_2 + 2X_1X_3 + 2X_1X_4 + 2X_2X_3 + 2X_2X_4 + 2X_3X_4$$

$$X_1^2 = [\sin(\omega_0 t)]^2 = \frac{1}{2}(1 - \cos 2\omega_0 t)$$

APPLYING $\sin^2 A = \frac{1}{2}(1 - \cos 2A)$ TRIG IDENTITY

$-\cos(2\omega_0 t)$ IS FILTERED OUT BY FREQUENCY RESPONSE OF PHOTO DIODE, THE OUTPUT IS A DC TERM, ½.

SIMILARLY, X_2^2, X_3^2, X_4^2 EACH PRODUCE A DC TERM AND A TWICE LIGHT FREQUENCY TERM,

$X_1X_2 = \sin \omega_0 t)(\sin((\omega_0 + \omega_m)t)$ $\qquad \sin A \sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$

$= \frac{1}{2}\cos(\omega_0 t - (\omega_0 + \omega_m)t) - \frac{1}{2}\cos(\omega_0 t + (\omega_0 + \omega_m)t)$

$= \frac{1}{2}\cos(-\omega_m t)$ + LIGHT $\qquad \cos A = \cos(-A)$

$= \frac{\cos \omega_m t}{2}$ 12 MHZ

SIMILARLY

$X_1X_3 = -\sin(\omega_0 t)\sin((\omega_0 - \omega_m)t) = -\frac{\cos(\omega_m t)}{2}$ + LIGHT

$X_1X_4 = \sin(\omega_0 t)\sin(\omega_0 t + \phi) = \frac{\cos(-\phi)}{2}$ + LIGHT

$= \frac{\cos \phi}{2}$ DC

$$X_2X_3 = -\sin[(\omega_0+\omega_m)t]\,\sin[(\omega_0-\omega_m)t]$$

$$= -\frac{1}{2}\cos(2\omega_m t) + \frac{1}{2}\cos(2\omega_0 t)$$

LIGHT

$$= -\frac{1}{2}\cos 2\omega_m t$$

$$X_2X_4 = \sin[(\omega_0+\omega_m)t]\cdot\sin[\omega_0 t+\phi]$$

$$= \frac{\cos((\omega_0+\omega_m)t-(\omega_0 t+\phi))}{2} - \frac{\cos((\omega_0+\omega_m)t+\omega_0 t+\phi))}{2}$$

$$= \frac{\cos(\omega_m t-\phi)}{2} \quad + \text{ LIGHT}$$

$$X_3X_4 = -[\sin(\omega_0-\omega_m)t\,\sin(\omega_0 t+\phi)] = -\frac{\cos(-(\omega_m t)-\phi)}{2} \quad + \text{LIGHT}$$

SUMMARIZING

$X_1^2 = 1/2$ DC

$X_2^2 = 1/2$ DC

$X_3^2 = 1/2$ DC

$X_4^2 = 1/2$ DC

$2X_1X_2 = \cos\omega_m t$

$2X_1X_3 = -\cos\omega_m t$

$2X_1X_4 = \cos\phi$ WOULD PROVIDE DC PHASE TERM, IF MODULATION SYSTEM NOT USED

$2X_2X_3 = \cos(2\omega_m t)$ 24 MHz

$2X_2X_4 = \cos(\omega_m t-\phi)$ 12 MHz WITH PHASE INFORMATION

$$2X_3X_4 = -\cos(-\omega_m t-\phi)$$

$$= -\cos(-(\omega_m t+\phi))$$

$$= -\cos(\omega_m t+\phi)$$

LOOKING AT TERMS NEAR MODULATION

$2X_1X_2 + 2X_1X_3 = \cos W_m t - \cos W_m t = 0$

$2X_2X_4 = 2\cos \frac{1}{2}\cos(W_m t - \phi) = \cos(W_m t - \phi)$

$2X_3X_4 = -\cos(-(W_m t) - \phi)$

$= -\cos(W_m t + \phi)$

MIXING WITH THE MODULATING SIGNAL, PHASE SHIFTED TO $\sin(W_m t)$

X_2X_4 TERM YIELDS

$\sin A \cos B = \frac{1}{2}\sin(A+B) + \frac{1}{2}\sin(A$

$\sin W_m t \cos(W_m t - \phi) = \frac{1}{2}\sin(2W_m t - \phi) + \frac{1}{2}\sin(+\phi)$

$= +\frac{1}{2}\sin\phi$

X_3X_4 TERM YIELDS

$-\sin W_m t \cos(W_m t + \phi) = -\frac{1}{2}\sin(2W_m t + \phi) - \frac{1}{2}\sin(-\phi)$

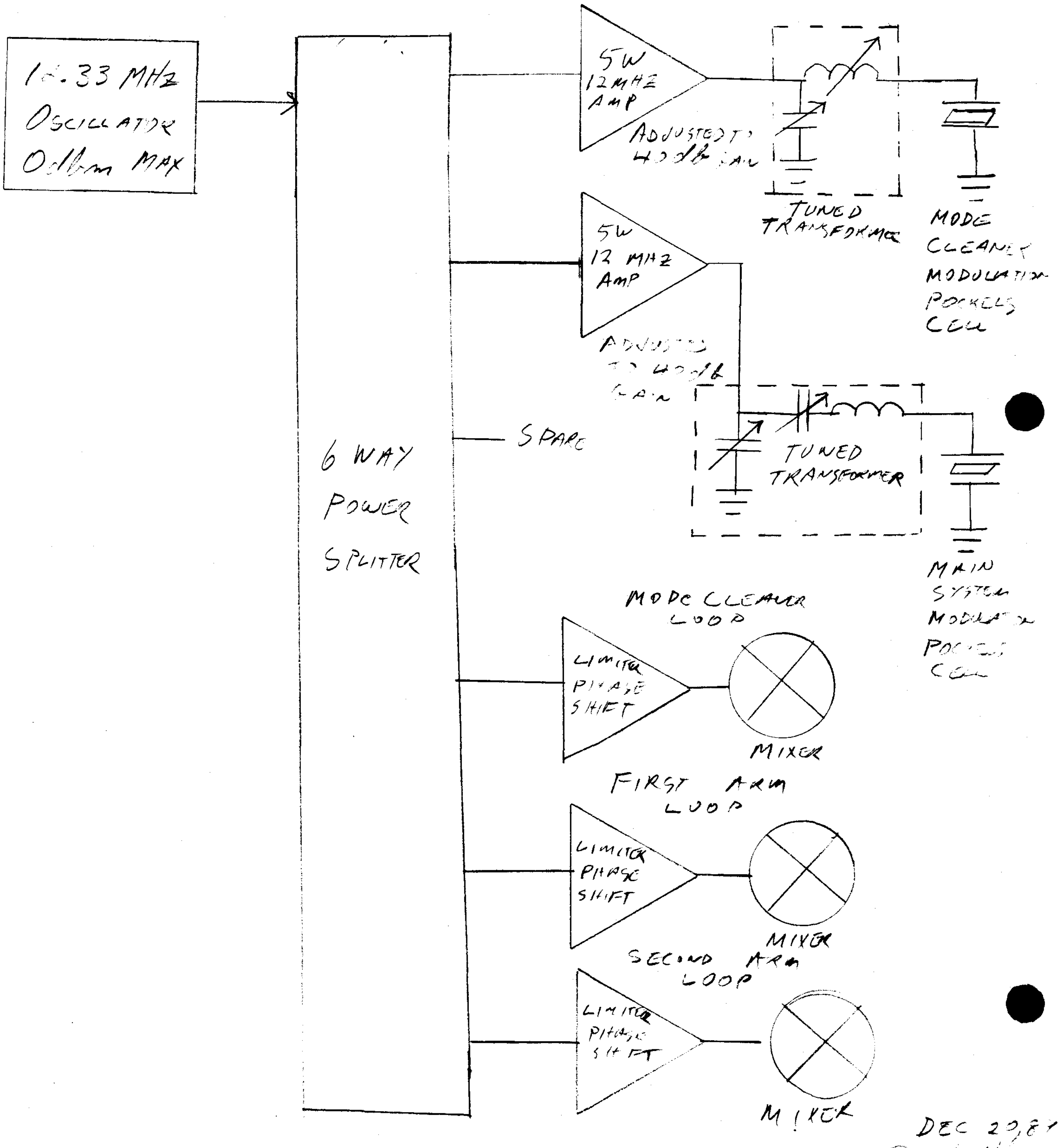
$= -\frac{1}{2}\sin(-\phi)$ $\quad \sin(-A) = -\sin A$

$= \frac{1}{2}\sin\phi$

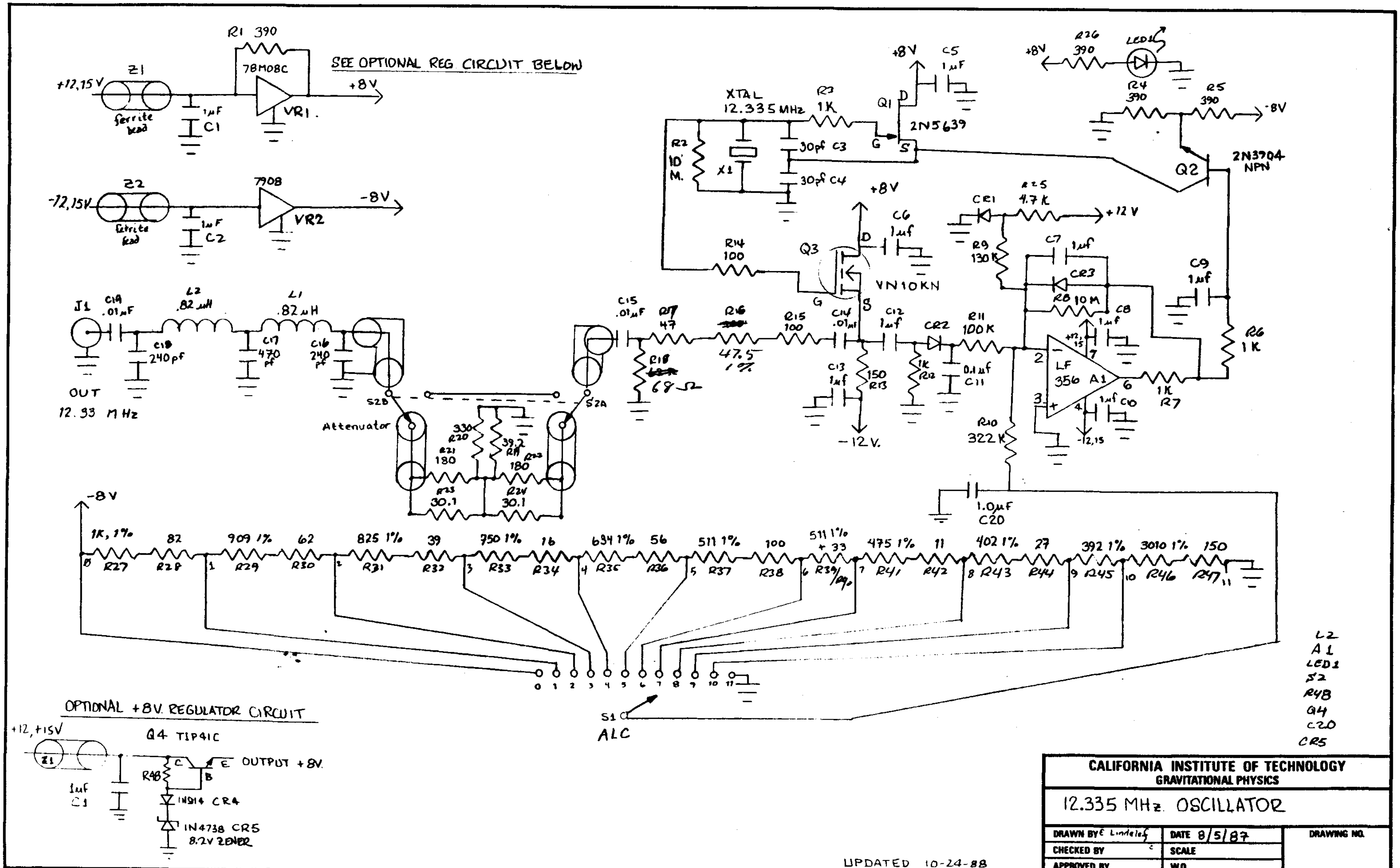
OUTPUT, AFTER FILTERING AND CANCELLING, IS

$\frac{1}{2}\sin\phi + \frac{1}{2}\sin\phi = \sin\phi$. THIS IS A VERY GOOD DC, BIPOLAR, ERROR TERM TO CONTROL ϕ

12 MHz RF DISTRIBUTION

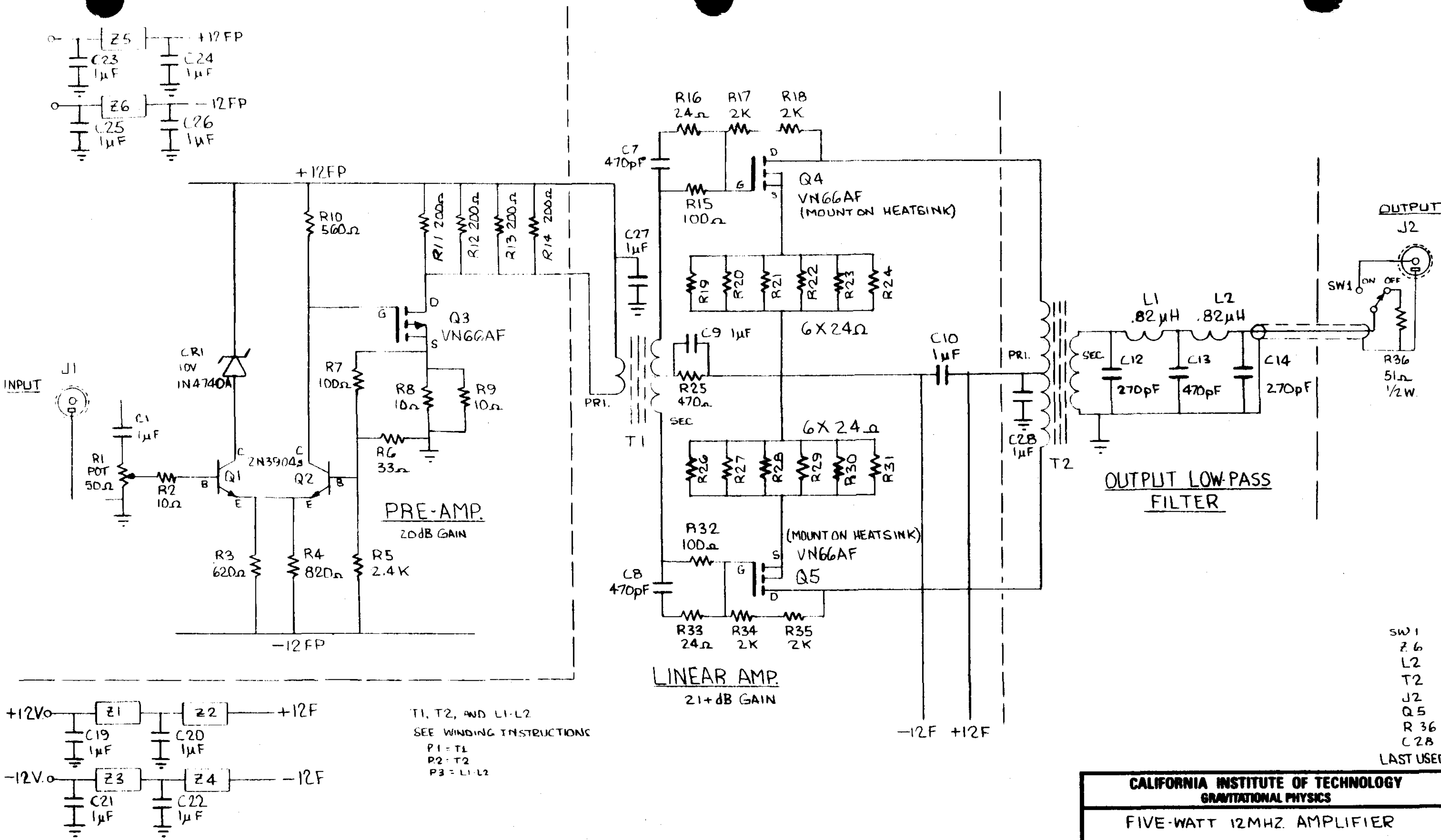


DEC 29,87



BISHOP GRAPHICS/ACCUPRESS REORDER NO. A38361

87-0805-1



T1, T2, AND L1-L2
SEE WINDING INSTRUCTIONS
P1 = T1
P2 = T2
P3 = L1-L2

SW1
Z6
L2
T2
J2
Q5
R36
C28
LAST USED

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

FIVE-WATT 12MHZ AMPLIFIER

DRAWN BY B.T.	DATE 11-22-89	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

89-1122-1

DETECTION PROCESS

PHASE MODULATED LIGHT FROM THE LASER IS REFLECTED FROM THE BACK OF THE MIRROR WHERE THE FABRY PEROT IS EXCITED. (APPROXIMATELY 99.9% OF THE LIGHT IS REFLECTED) ADDED TO THIS LIGHT IS THE LIGHT ESCAPING THROUGH THE SAME MIRROR FROM THE FABRY PEROT. THIS ESCAPING LIGHT HAS BEEN STRIPPED OF ITS SIDEBANDS DUE TO THE NARROW BANDWIDTH OF THE FABRY PEROT. (THE ESCAPING LIGHT IS NEARLY AS INTENSE AS THE INCIDENT LIGHT, SINCE AS IN ANY RESONATOR, THE ENERGY INSIDE BUILDS UP UNTIL THE LOSSES ARE EQUAL TO THE EXCITATION; THIS RATIO IS THE "CONTRAST".) THE INTERFERED BEAM TRAVELLING FROM THE FABRY PEROT INPUT MIRROR TO THE PHOTODIODE IS THUS, TO A FIRST APPROXIMATION:

$$k\left(\sin(\omega_0 t) + k_m\left[\sin(\omega_0+\omega_m)t - \sin(\omega_0-\omega_m)t\right]\right)$$

REFLECTED LIGHT WITH SIDEBANDS

$$+ \sin(\omega_0 t+\phi)$$

LIGHT FROM CAVITY

THIS EQUATION IS THE EQUATION OF THE STRENGTH OF THE ELECTRIC (OR MAGNETIC) FIELD. THE PHOTODIODE RESPONDS TO THE POWER IN THE LIGHT, PROPORTIONAL TO THE SQUARE OF THE FIELD. THUS IT SERVES AS A "SQUARE LAW DETECTOR". EXAMINING THE ACTION OF A SQUARE LAW DETECTOR ON THE EQUATION OF THE INTERFERED BEAM WILL SHOW HOW THE PHASE DIFFERENCE IN THE LIGHT IS DETECTED.

DETECTION PROCESS

FOR SIMPLICITY, LET ALL CONSTANTS BE ASSUMED 1,

LET $X_1 = \sin \omega_0 t$

$X_2 = \sin[(\omega_0 + \omega_m)t]$

$X_3 = -\sin[(\omega_0 - \omega_m)t]$

$X_4 = \sin[\omega_0 t + \phi]$

$$(X_1 + X_2 + X_3 + X_4)^2 = X_1^2 + X_2^2 + X_3^2 + X_4^2 + 2X_1X_2 + 2X_1X_3 + 2X_1X_4 + 2X_2X_3 + 2X_2X_4 + 2X_3X_4$$

$$X_1^2 = [\sin(\omega_0 t)]^2 = \frac{1}{2}(1 - \cos 2\omega_0 t)$$

APPLYING $\sin^2 A = \frac{1}{2}(1 - \cos 2A)$ TRIG IDENTITY

$-\cos(2\omega_0 t)$ IS FILTERED OUT BY FREQUENCY RESPONSE OF PHOTO DIODE. THE OUTPUT IS A DC TERM, ½.

SIMILARLY, X_2^2, X_3^2, X_4^2 EACH PRODUCE A DC TERM AND A TWICE LIGHT FREQUENCY TERM.

$X_1 X_2 = \sin \omega_0 t)(\sin((\omega_0 + \omega_m)t)$ $\quad \sin A \sin B = \frac{\cos(A-B) - \cos(A+B)}{2}$

$= \frac{1}{2}\cos(\omega_0 t - (\omega_0 + \omega_m)t) - \frac{1}{2}\cos(\omega_0 t + (\omega_0 + \omega_m)t)$

$= \frac{1}{2}\cos(-\omega_m t)$ + LIGHT $\quad \cos A = \cos(-A)$

$= \frac{\cos \omega_m t}{2}$ 12 MHZ

SIMILARLY

$X_1 X_3 = -\sin(\omega_0 t)\sin(\omega_0 - \omega_m)t = -\frac{\cos(\omega_m t)}{2}$ + LIGHT

$X_1 X_4 = \sin(\omega_0 t)\sin(\omega_0 t + \phi) = \frac{\cos(-\phi)}{2}$ + LIGHT

$= \frac{\cos \phi}{2}$ DC

$X_2 X_3 = -\sin[(\omega_0+\omega_m)t]\,\sin[(\omega_0-\omega_m)t]$

$= -\frac{1}{2}\cos(2\omega_m t) + \frac{1}{2}\cos(2\omega_0 t)$

LIGHT

$= -\frac{1}{2}\cos 2\omega_m t$

$X_2 X_4 = \sin[(\omega_0+\omega_m)t]\cdot\sin[\omega_0 t+\phi]$

$= \frac{\cos((\omega_0+\omega_m)t-(\omega_0 t+\phi))}{2} - \frac{\cos((\omega_0+\omega_m)t+\omega_0 t+\phi)}{2}$

$= \frac{\cos(\omega_m t-\phi)}{2}$ + LIGHT

$X_3 X_4 = -[\sin(\omega_0-\omega_m)t\,\sin(\omega_0 t+\phi)] = -\frac{\cos(-(\omega_m t)-\phi)}{2}$ + LIGHT

SUMMARIZING

$X_1^2 = 1/2$ DC

$X_2^2 = 1/2$ DC

$X_3^2 = 1/2$ DC

$X_4^2 = 1/2$ DC

$2X_1X_2 = \cos\omega_m t$

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$2X_1X_4 = \cos\phi$ WOULD PROVIDE DC PHASE TERM, IF MODULATION SYSTEM NOT USED

$2X_2X_3 = \cos(2\omega_m t)$ 24 MHz

$2X_2X_4 = \cos(\omega_m t-\phi)$ 12 MHz WITH PHASE INFORMATION

$2X_3X_4 = -\cos(-\omega_m t-\phi)$

$= -\cos(-(\omega_m t+\phi))$

$= -\cos(\omega_m t+\phi)$

LOOKING AT STATUS NEAR MODULATION [illegible]

$$2X_1X_2 + 2X_1X_3 = \cos W_m t - \cos W_m t = 0$$

$$2X_2X_4 = 2\cos \quad \frac{1}{2}\cos(\omega_m t - \phi) = \cos(\omega_m t - \phi)$$

$$2X_3X_4 = \quad -\cos(-(\omega_m t) - \phi)$$

$$= \quad -\cos(W_m t + \phi)$$

MIXING WITH THE MODULATING SIGNAL, PHASE SHIFTED TO $\sin(\omega_m t)$

X_2X_4 TERM YIELDS

$$\sin A \cos B = \frac{1}{2}\sin(A+B) + \frac{1}{2}\sin(A$$

$$\sin W_m t \cos(W_m t - \phi) = \frac{1}{2}\sin(2\omega_m t - \phi) + \frac{1}{2}\sin(+\phi)$$

$$= +\frac{1}{2}\sin\phi$$

X_3X_4 TERM YIELDS

$$-\sin W_m t \cos(W_m t + \phi) = -\frac{1}{2}\sin(2W_m t + \phi) - \frac{1}{2}\sin(-\phi)$$

$$= -\frac{1}{2}\sin(-\phi) \quad \sin(-A) = -\sin A$$

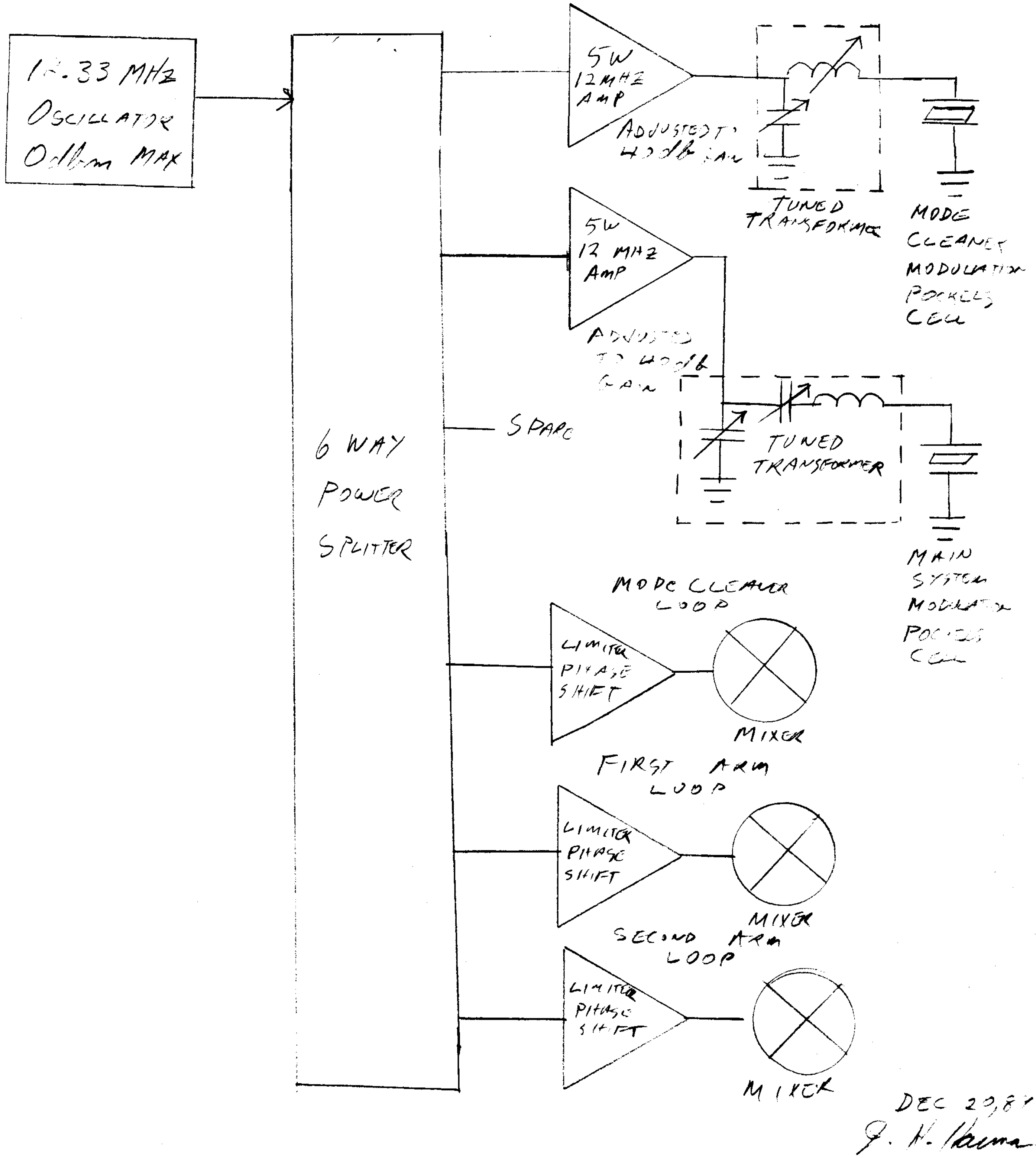
$$= \frac{1}{2}\sin\phi$$

OUTPUT, AFTER FILTERING AND CANCELLING, IS

$$\frac{1}{2}\sin\phi + \frac{1}{2}\sin\phi = \sin\phi.$$ THIS IS

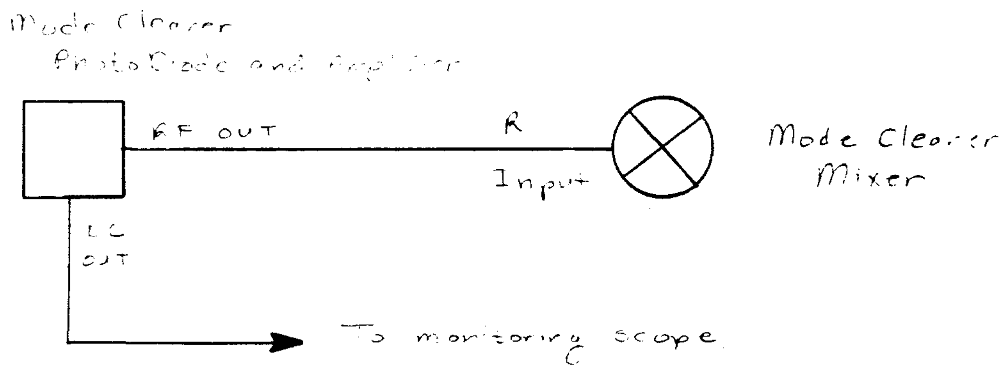
A VERY GOOD DC, BIPOLAR, ERROR TERM TO CONTROL ϕ

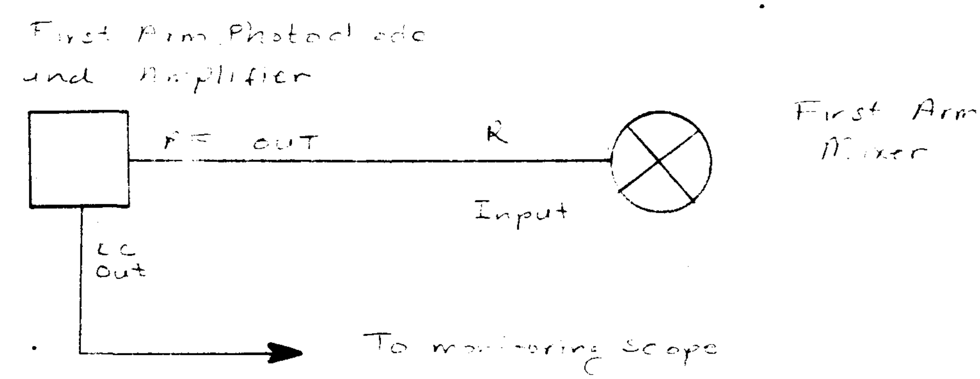
12 MHz RF DISTRIBUTION

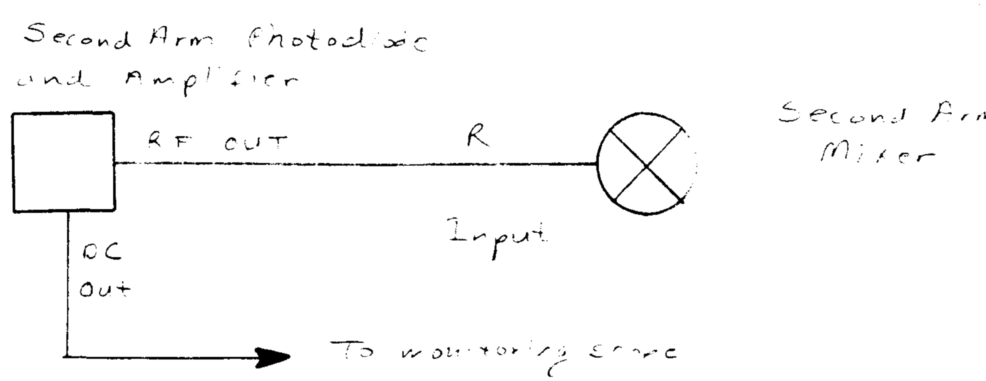


DEC 20,87
J. H. [illegible]

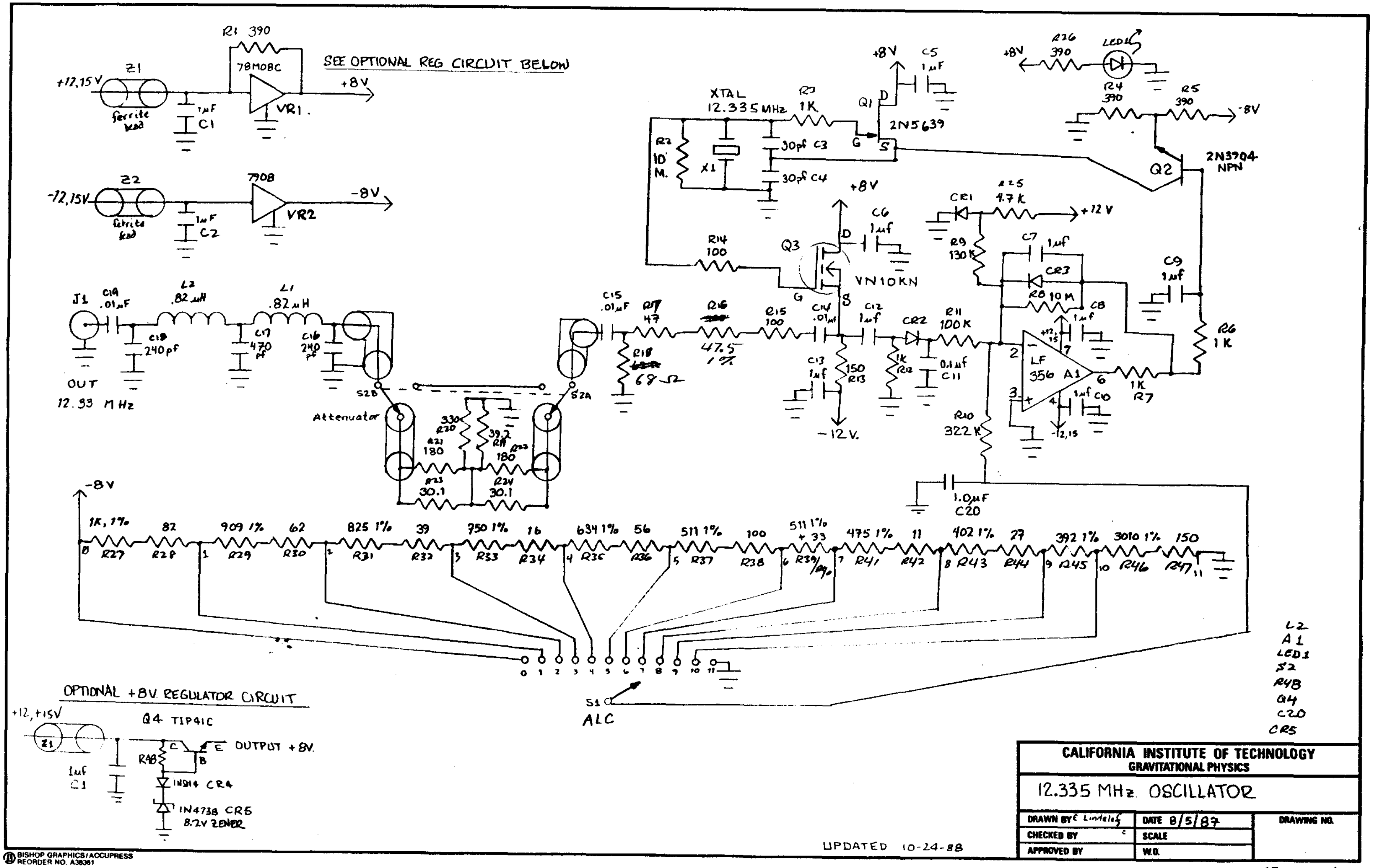
Photo Detector Electrical Wiring Diagram:





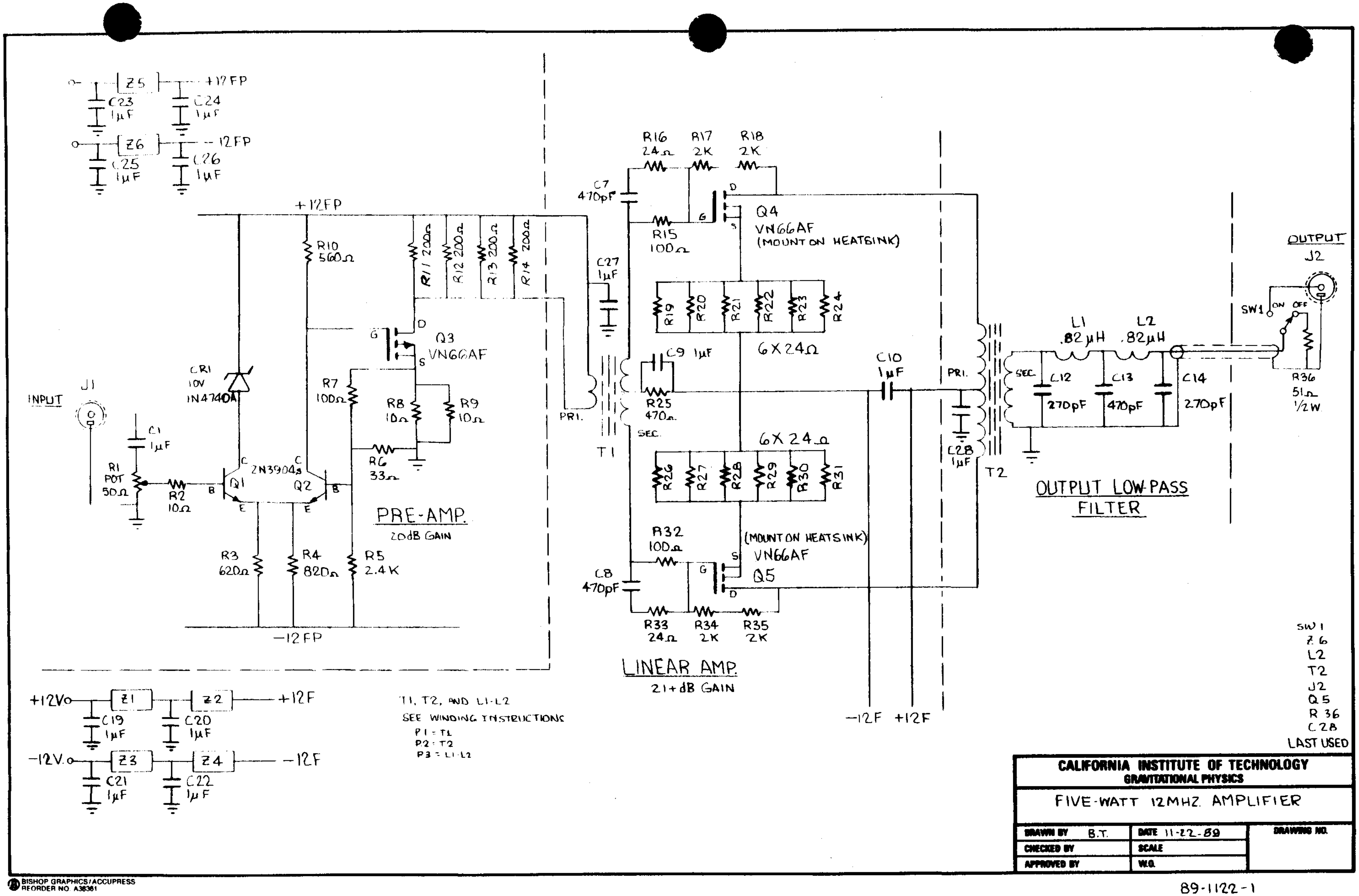


July 29, 1980



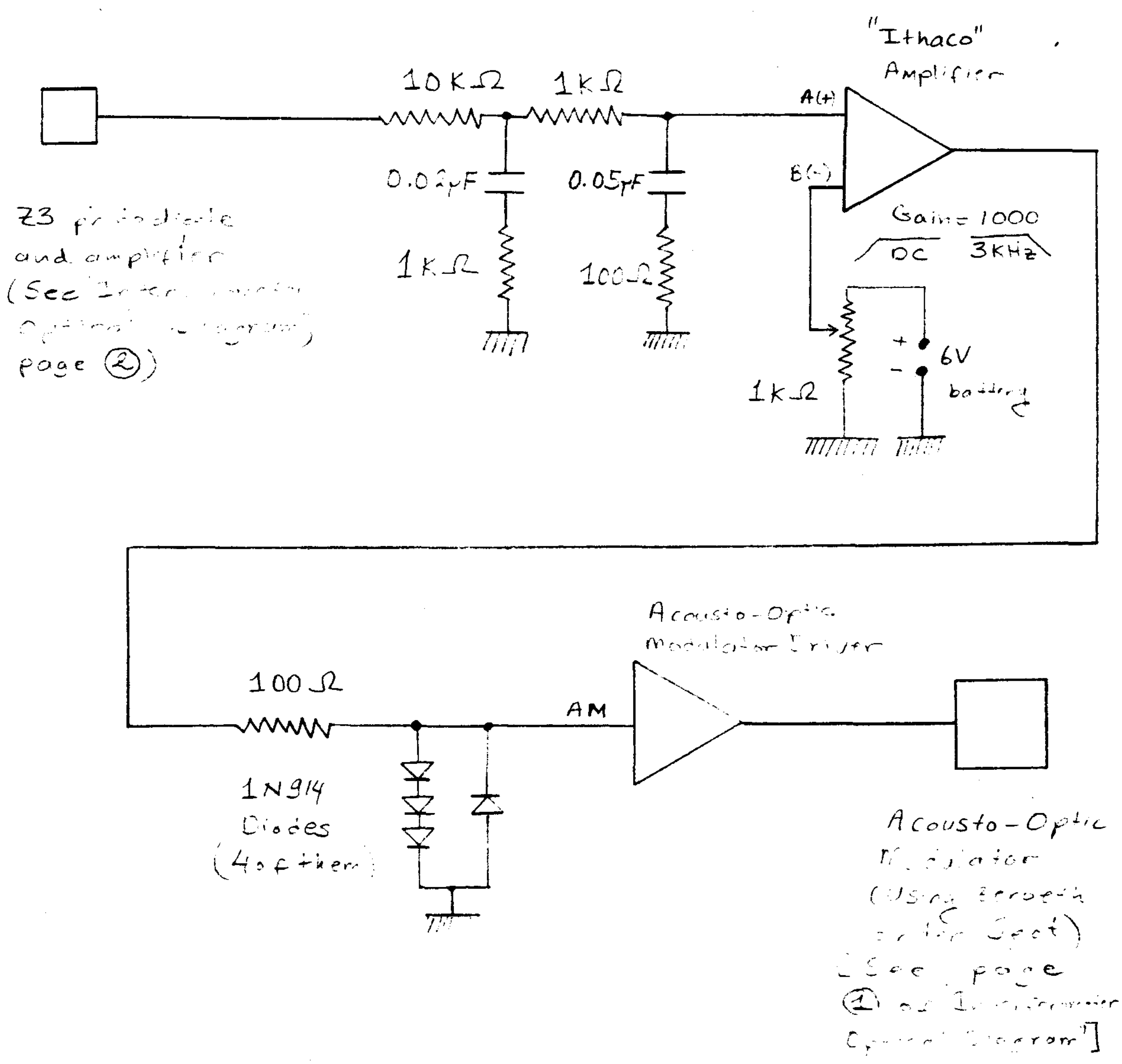
SEE OPTIONAL REG CIRCUIT BELOW
R1 390
78M08C
VR1
+12,15V
Z1
ferrite bead
1μF C1
+8V
Z2
-12,15V
7908
VR2
1μF C2
-8V
XTAL 12.335 MHz
R3 1K
Q1 2N5639
+8V C5 1μF
R2 10 M.
X1
30pf C3
30pf C4
R26 390
LED1
R4 390
R5 390
-8V
2N3904 NPN
Q2
CR1
R25 4.7K
+12 V
R9 130K
C7 1μf
CR3
R8 10 M
C8
C9 1μf
R14 100
Q3
C6 1μf
VN10KN
R6 1K
J1
C19 .01μF
L2 .82 μH
L1 .82 μH
C18 240pf
C17 470 pf
C16 240 pf
OUT 12.93 MHz
S2B
S2A
Attenuator
R20 330
R21 180
R22 39.2
R23 180
R23 30.1
R24 30.1
C15 .01μF
R17 47
R16 47.5 1%
R15 100
C14 .01μf
C12 1μf
CR2
R11 100K
R18 68 Ω
C13 1μf
150 R13
1K R12
0.1μf C11
-12 V.
LF 356 A1
1μf C10
1K R7
R10 322K
1.0μF C20
-8V
1K, 1% R27
82 R28
909 1% R29
62 R30
825 1% R31
39 R32
750 1% R33
16 R34
634 1% R35
56 R36
511 1% R37
100 R38
511 1% + 33 R39/R40
475 1% R41
11 R42
402 1% R43
27 R44
392 1% R45
3010 1% R46
150 R47
S1
ALC
OPTIONAL +8V REGULATOR CIRCUIT
+12,+15V
Q4 TIP41C
R48
OUTPUT +8V.
1μF C1
IN914 CR4
IN4738 CR5 8.2V ZENER
L2
A1
LED1
S2
R48
Q4
C20
CR5
UPDATED 10-24-88
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS
12.335 MHz OSCILLATOR
DRAWN BY E. Lindelof
DATE 8/5/87
DRAWING NO.
CHECKED BY
SCALE
APPROVED BY
W.O.
BISHOP GRAPHICS/ACCUPRESS REORDER NO. A38361

87-0805-1



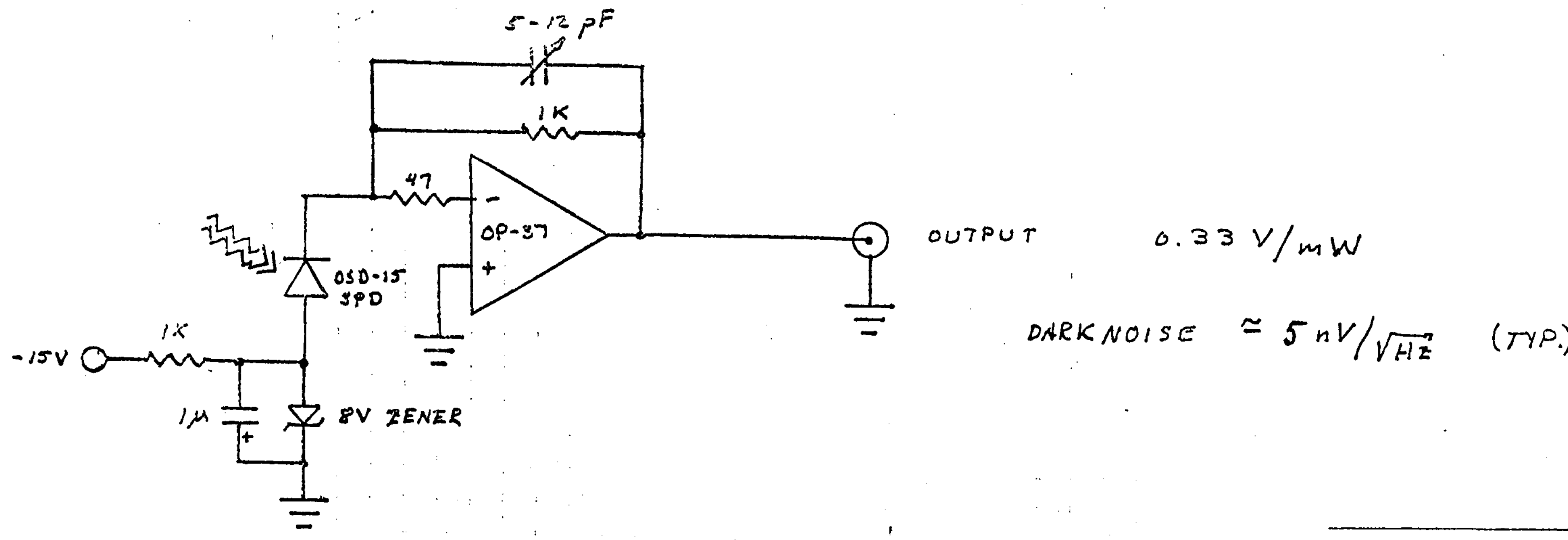
+12FP
-12FP
Z5
Z6
C23 1μF
C24 1μF
C25 1μF
C26 1μF
INPUT
J1
C1 1μF
R1 POT 50Ω
R2 10Ω
CR1 10V 1N4740A
2N3904s
Q1
Q2
R3 620Ω
R4 820Ω
R5 2.4K
R6 33Ω
R7 100Ω
R8 10Ω
R9 10Ω
R10 560Ω
R11 200Ω
R12 200Ω
R13 200Ω
R14 200Ω
Q3 VN66AF
PRE-AMP.
20dB GAIN
C27 1μF
PRI.
SEC.
T1
C7 470pF
C8 470pF
C9 1μF
R15 100Ω
R16 24Ω
R17 2K
R18 2K
R25 470Ω
R32 100Ω
R33 24Ω
R34 2K
R35 2K
Q4 VN66AF (MOUNT ON HEATSINK)
Q5 VN66AF (MOUNT ON HEATSINK)
R19 R20 R21 R22 R23 R24
6X24Ω
R26 R27 R28 R29 R30 R31
6X24Ω
LINEAR AMP.
21+dB GAIN
C10 1μF
C28 1μF
-12F
+12F
T2
L1 .82μH
L2 .82μH
C12 270pF
C13 470pF
C14 270pF
OUTPUT LOW-PASS FILTER
SW1 ON OFF
R36 51Ω 1/2W
OUTPUT
J2
+12V
-12V
Z1
Z2
Z3
Z4
C19 1μF
C20 1μF
C21 1μF
C22 1μF
+12F
-12F
T1, T2, AND L1-L2
SEE WINDING INSTRUCTIONS
P1 = T1
P2 = T2
P3 = L1-L2
SW1
Z6
L2
T2
J2
Q5
R36
C28
LAST USED
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS
FIVE-WATT 12MHZ AMPLIFIER
DRAWN BY B.T.
DATE 11-22-89
DRAWING NO.
CHECKED BY
SCALE
APPROVED BY
W.O.
BISHOP GRAPHICS/ACCUPRESS
REORDER NO. A38361
89-1122-1

Intensity Stabilizing Servo
(The Noise Eater)



July 25, 1989 YG

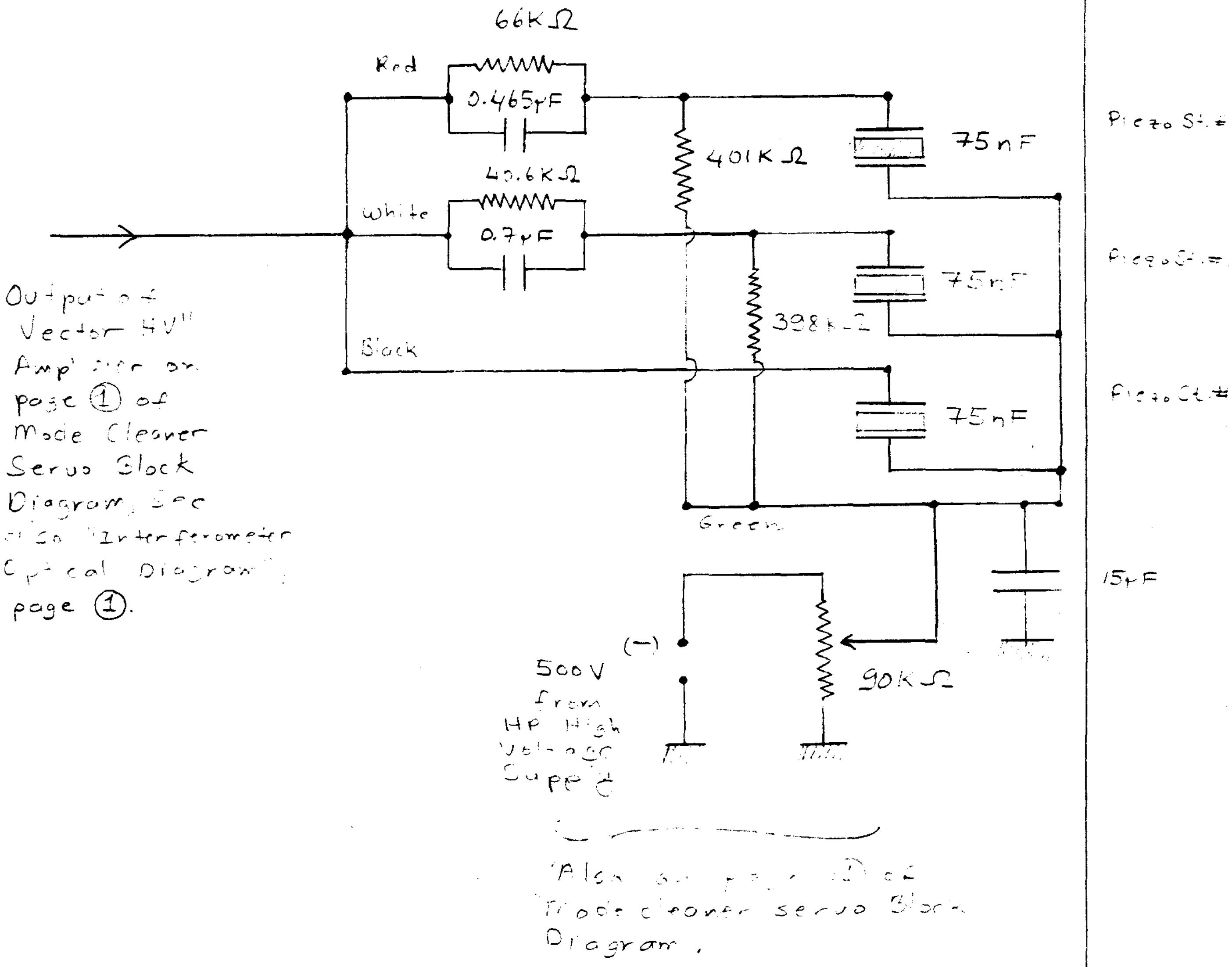
NOISE EATER SENSING DIODE 2/27/85 MEZ



Photodiode Amplifier
(See "The Intensity Stabilizing Servo" and the "Interferometer Optical Diagrams")

3 Piezo Stack Balancing Network

(For the Laser "BARNEY")

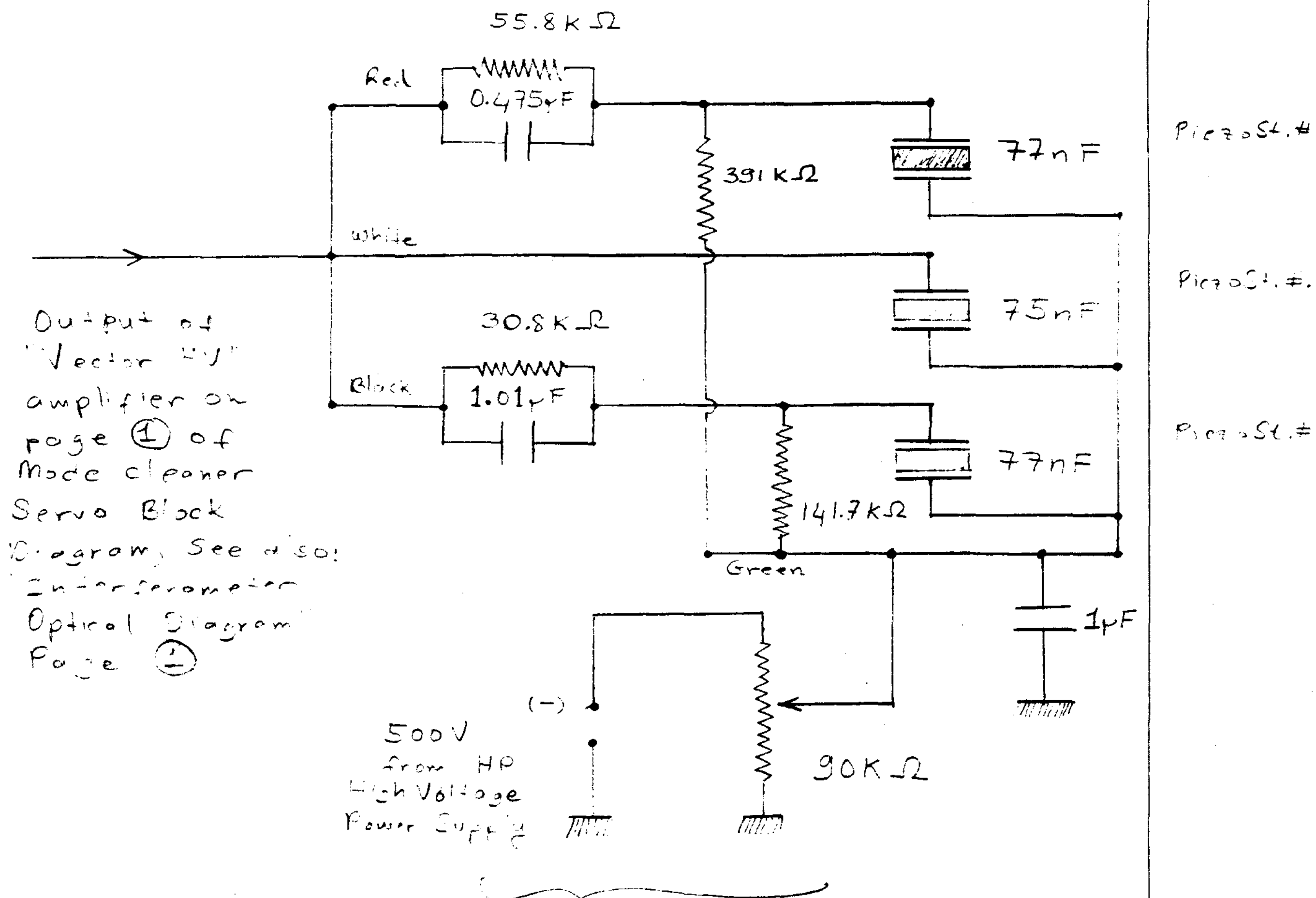


Page ① of ①

July 25, 1989

3 Piezo Stack Balancing Network

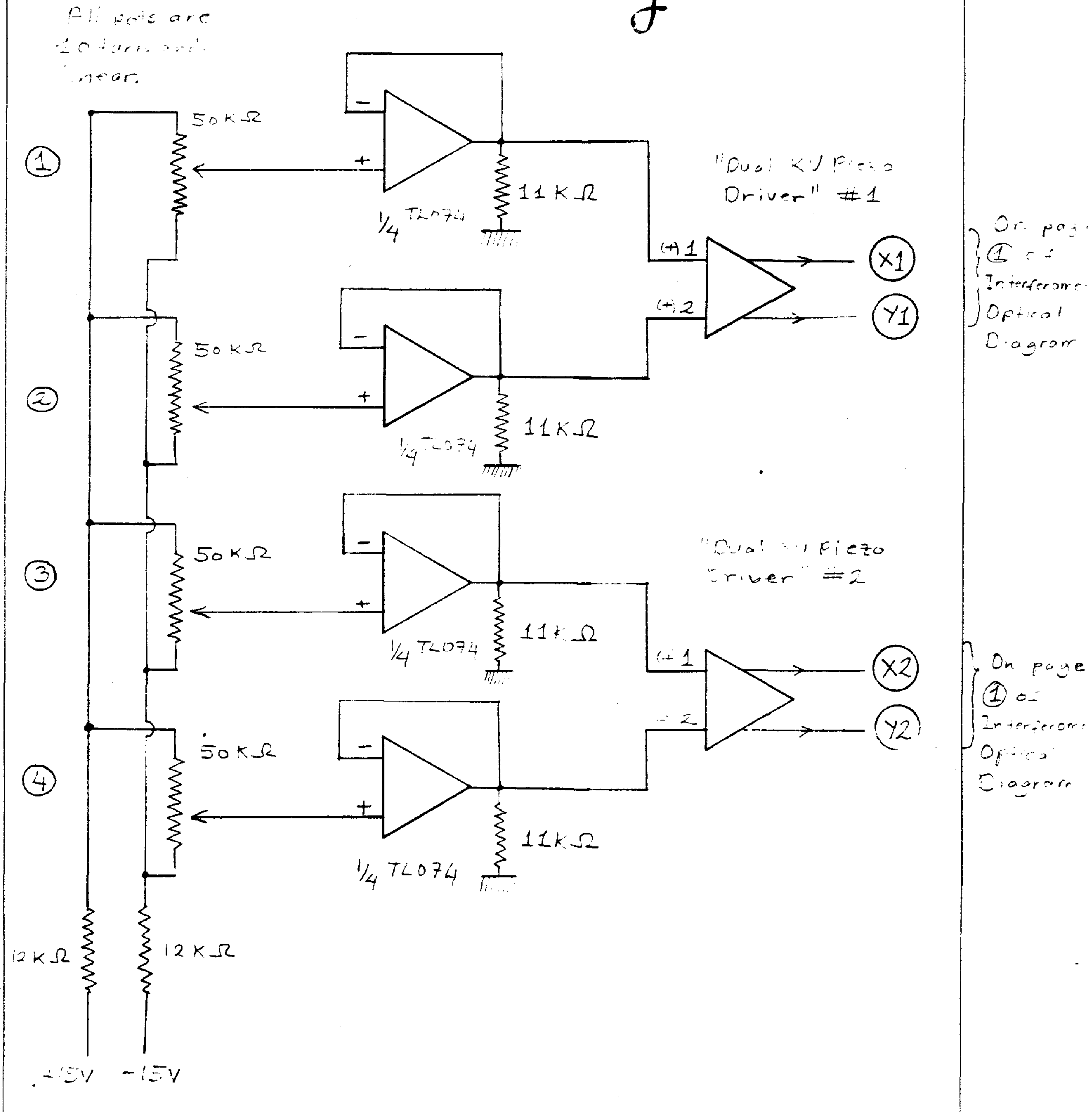
(For the laser "FRED")



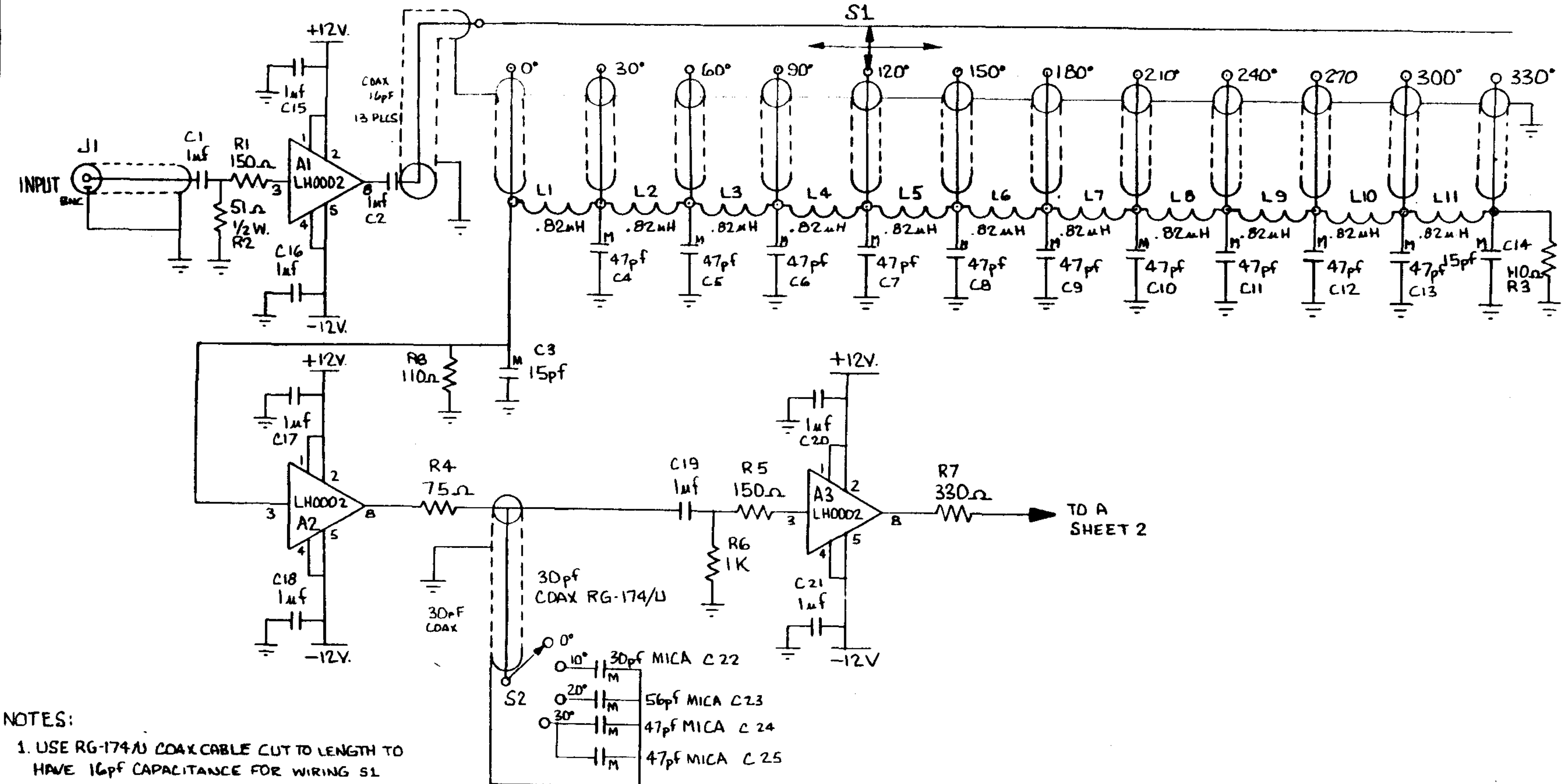
Also on page ① of Mode Cleaner Servo Block Diagram

July 25, 1989

Mode Cleaner Alignment Fine Tuning



July 20, 1988

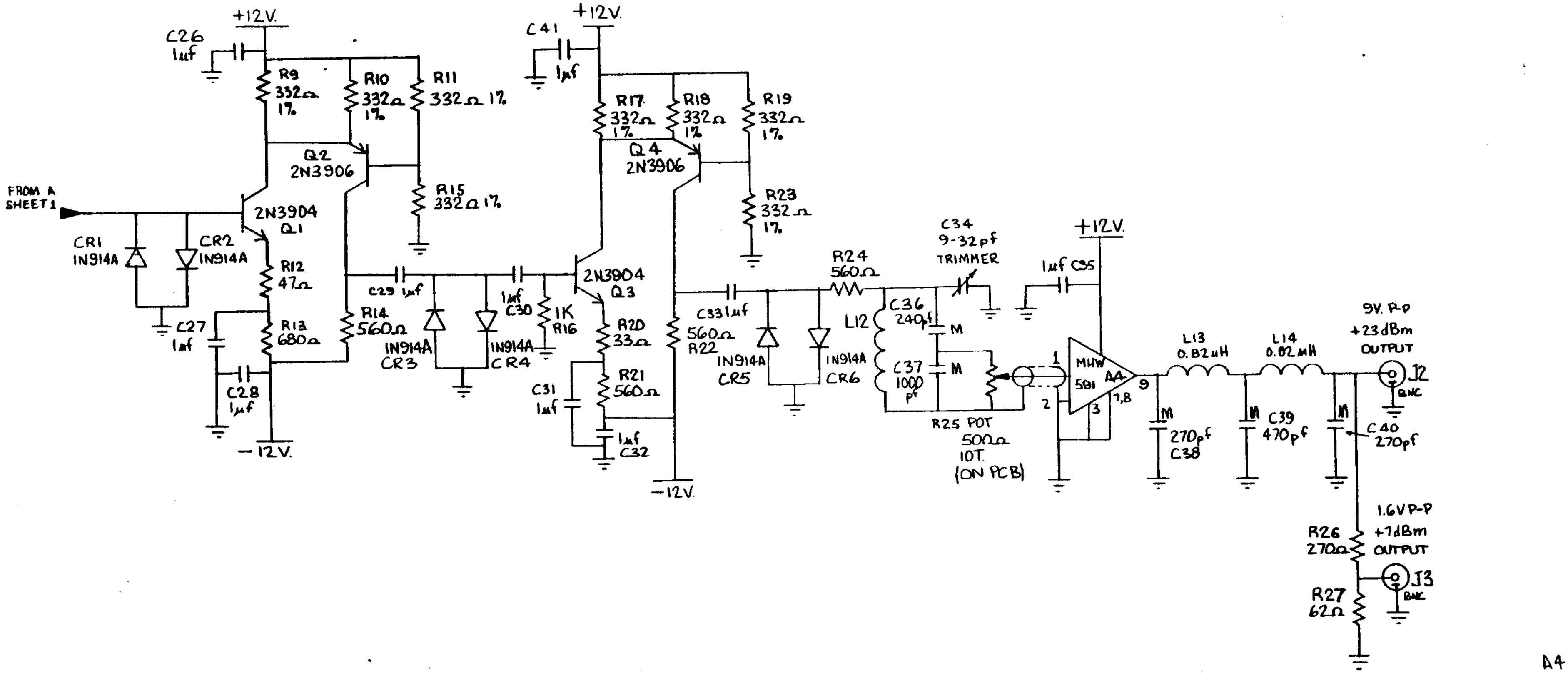


NOTES:

1. USE RG-174/U COAX CABLE CUT TO LENGTH TO HAVE 16pF CAPACITANCE FOR WIRING S1 FROM TERMINALS TO IND. 0.82uH
2. COAX FROM 75Ω/1uf NODE (OUTPUT OF A2) TO S2 WILL BE CUT TO A LENGTH TO HAVE A 30pf CAPACITANCE. DRESS COAX AWAY FROM COMPONENTS ON P.C.B.
3. GND ALL COAX FROM ISO-BNC ON FRONT PANEL TO P.C. CARD GND. PLANE.

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
12.33 MHZ. LIMITER PHASE SHIFTER SHEET 1		
DRAWN BY B T	DATE 11-6-87	DRAWING NO.
CHECKED BY	SCALE NONE	-1
APPROVED BY	W.O.	

87-1106-1



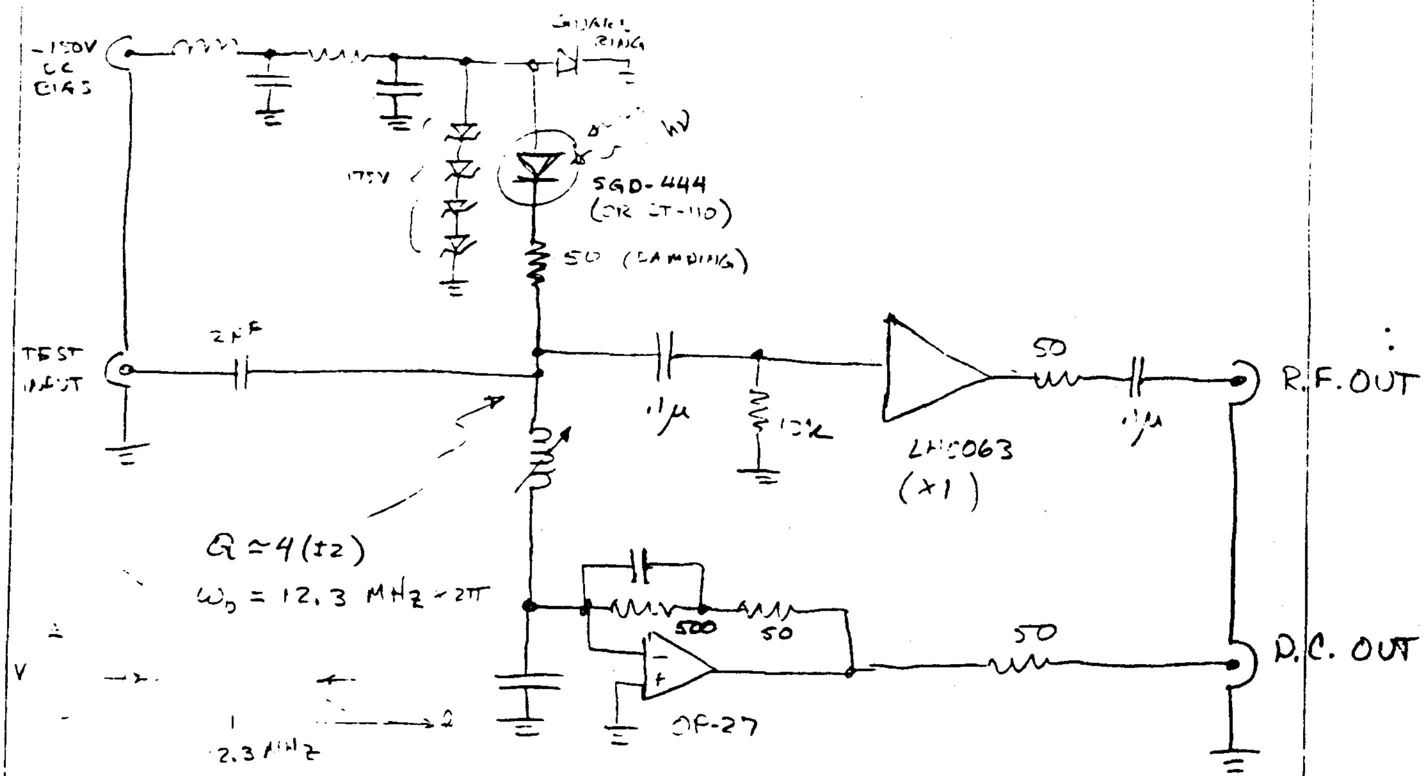
A4
Q4
J3
L14
CR6
C40
LAST NO. USED R27

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS	
12.33 MHZ. LIMITER PHASE SHIFTER SHEET 2	
DRAWN BY B.T.	DATE 11-6-87
CHECKED BY	SCALE
APPROVED BY	W.O.
DRAWING NO.	-2

87-1106-2

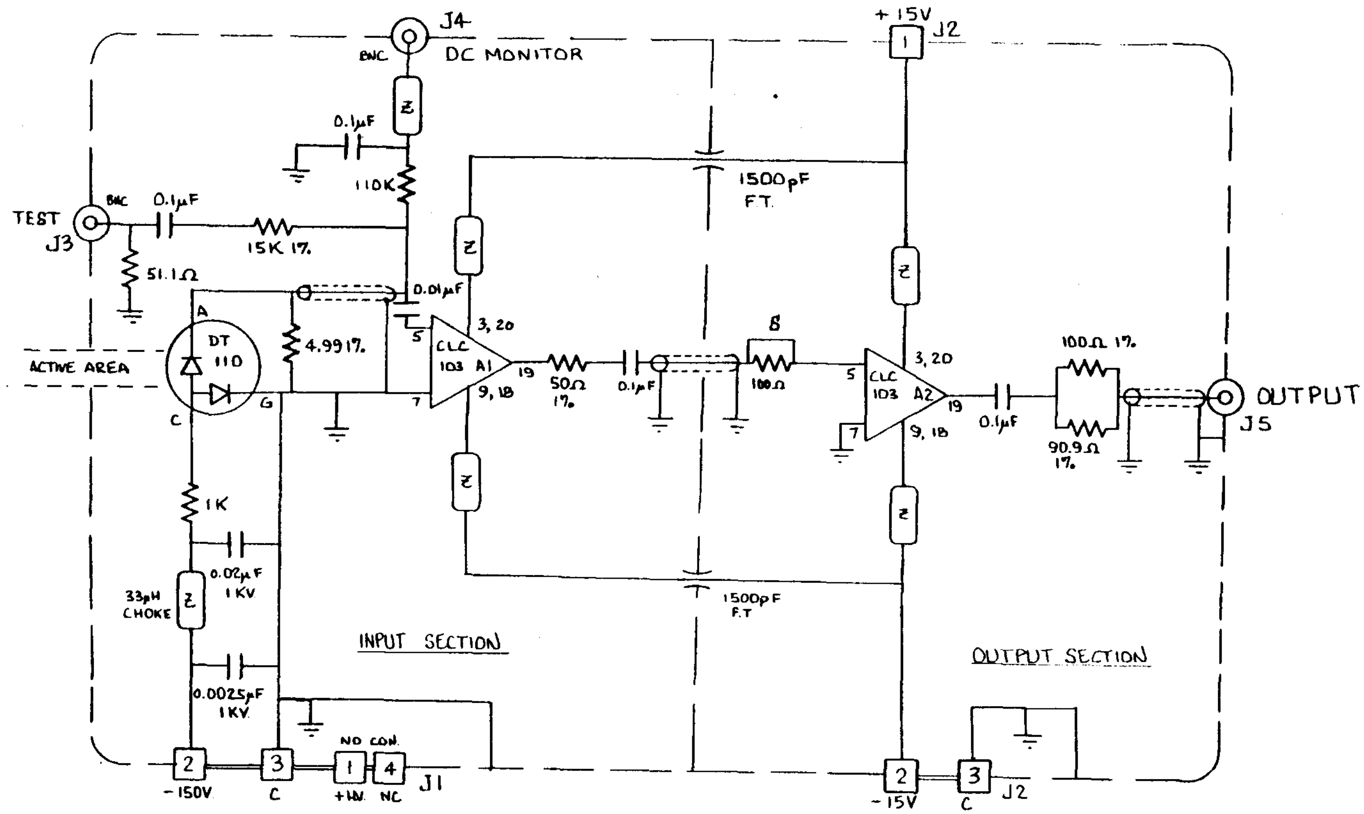
11/14/88 MEZ

MODE CLEANER SERVO PHOTODIODE / BUFFER
(STANDARD CALTECH FRONT END)



R.F. DARK NOISE ≃ SHOT NOISE AT 1mW, 5145 Å

The First and The Second Arm Photodiodes are the same as this one. [illegible] July [illegible], 198[illegible]

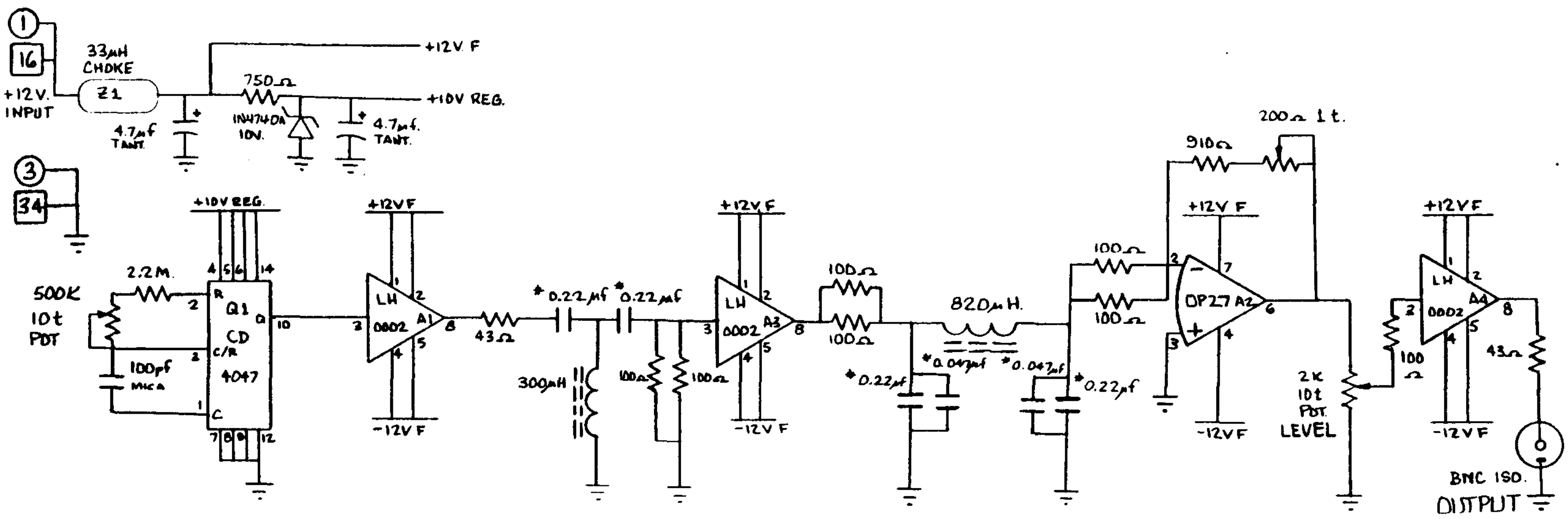


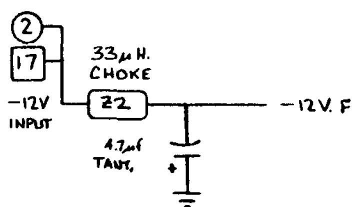
NOTE
1. COMPONENTS MARKED "Z" ARE 33µH CHOKES
2. RESISTORS 1/4W 5% UNLESS MARKED.
3. J1 IS 4-PIN LEMO
4. J2 IS 3-PIN LEMO

FAST PHOTODIODE AMP 3/29/88

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
FAST PHOTODIODE AMPLIFIER SHT. 1		
DRAWN BY B.T.	DATE 3/29/88	DRAWING NO.
CHECKED BY	SCALE	-1
APPROVED BY	W.O.	

32 329-1





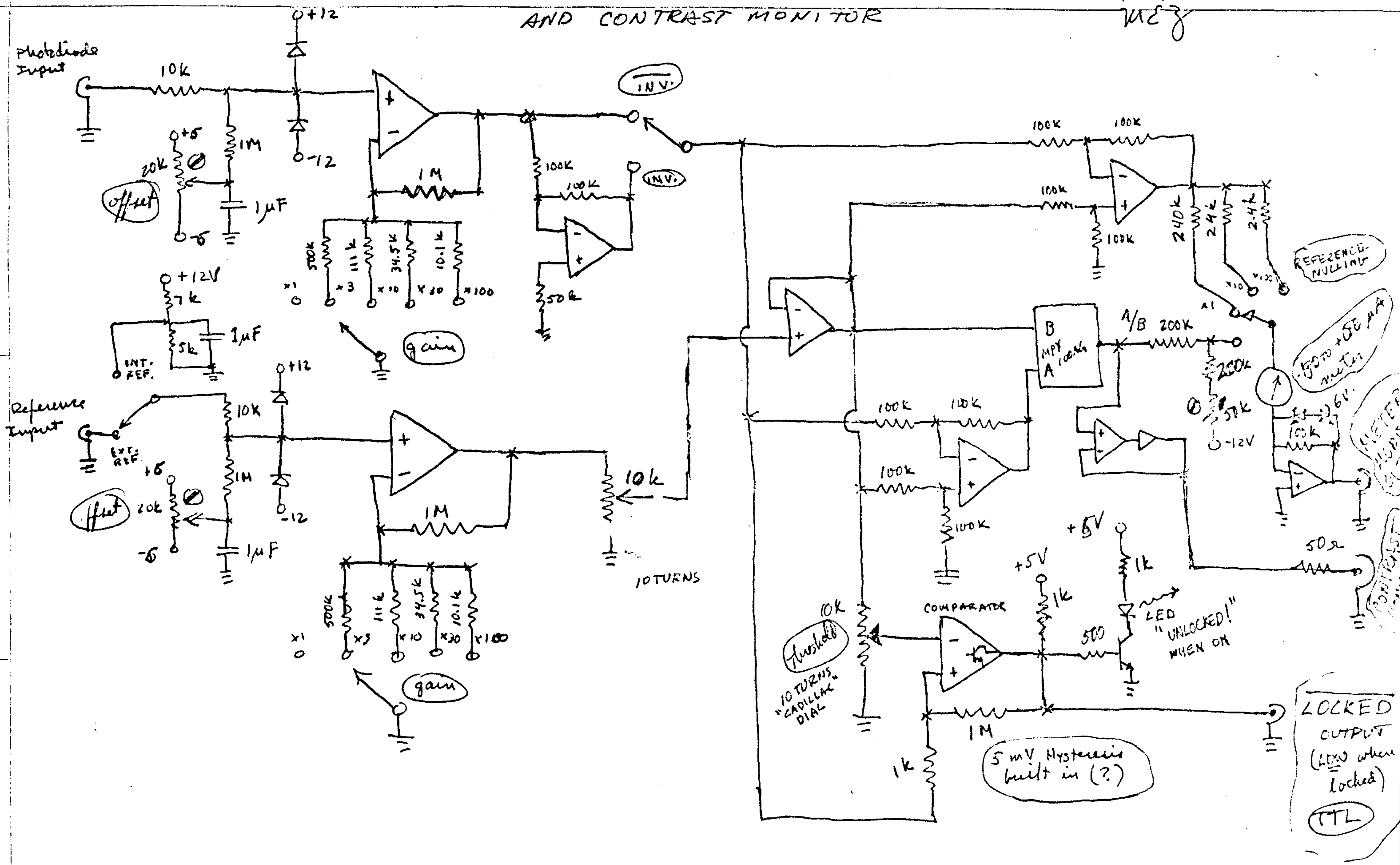
3. * DESIGNATES MYLAR DIELECTRIC CAPACITOR.
2 ◯ LEMO CONN. F.P.
NOTES: 1 ☐ NIM-BIN POWER CONNECTOR. BACK PANEL

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
COMB CALIBRATOR		
DRAWN BY B.T.	DATE 9-24-87	DRAWING NO.
CHECKED BY	SCALE	-1
APPROVED BY	W.O.	

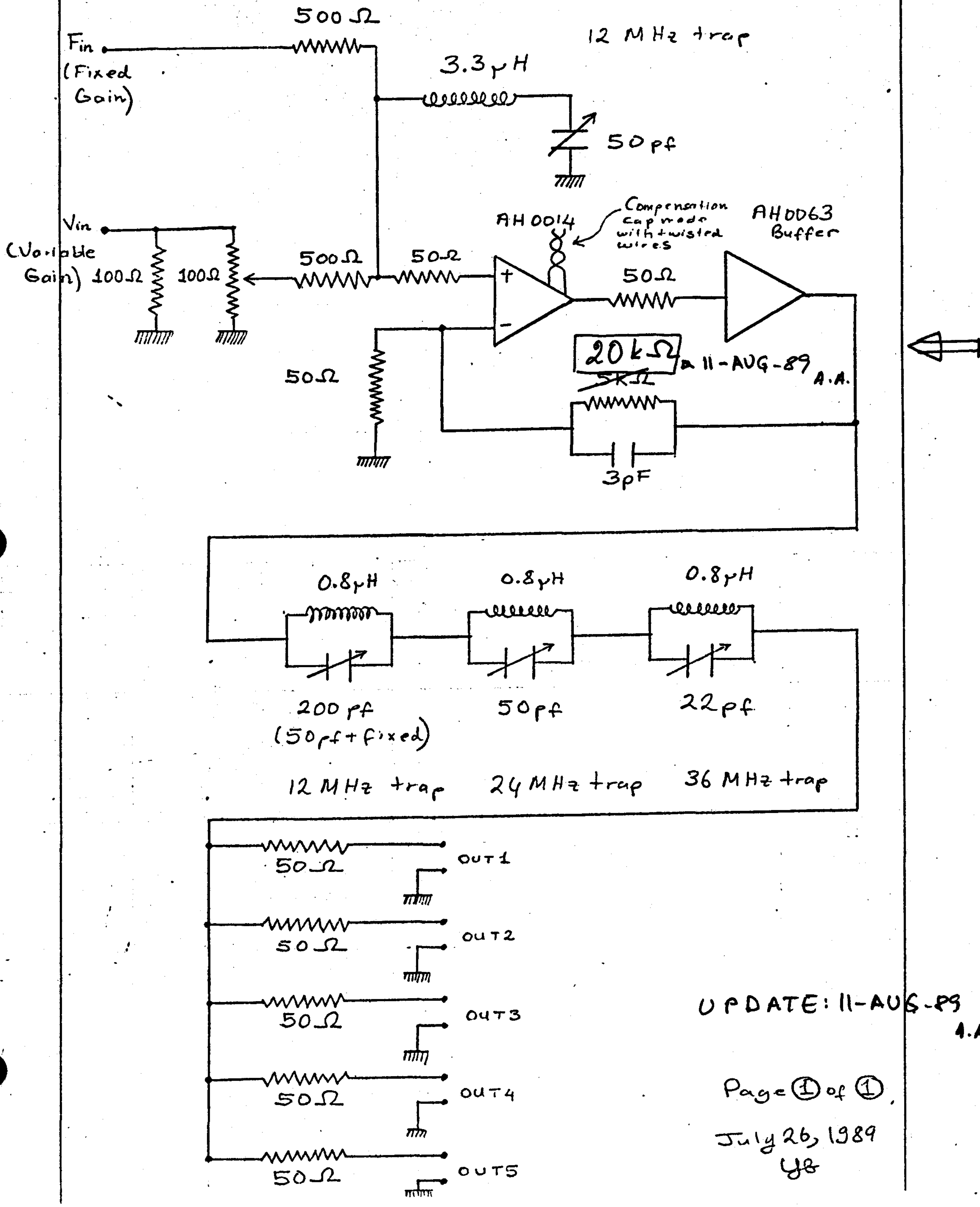
87-0924-1

LOCKUP DISCRIMINATOR AND CONTRAST MONITOR

7/17/86
MEZ



"Fast 1" Amplifier

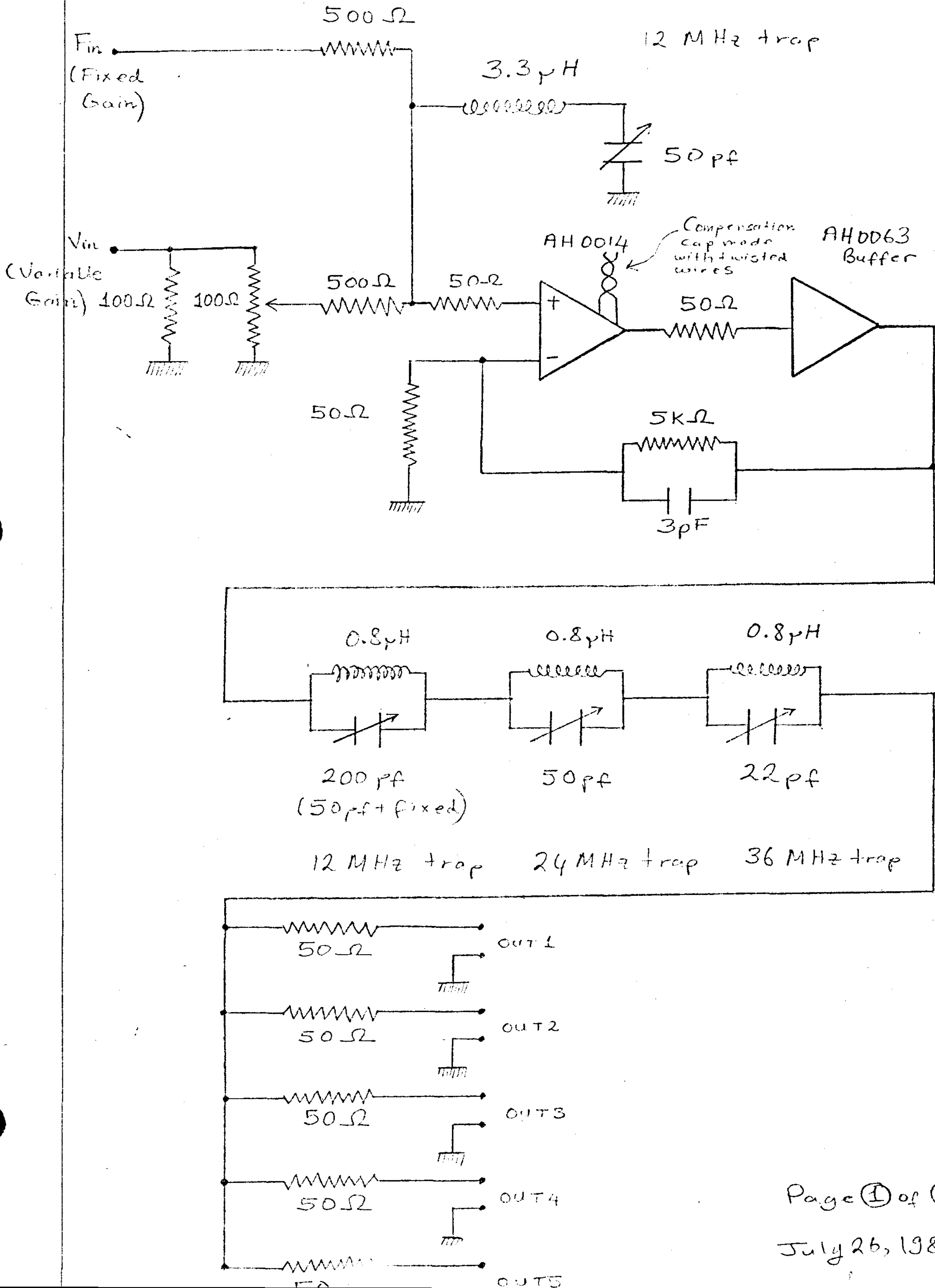


UPDATE: 11-AUG-89
A.A.

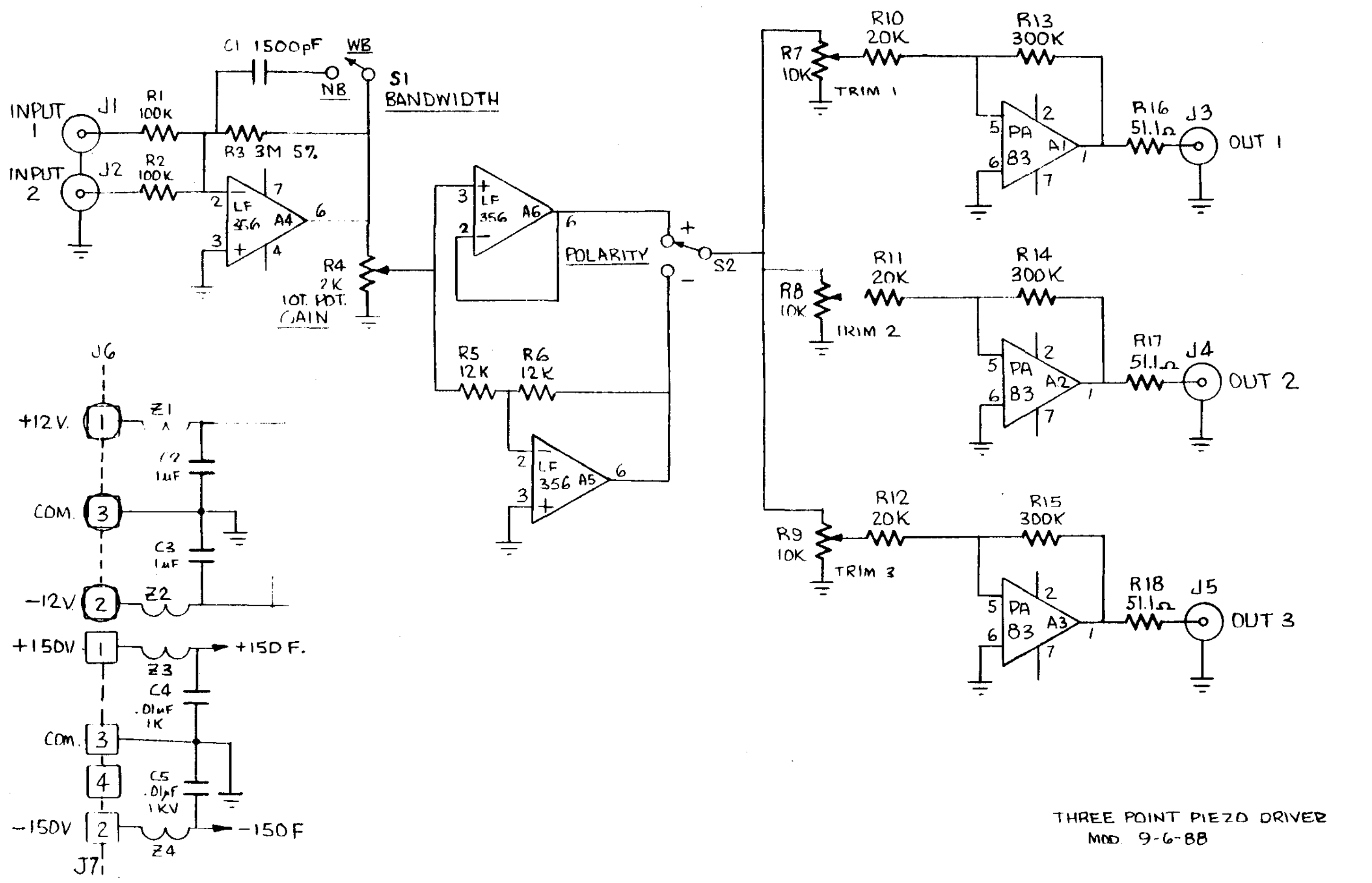
Page 1 of 1

July 26, 1989
YB

"Fast 1" Amplifier



July 26, 1989



THREE POINT PIEZO DRIVER
MOD. 9-6-88

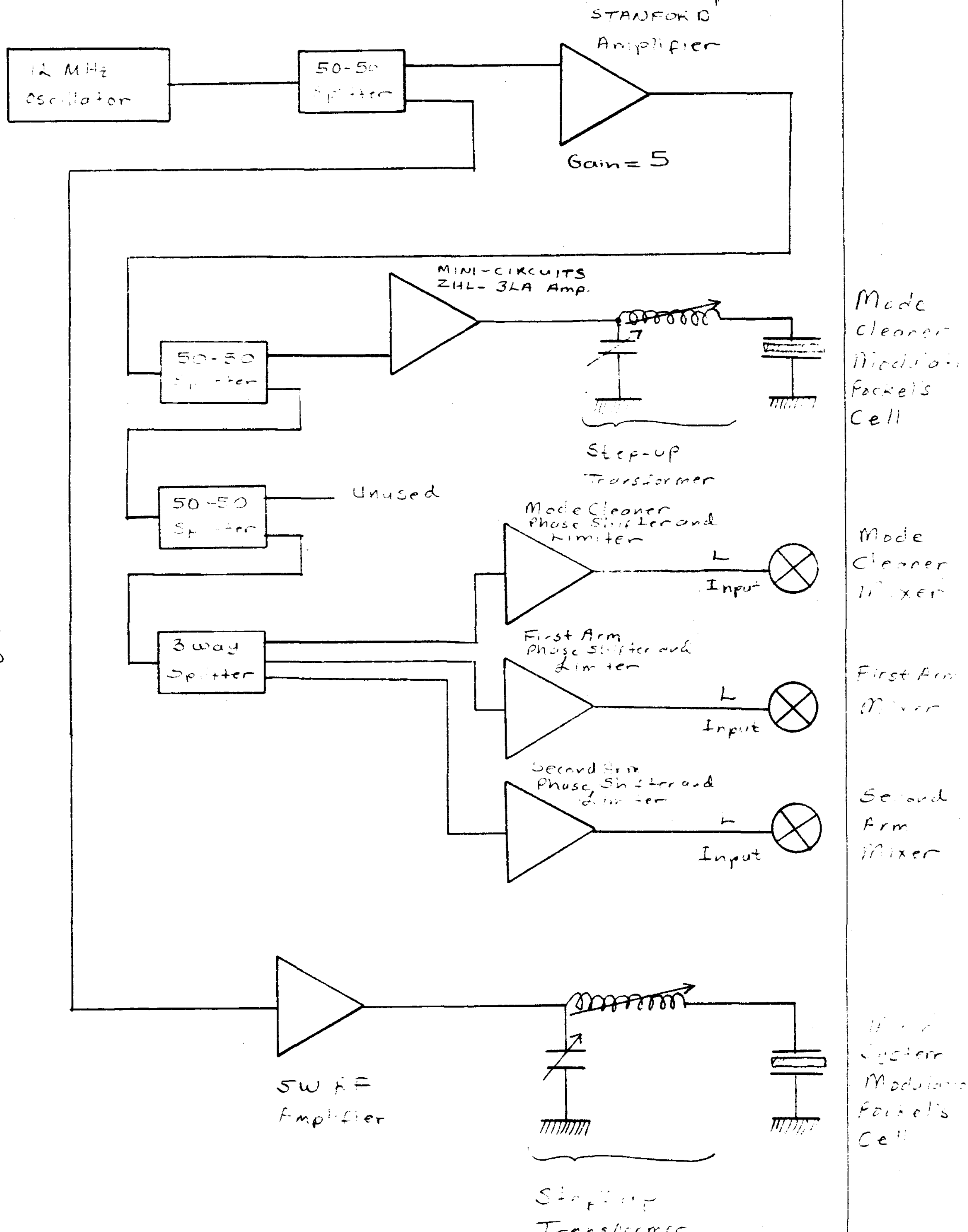
A6
S2
C1
R18
LAST J5

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
THREE POINT PIEZO DRIVER		
DRAWN BY B.T.	DATE 9-1-88	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

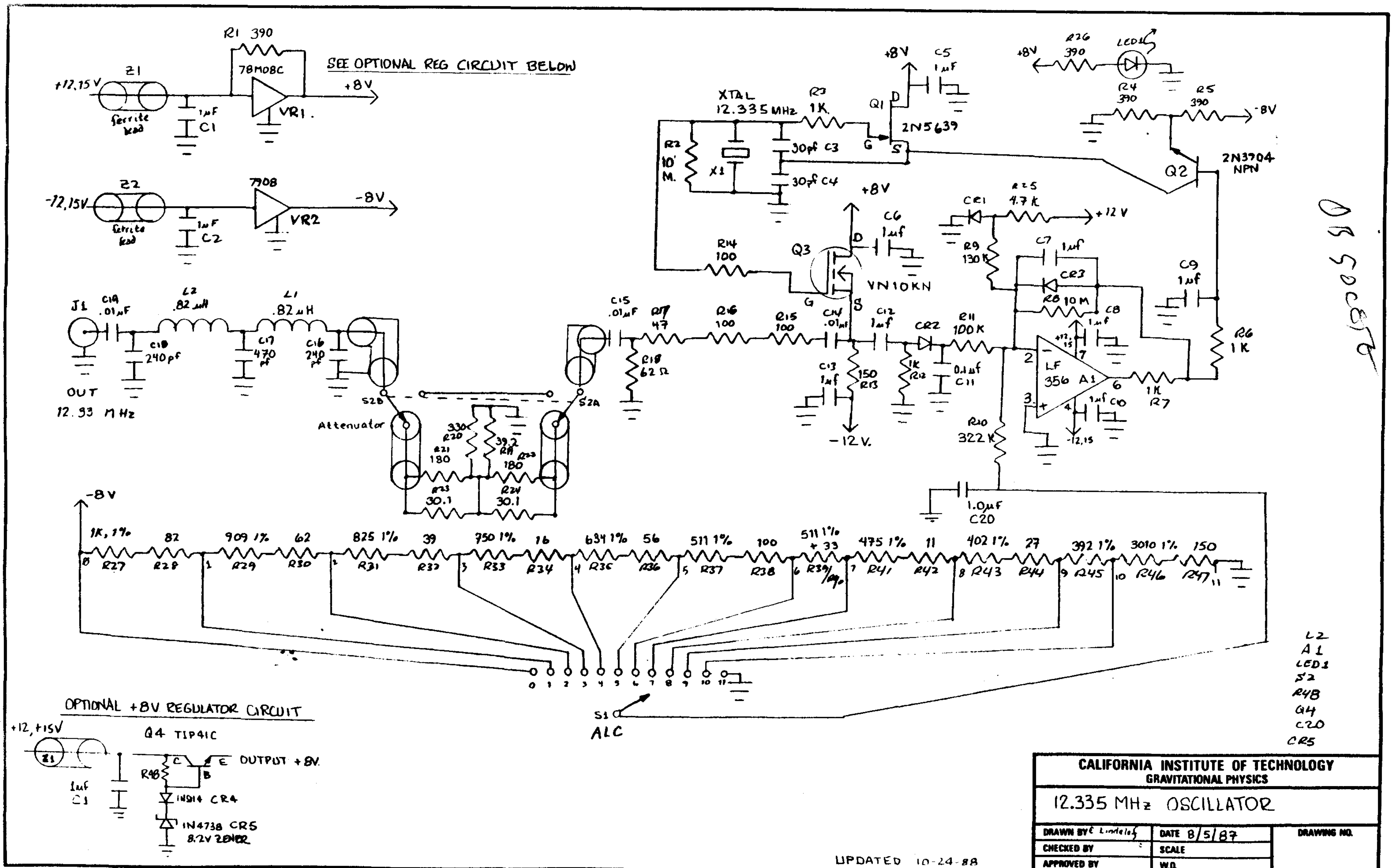
SEP 6 '88
UPDATED TO —

88-0901-1

12 MHz RF distribution for Modulation:



July 24, 1986



BISHOP GRAPHICS/ACCUPRESS REORDER NO. A38361

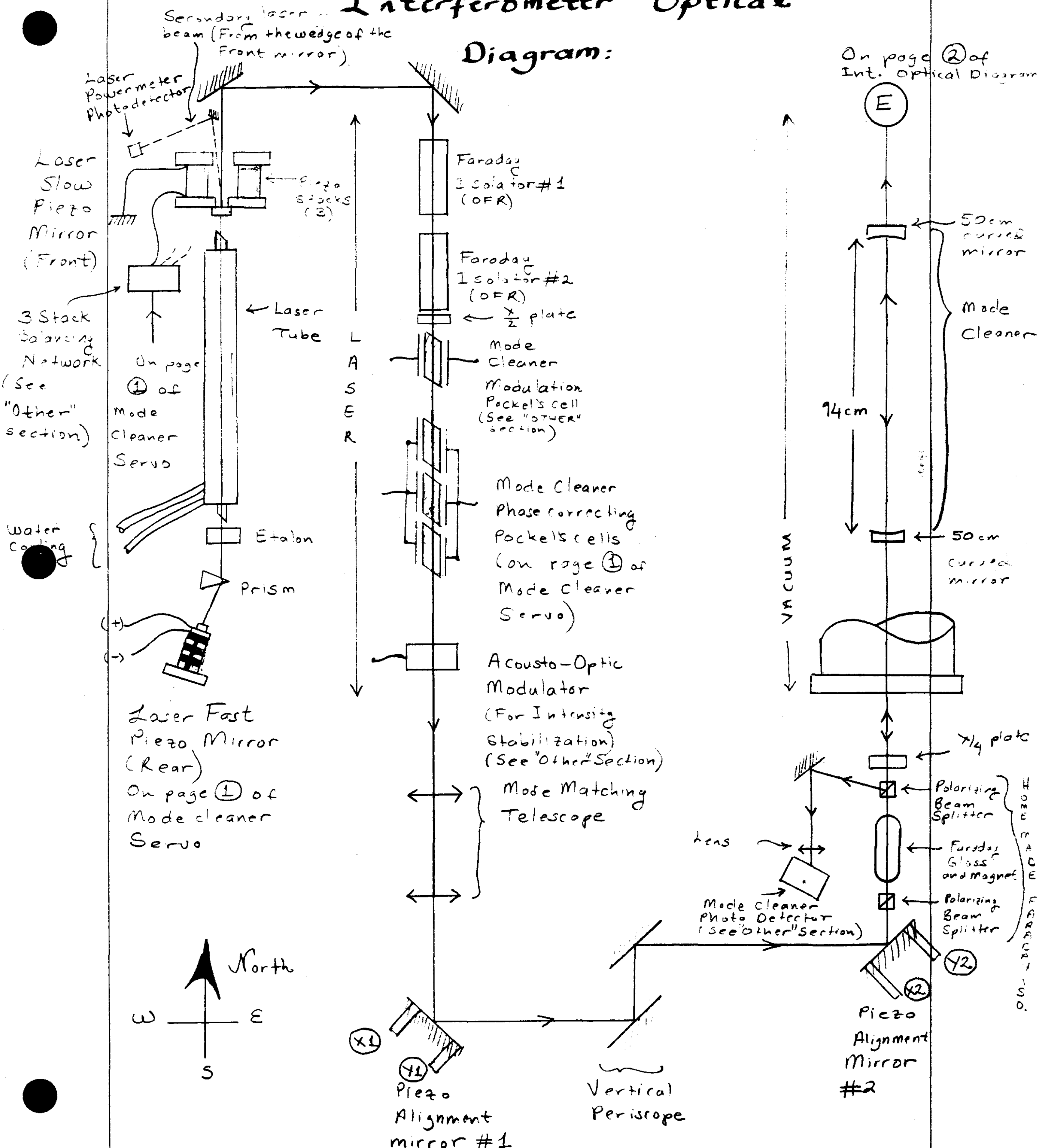
87-0805-1

BATCH START

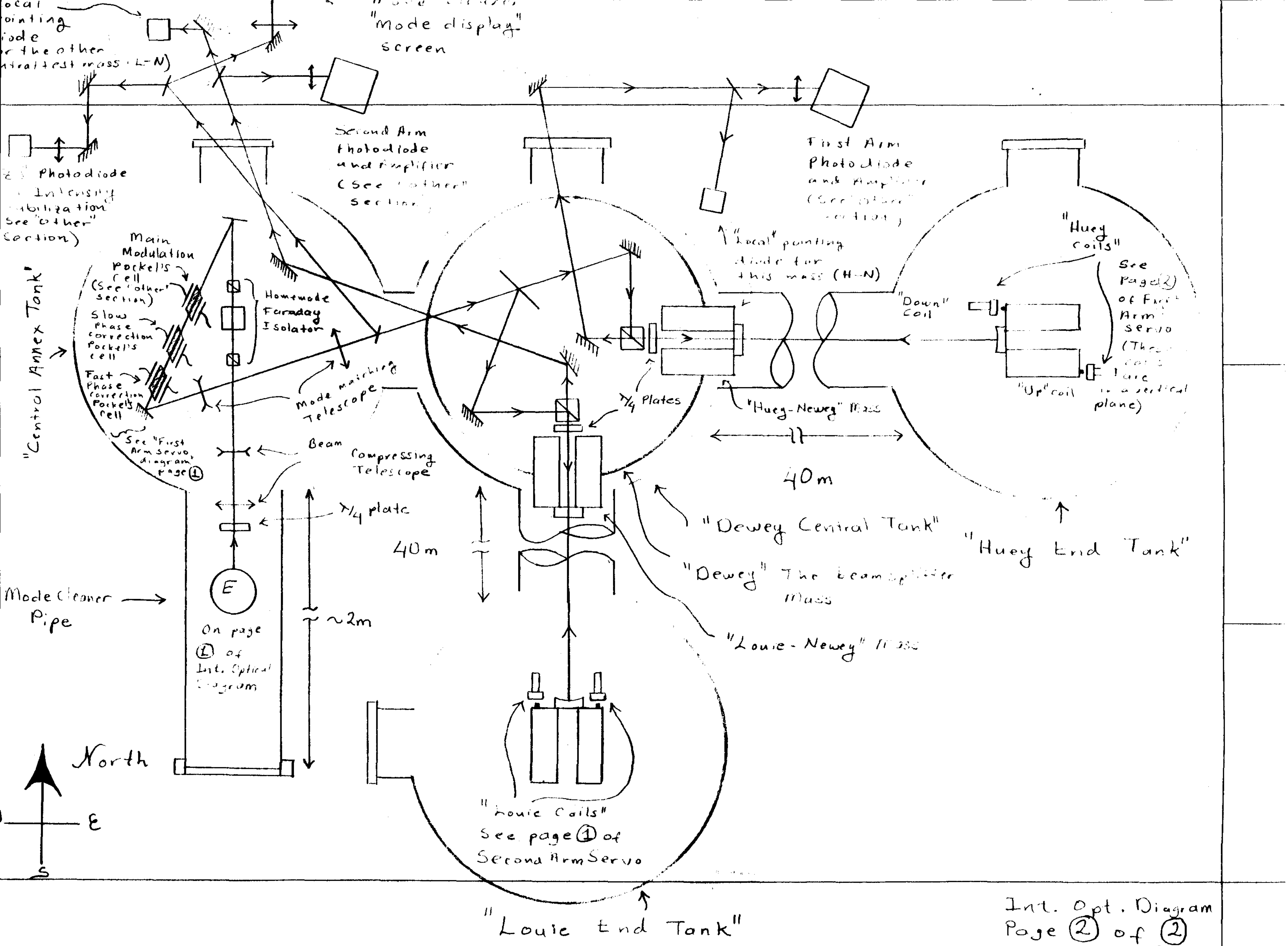
Optical

STAPLE
OR
DIVIDER

Interferometer Optical Diagram:



July 24, 1989 YG



Int. Opt. Diagram
Page 2 of 2
July 25, 19 96