New Folder Name Prototype Data Book

LIGO-T900033-00-D

LIGO 40m PROTOTYPE SERVO SYSTEM DATA BOOK

M. E. ZUCKER

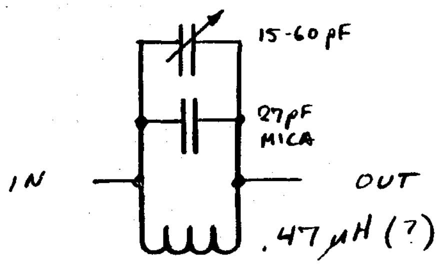
5 DECEMBER 1990
VERSION 1.0

B. LASER LOOP: GENERAL

10/10/90 MEZ

LASER STABILIZATION LOOP

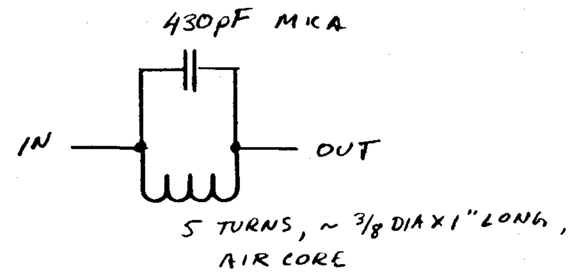
RF REJECTION FILTERS;



12.3 MHz REJECT

-35 dB peak atten

-3dB BW 7MHz - 16MHz



24.6 MHz REJECT

- 17 dB peak atten

-3dB BW 23 MHz - 25 MHz

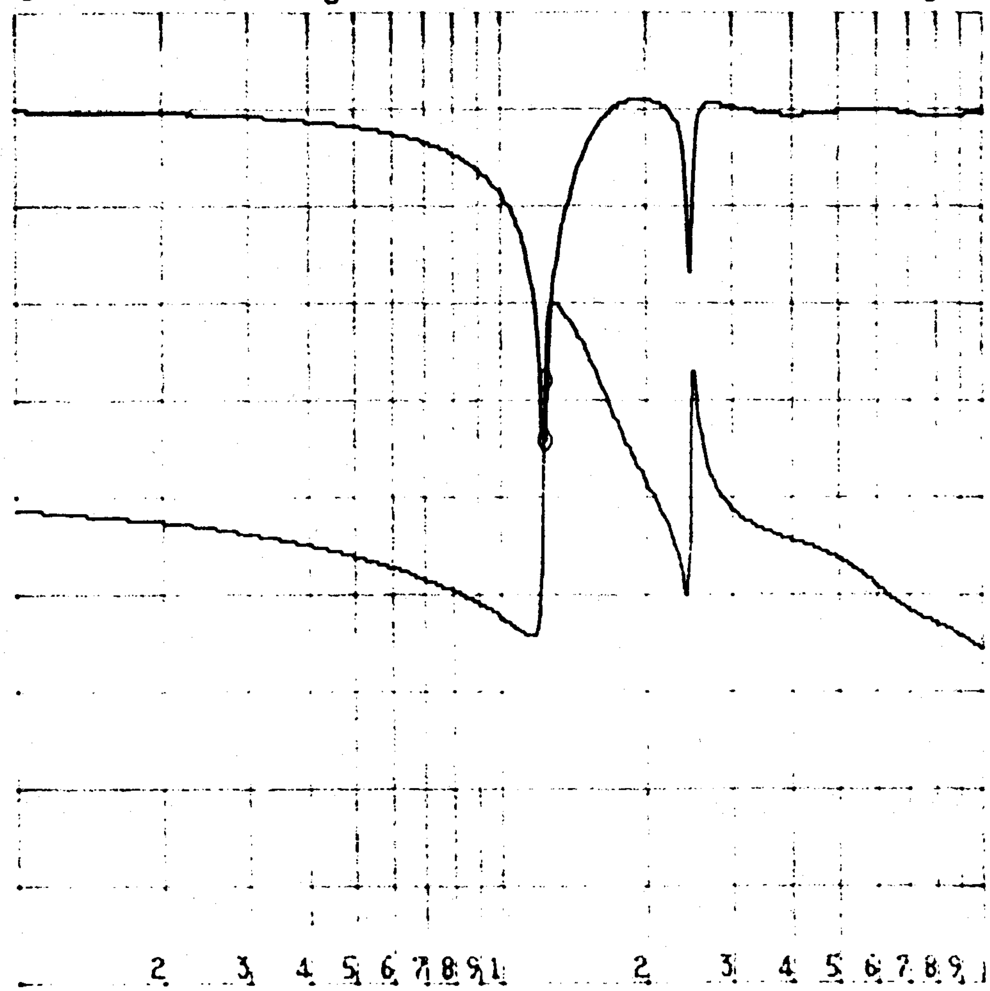
TRANSFER FUNCTION OF BOTH IN SERIES
STORED ON HP4195A FLOPPY DISK
DISK LABEL "ZUCKER, START 10/10/90, DISK #1"
FILE NAME "LLNOTCHES1"

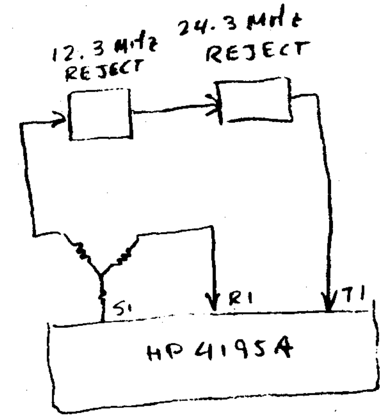
10/10/90 mEγ

NETWORK

A: REF B: REF 0 MKR 12 302 687.708 Hz
10.00 225.0 T/R -34.1216 dB
[dB][deg] θ 54.4350 deg

TRANSFER FUNCTION,
LASER SERVO LOOP
RF REJECTION
NOTCH FILTERS



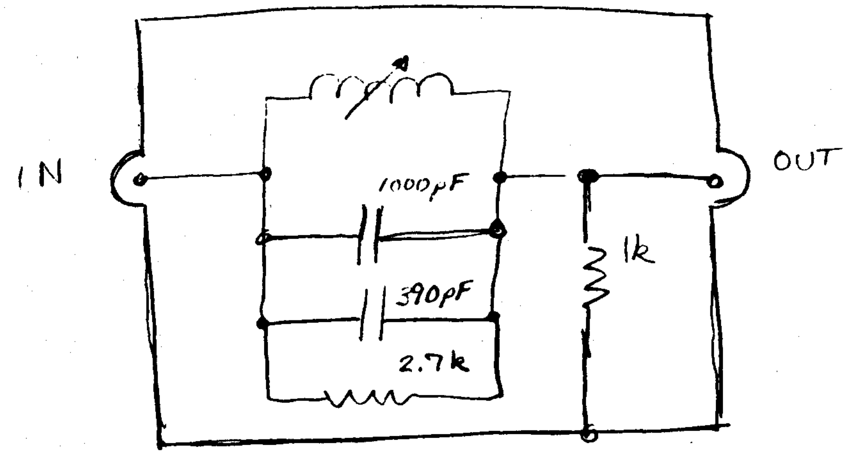


FILE "LLNOTCHES1"
DISK #1, 10/10/90, "ZUCKER"

DIV DIV START 1 000 000.000 Hz
10.00 45.00 STOP 100 000 000.000 Hz
RBW: 1 KHz ST: 4.33 sec RANGE: R= 10, T= 10dBm

11/8/90
MEZ

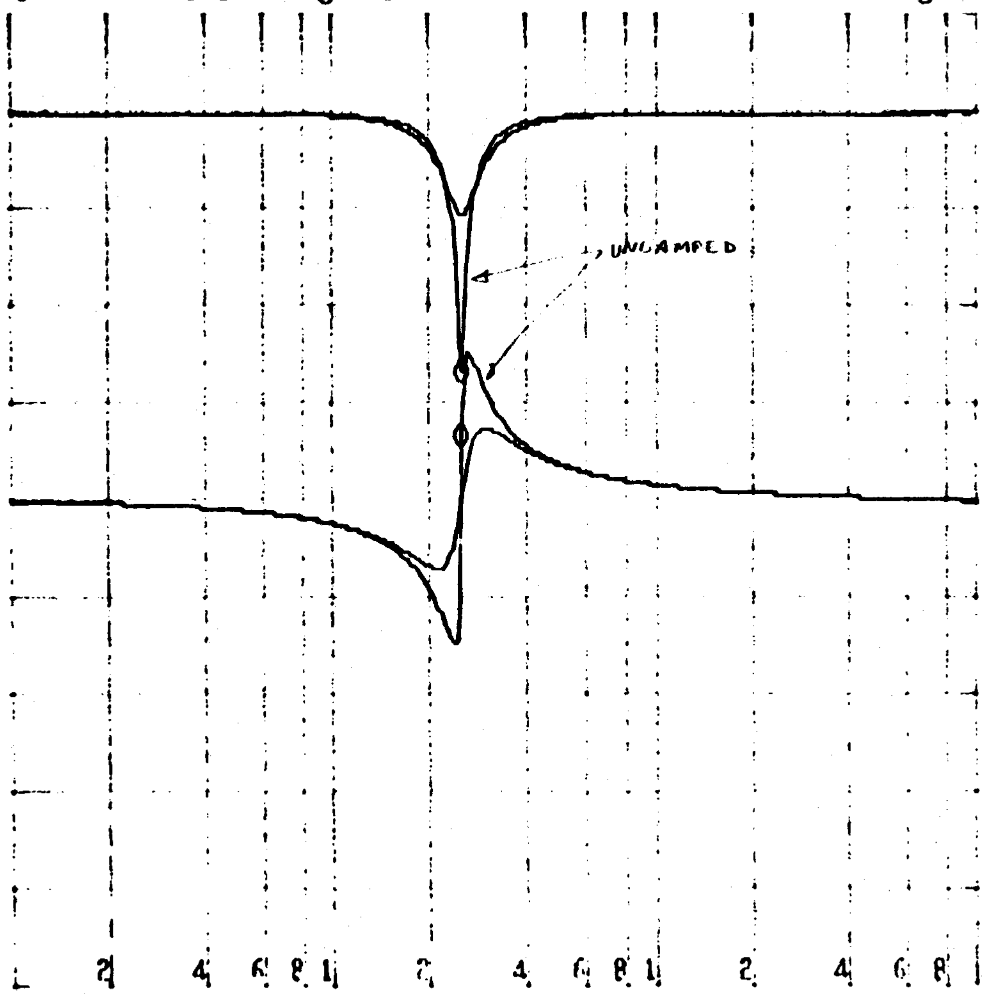
FAST PZT NOTCH FILTER



11/6/9[illegible] -2}

NETWORK Cor

A: REF	B: REF	0 MKR	252 638.771 Hz	
10.00	225.0	T/R	-27.0474	dB
[dB]	[deg]	θ	28.8915	deg



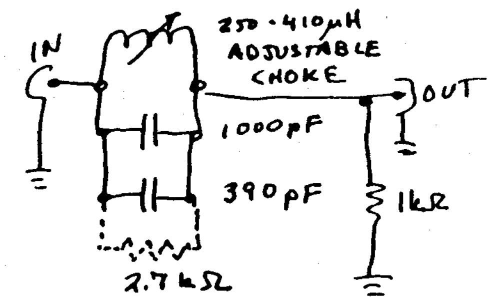
DIV	DIV	START	10 000.000 Hz
10.00	45.00	STOP	10 000 000.000 Hz

RBW: 300 Hz ST: 13.7 sec RANGE: R= 10, T= 0dBm
REF= 1.00000E+01

XF
FP2T NOTCH FILTER

RED, BLUE :
AS BEFORE,
NO DAMPING SHUNT

BLACK, PURPLE :
2.7kΩ DAMPING
SHUNT ACROSS LC

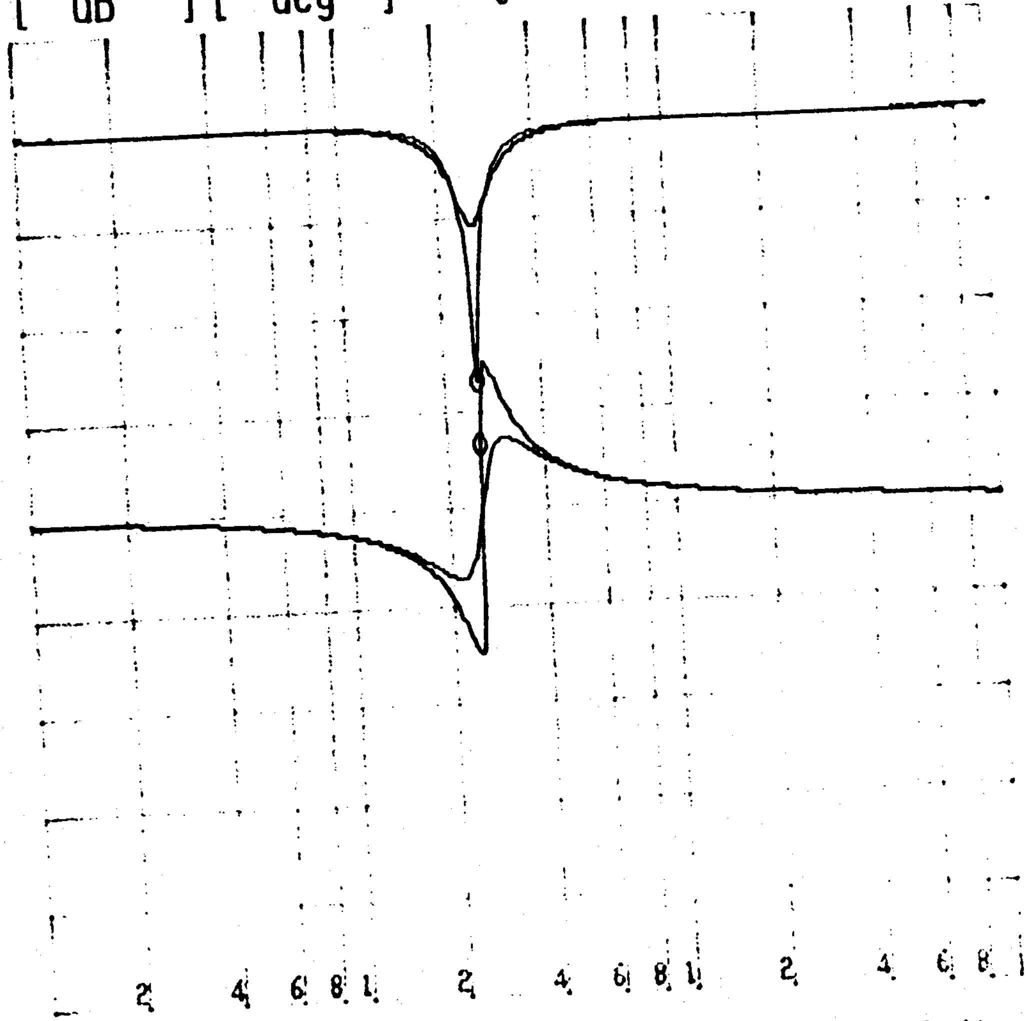


(TEST COND: DRIVEN BY
50Ω SOURCE
OF 4195A & SPLITTER)

85

11/6/90 mej

NETWORK Cor
A: REF B: REF 0 MKR 252 638.771 Hz
10.00 225.0 T/R -27.0474 dB
[dB][deg] θ 28.8915 deg

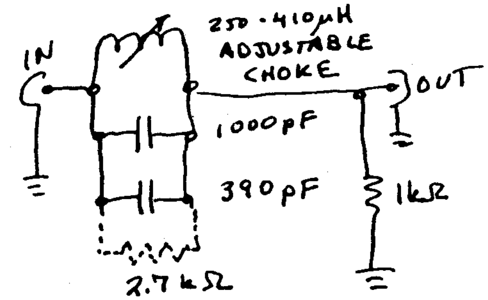


DIV DIV START 10 000.000 Hz
10.00 45.00 STOP 10 000 000.000 Hz
RBW: 300 Hz ST: 13.7 sec RANGE: R= 10, T= 0dBm

XF
FP3T NOTCH FILTER

RED, BLUE:
AS BEFORE,
NO DAMPING SHUNT

BLACK, PURPLE:
2.7kΩ DAMPING
SHUNT ACROSS LC



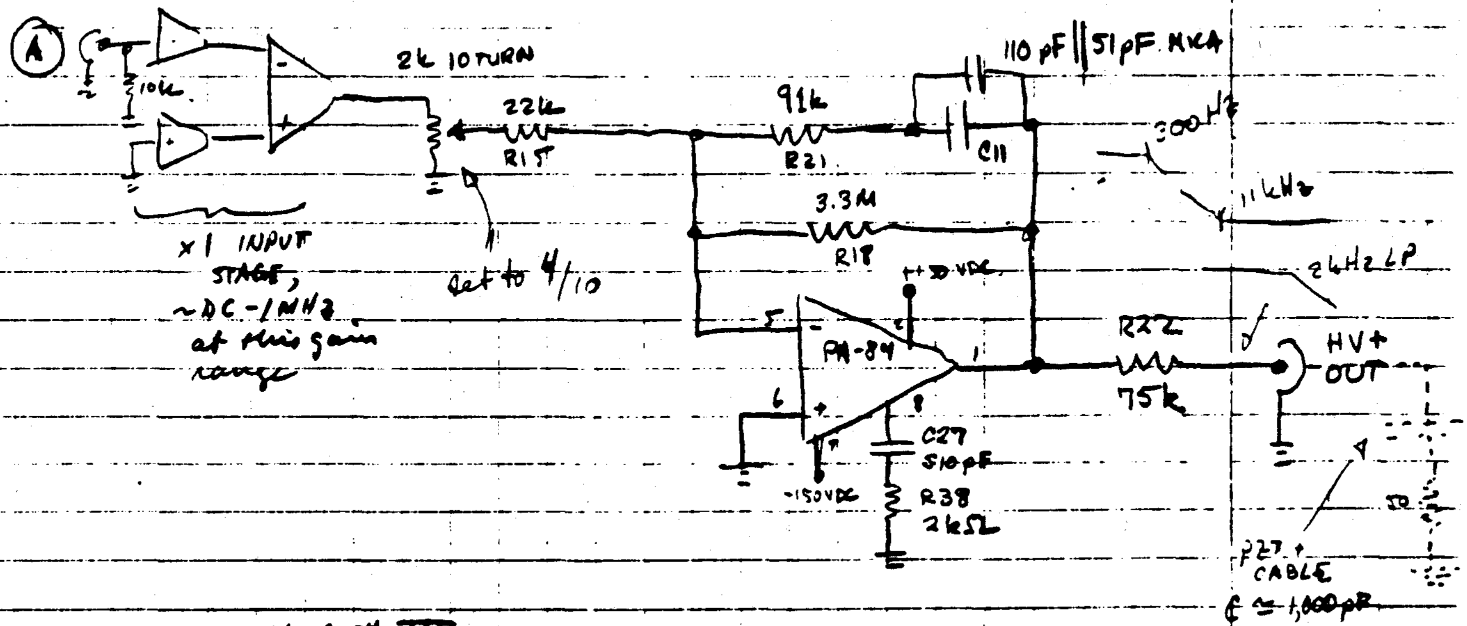
(TEST COND: DRIVEN BY
50Ω SOURCE
OF 4195A & SPLITTER)

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 amplifiers. Previously HV #1 had been used, range x1, vernier + 3/10, ⇒ D.C. Gain = 6dB effective single pole (due to Z_{out} = 160 kΩ / Z_{PZT} ≈ 800 pF) @ 1 kHz, extra phase shift at 100 kHz of about 20° due to strays in amplifier circuit (5 pF ∥ 330k ⇒ 100 kHz due to strays across FB loop!)

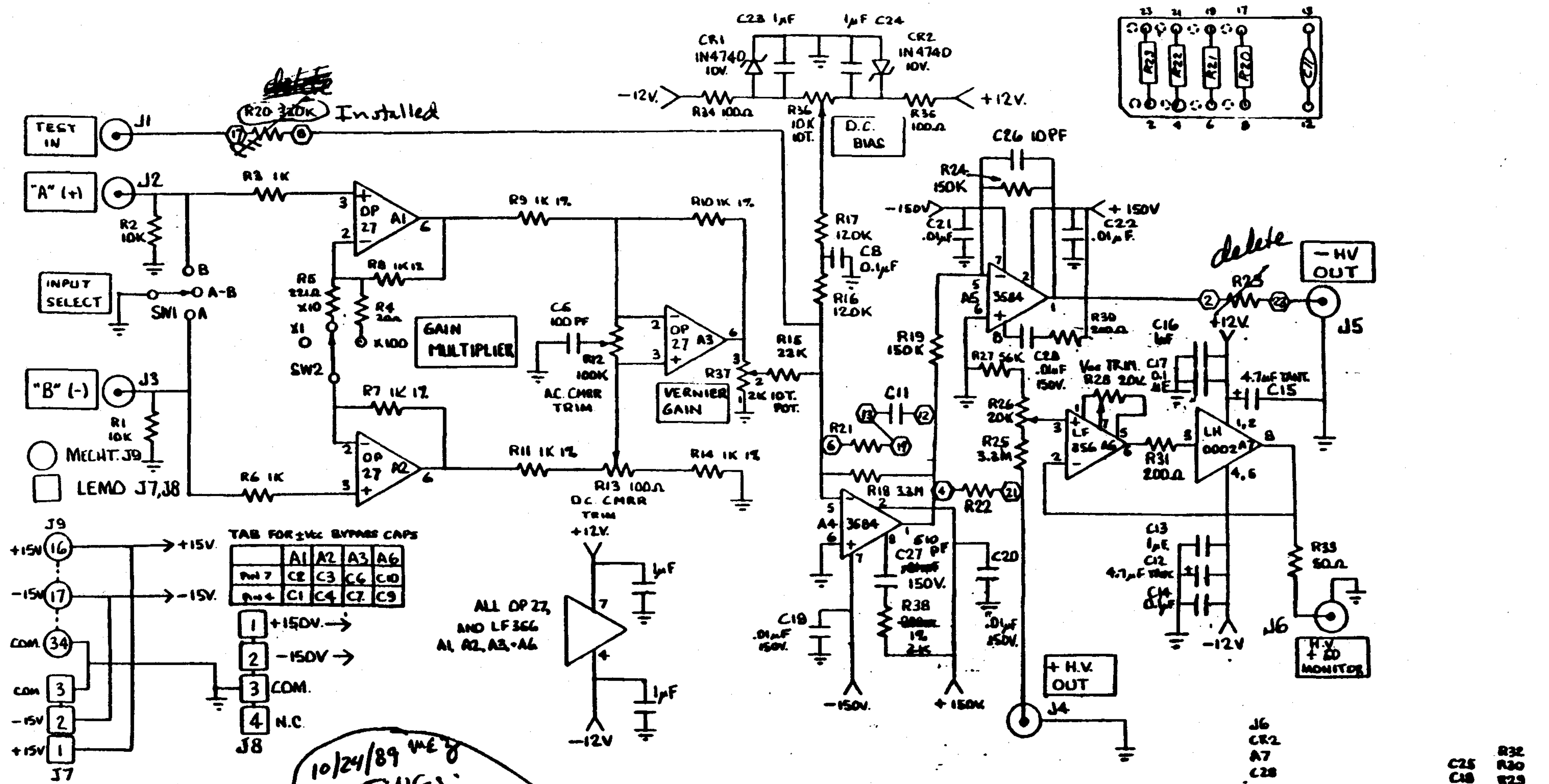
Installed improved circuit (abbreviated diagram below, complete diagram + xfer-function to follow)



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



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

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

REPLACES 87-0901-1

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

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

R20 = 330K
C11 = ~~51~~ pF → 150 pF 10/24/89 MEZ
R21 = 91K
R22 = 75K
~~R20~~ } not used
R23 }

MODIFIED 10-2~~0~~-89 B.T.

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

MOD. 1 S/N. 3

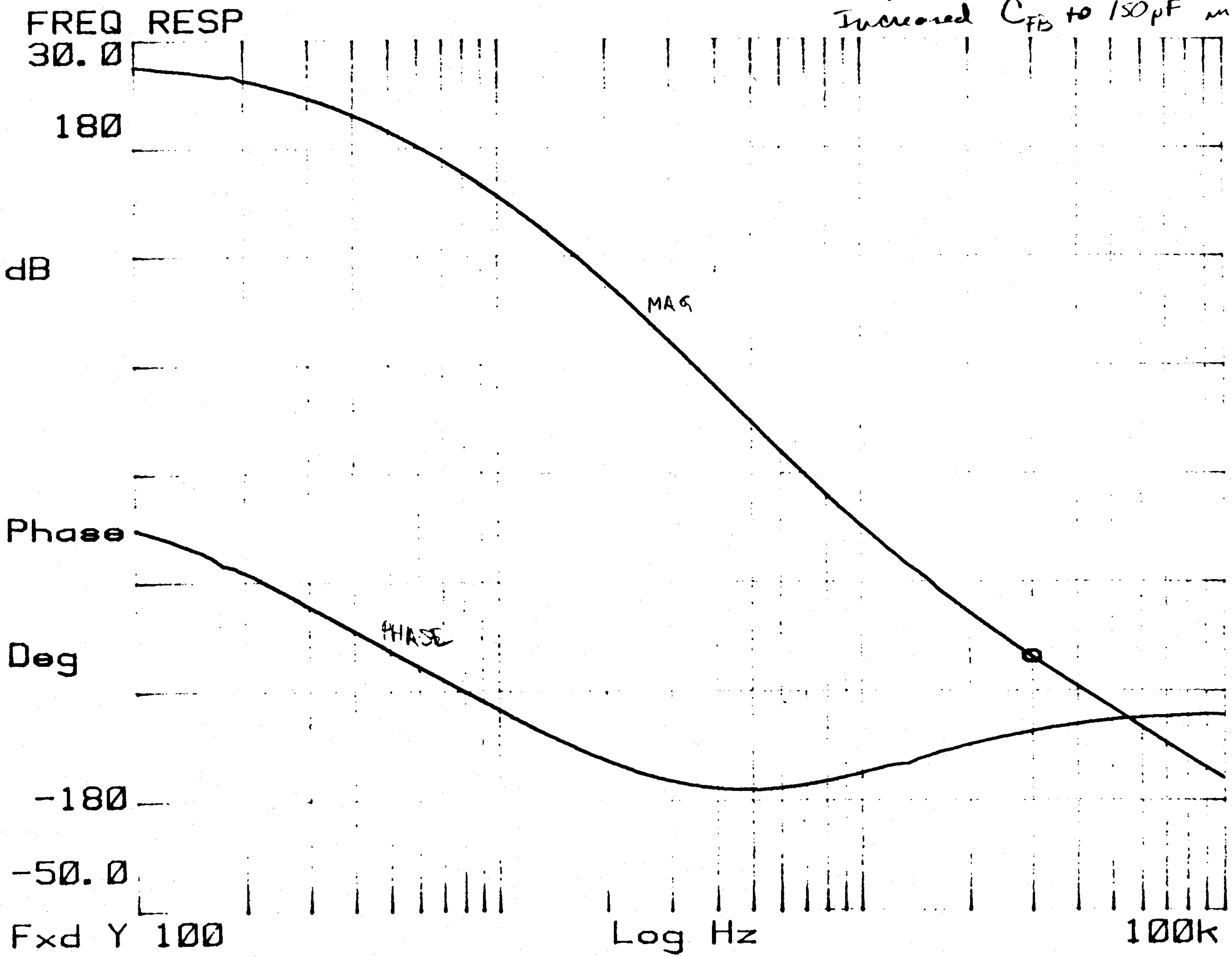
X=29.854kHz
Ya: 6.758 dB

FREQ RESP

(3)

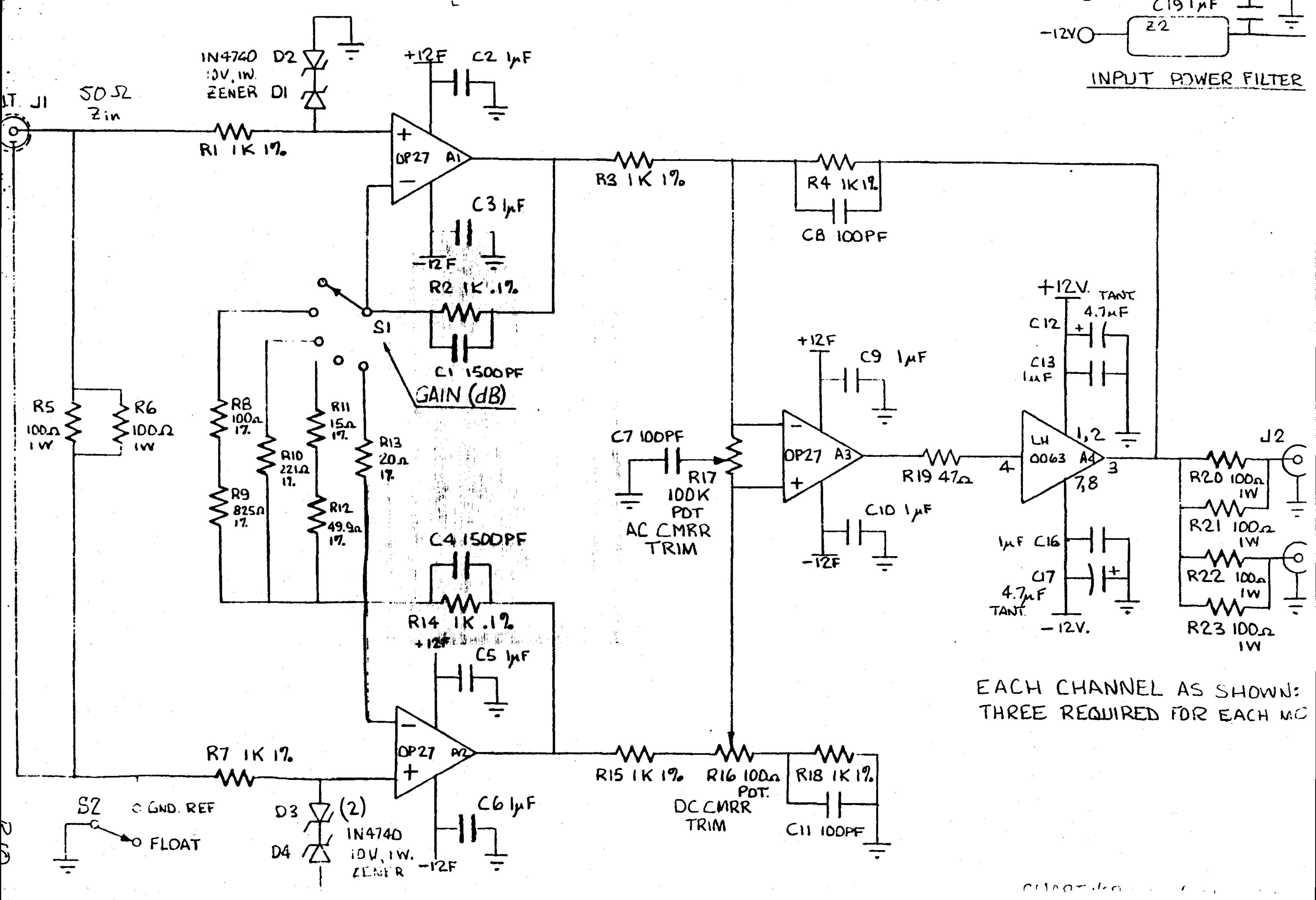
10/24/89 15:41

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



DIFFERENTIAL LINE RECEIVER

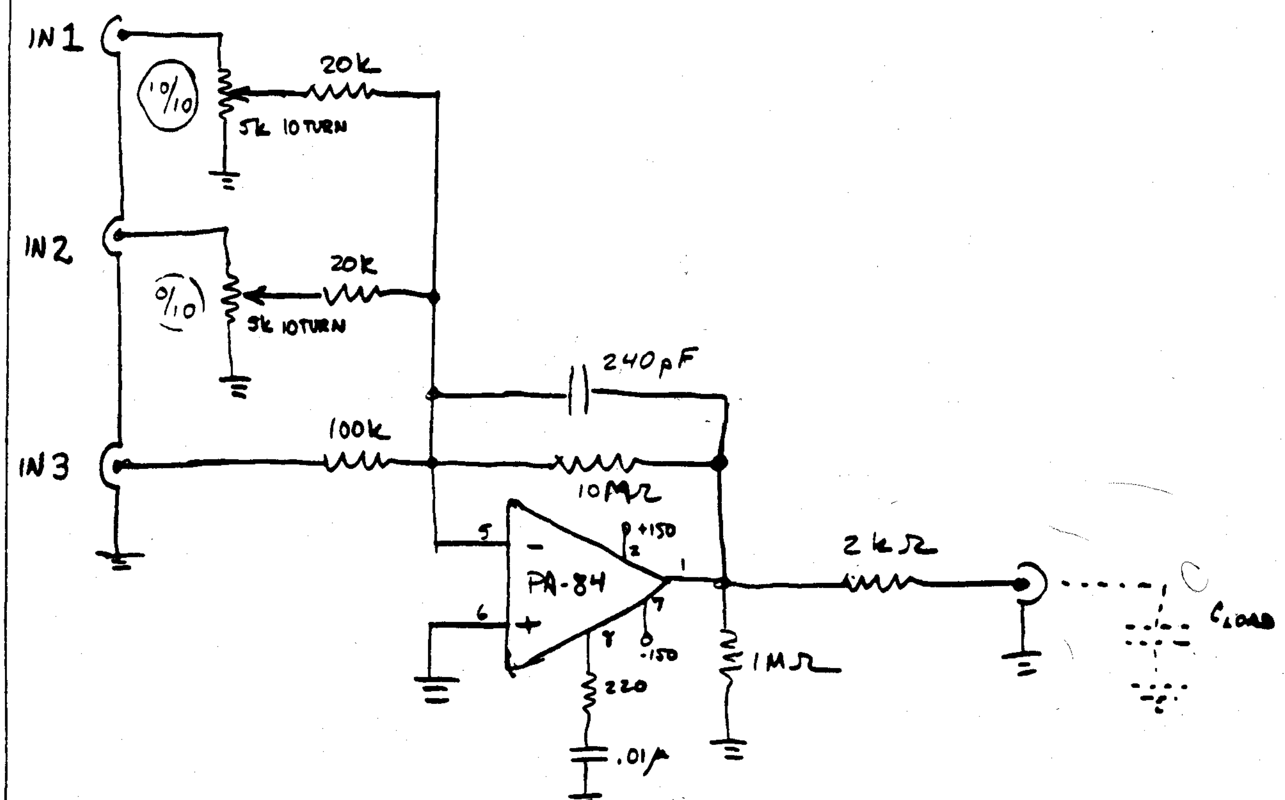
[LABELED "LINE DRIVER A" ON PANEL]

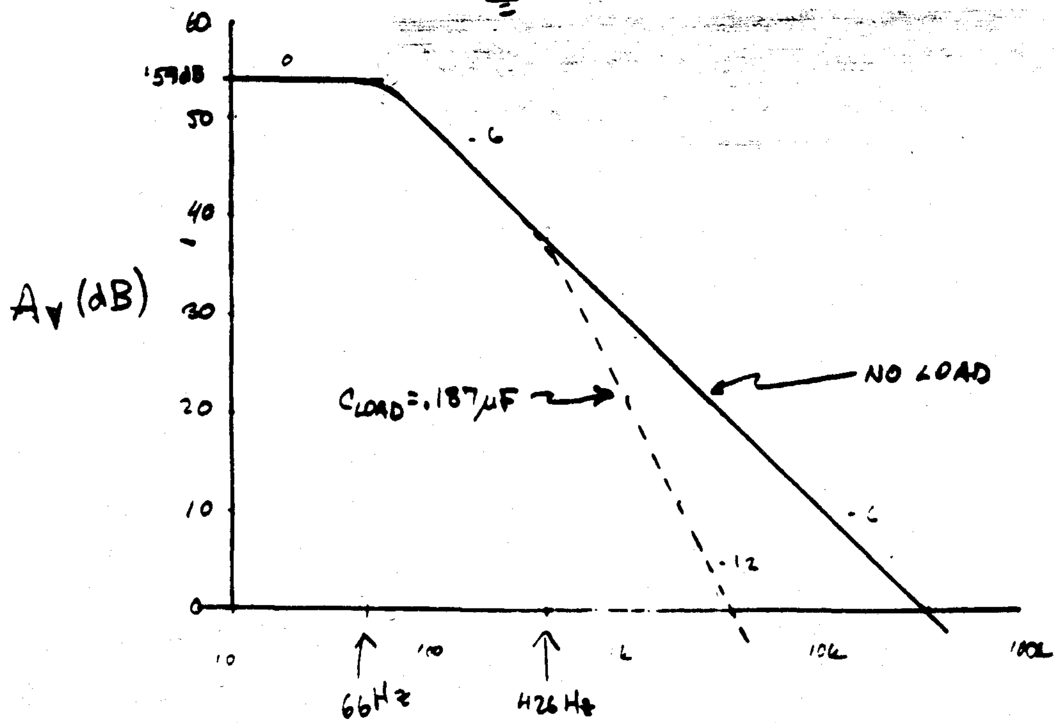


EACH CHANNEL AS SHOWN: THREE REQUIRED FOR EACH MC

11/15/88 MEZ

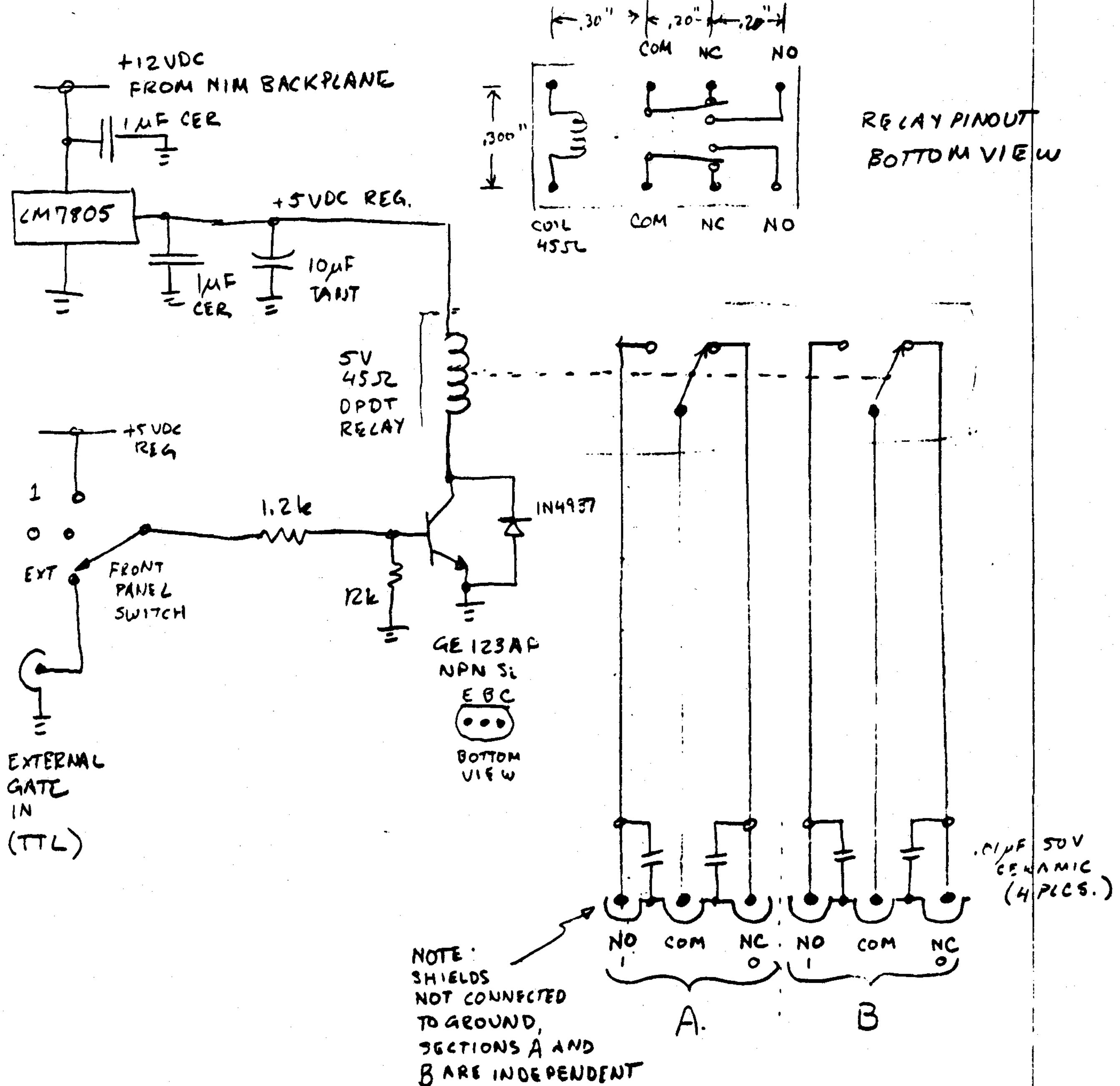
MODE CLEANER SERVO LOOP "VICTOR H.V. AMP"



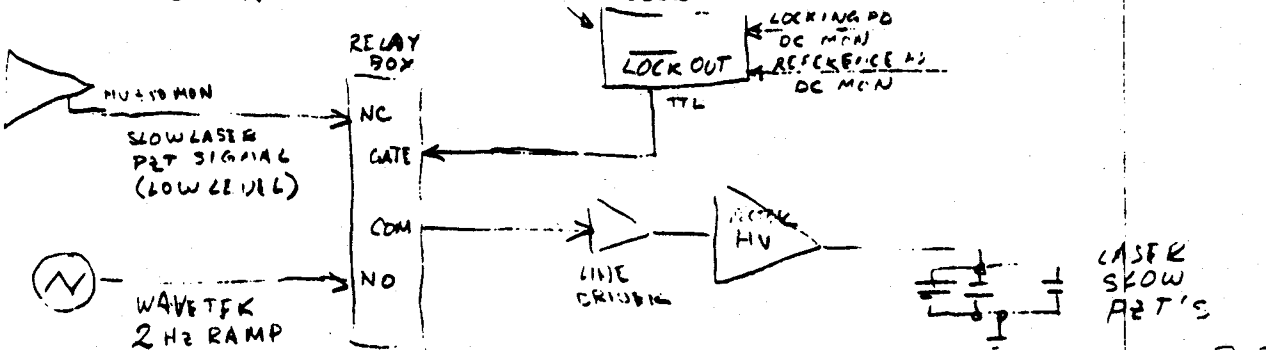


10/31/87 MEZ

DPDT RELAY FOR AUTOMATIC LASER RE-LOCK



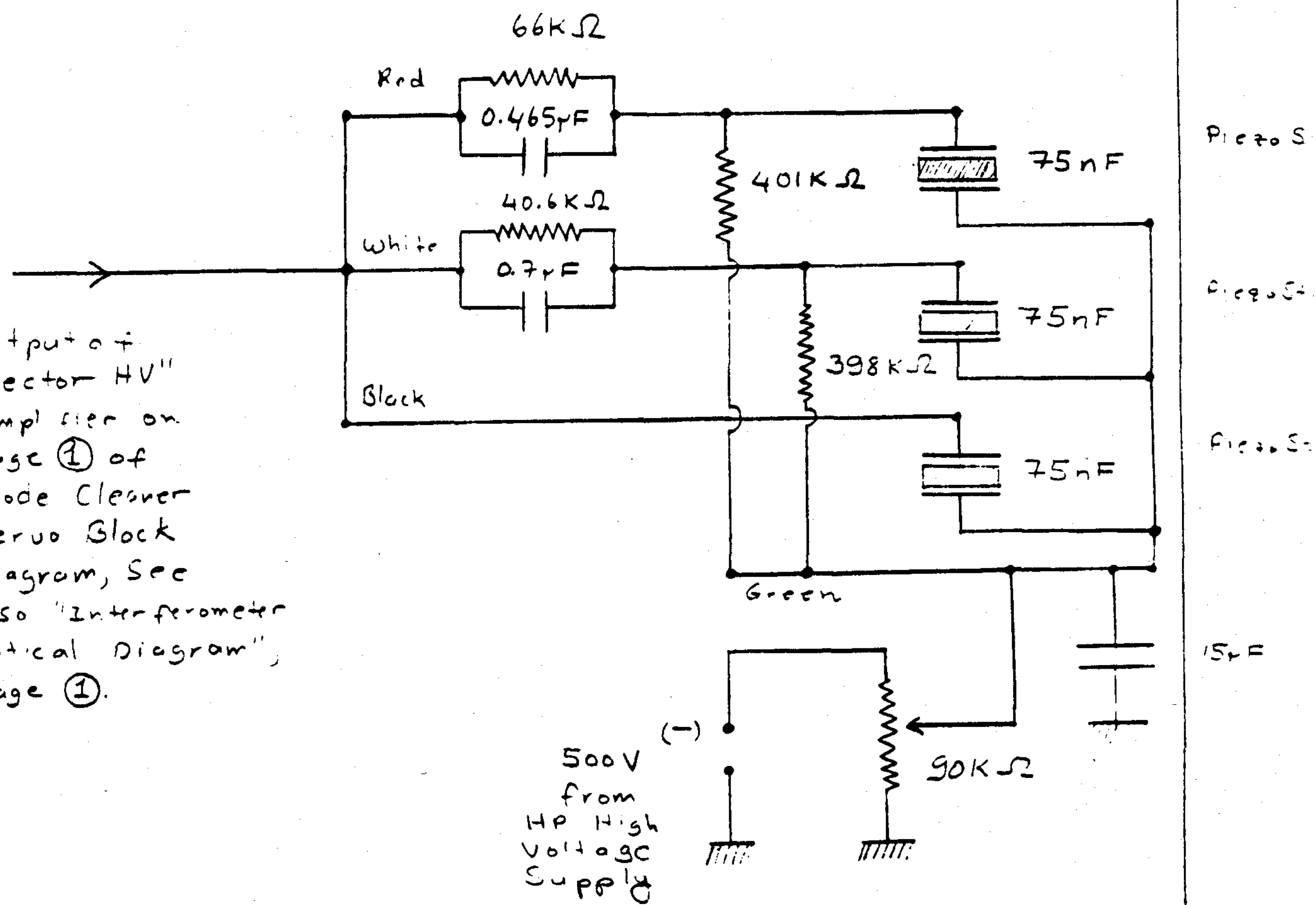
"TYPICAL" APPLICATION:



B12

3 Piezo Stack Balancing Network

(For the Laser "BARNEY")



Output of "Vector HV" Amplifier on page ① of Mode Cleaner Servo Block Diagram, See also "Interferometer Optical Diagram", page ①.

"Also on page ① of "Mode cleaner servo Block Diagram".

Page ① of ①
July 25, [illegible] 96

C. LASER LOOP: SENSORS AND ACTUATORS

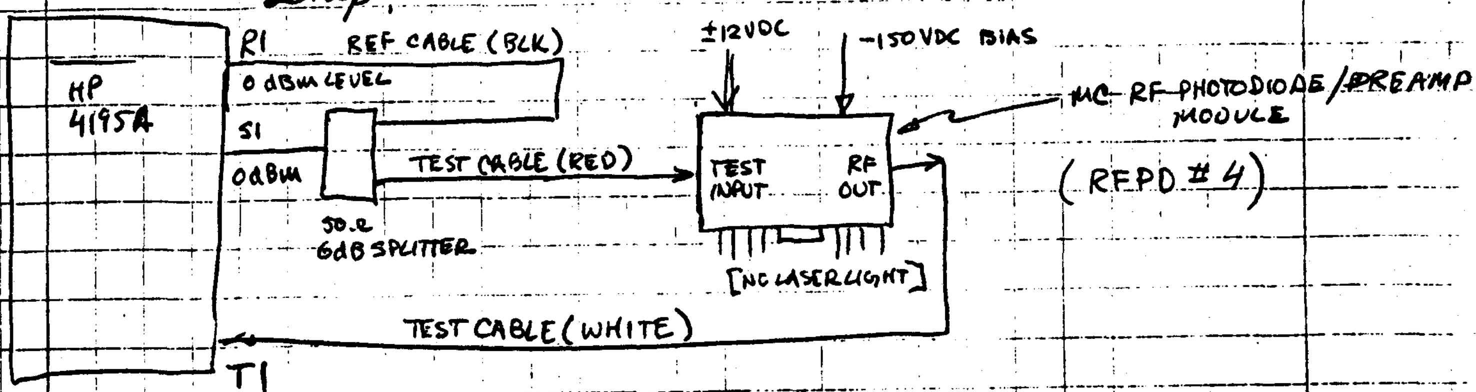
SENSITIVITY OF RF DETECTION SYSTEM + "OPTICAL GAIN"

8/4/89 M. E. Zucker 18:20

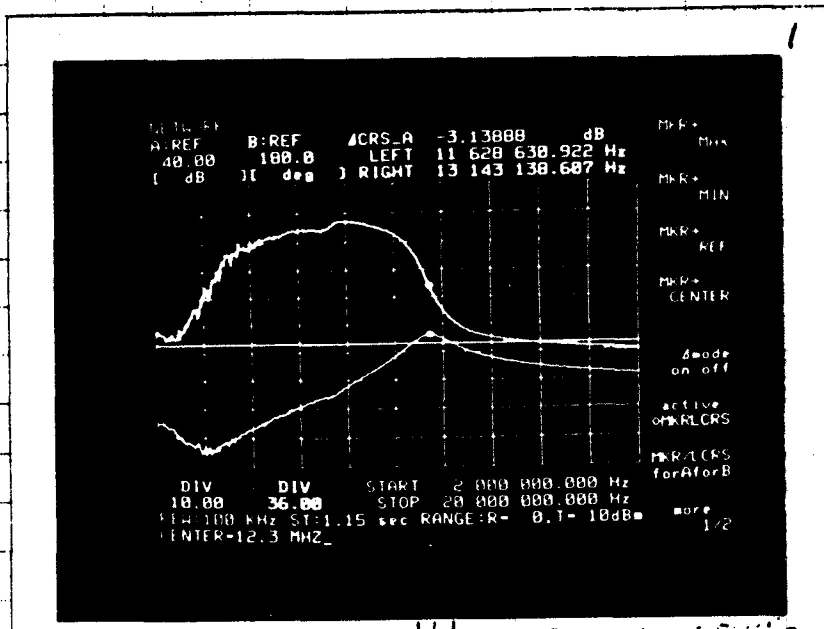
Recording measurements of optical and electronic transfer functions of various key elements of the estalater-pockels cell laser stabilization loop. (A.K.A. "Mode Cleaner Servo")

① Measured response of mode cleaner RF photodiode / preamp module at RF frequency using HP 4195A network analyzer

Setup:



8/9/89 10:15



UPPER TRACE: ARG(T_1/R_1), DEG

LOWER TRACE: $|T_1/R_1|$, dB

→| |← 3dB WIDTH ≅ 1.5 MHz

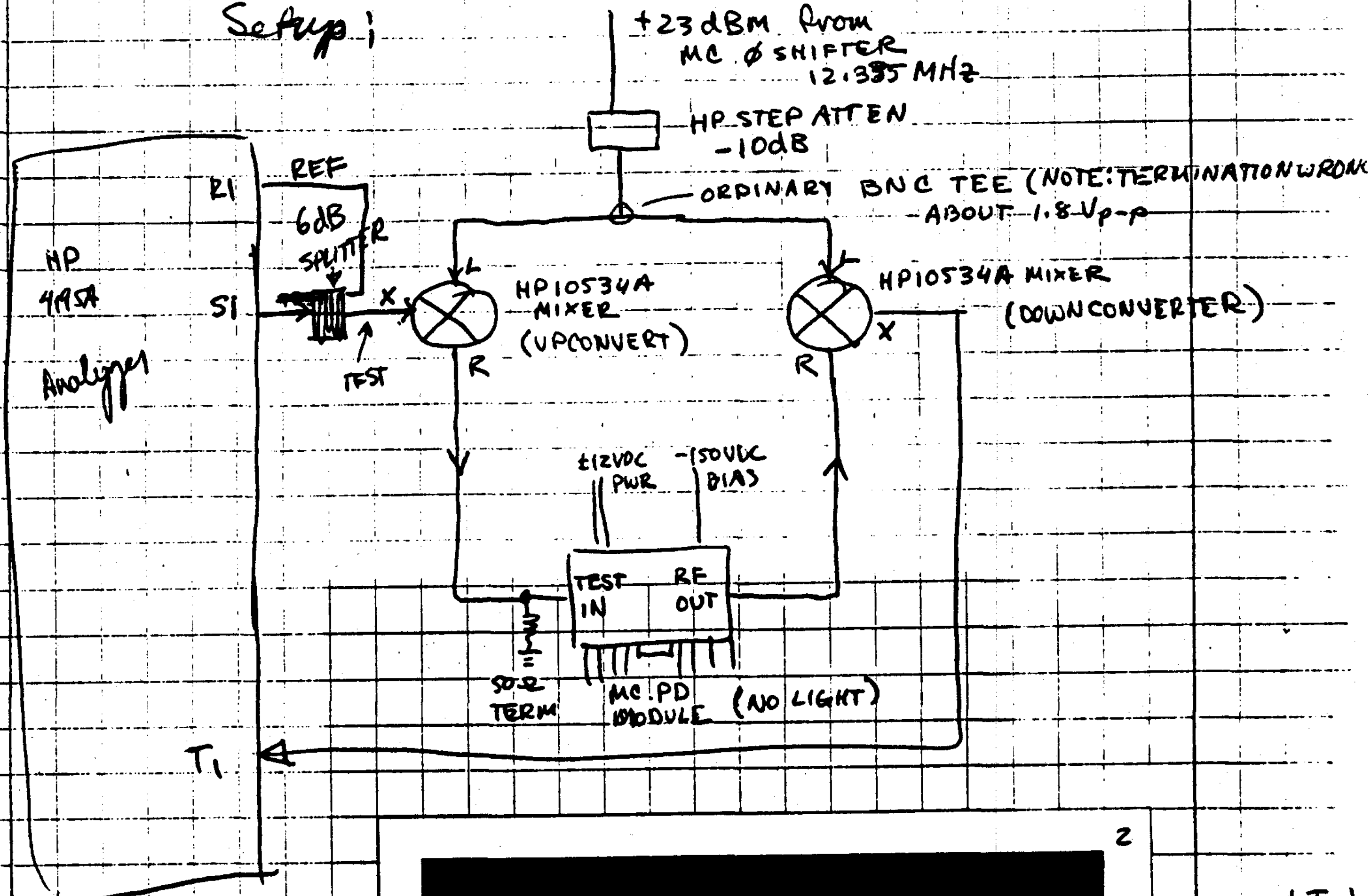
LINEAR FREQUENCY SCALE, 2 MHz → 20 MHz

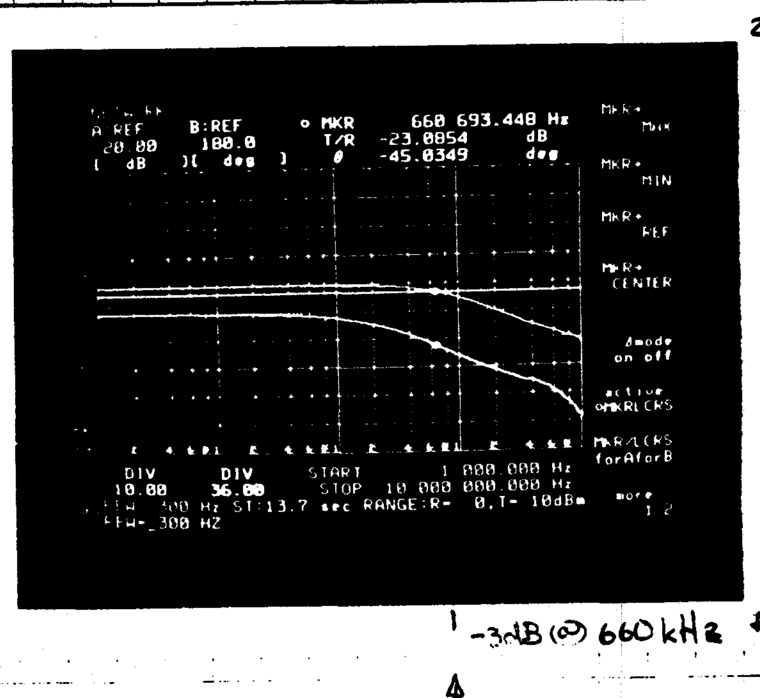
NOTE THAT PHASE IS + 40° AT CENTER FREQUENC

8/4/89 Cont'd. MEZ

(2) Measured "equivalent baseband response" of RF photodiode unit by upconverting the network analyzer's sweep to 12.33 MHz (amplitude modulation, suppressed carrier, just like an optical phase error producer).

Setup:





TOP: $\left|\frac{T_1}{R_1}\right|$

BELOW: ARG(

-3dB @ 660 kHz

EFFECTIVE POLE DUE TO PHOTODIODE BANDPASS

8/8/89 Analysis of "Optical transfer function" measurements;

(MEZ) Transfer function on page 0044 must be corrected for
ⓐ mis-termination of mixer
ⓑ delay in long cable used to excite PC
ⓒ the bandpass transfer function of the photodiode.
ⓓ the propagation delay in the light path and in the RF cable from the photodiode to the mixer.

The results of this analysis (which is attached to subsequent page for future reference) are summarized as follows;

With; photodiode now in use on MC (700 kHz "pole" due to bandpass)
950 mV out of lock, 400 mVDC in lock (contrast = 58%)
modulation index ≃ 0.4 $\left(\frac{P_{SIDEBAND}}{P_{CARRIER}} \approx 0.04\right)$

we get; $\frac{\delta V(\text{mixer output; } 50\Omega \text{ term})}{\delta V(\text{ONE GSÄNGER PM-25 POCKELS CELL})} \simeq 5\times10^{-3}\frac{V}{V} \times \left(\frac{1}{1+\frac{jf}{700\,kHz}}\right)$

Also, from the pockels cell terminals to the mixer output there is a frequency-dependent phase shift which is consistent with a propagation delay of (40 ± 10) nsec; the optical path between pockels cell → cavity → photodiode is about 6.5 m (⇒ 22 nsec), and the cable linking the PD w/ the mixer is 2.3 m (⇒ 11 nsec at 0.7c) for a calculated delay of 33 nsec. There are probably also delays associated with the diode proper, the internal buffer, or the pockels cell itself, but these should not contribute more than 5 nsec total in my estimation.

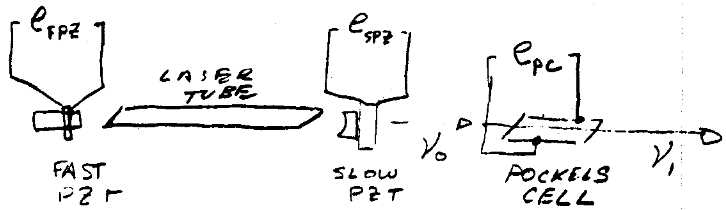
LASER PHASE & FREQUENCY ADJUSTMENT ACTUATORS

MEZ 10/17/90

ν = laser frequency $\simeq 5.8 \times 10^{14}$ Hz or so

ϕ = laser phase

f = audio or video fluctuation frequency



1. Pockels cell;

$$\dot{\phi}_0 = 2\pi\nu_0 , \quad \phi_1 = 2\pi\nu_0 t + \frac{2\pi n_{pc} l_{pc}}{\lambda}$$

where l_{pc} = length of Pockels cell, and
n_{pc} = refractive index of cell ;

$$n_{pc} = n_0 + \alpha e_{pc}$$

where α = electrooptic coefficient of cell crystal (V^{-1})

so $\nu_1 = \dot{\phi}_1/2\pi = \nu_0 + \frac{\alpha l}{\lambda}\dot{e}_{pc}$

Example: Gränger PM-25 cell, at $\lambda = 514.5$ nm, has $\alpha l = 0.26$ nm/V *, so for a sinusoidal e_{pc} at frequency f,

$$e_{pc} = V_0 \cos(2\pi f t),$$ we get an output frequency

$$\nu_1(t) = \nu_0 - \frac{2\pi\alpha l f}{\lambda} e_0 \sin(2\pi f t)$$

$$= \nu_0 - 3.2\times10^{-3}\left(\frac{e_0}{1V}\right)\left(\frac{f}{1 Hz}\right)\sin(2\pi f t) \text{ Hz}$$

*corresponding to 1kV/order at this λ.

10/17/90 MEZ

2. Fast PZT mirror;

as long as the laser oscillates in a single longitudinal mode labeled k

$$\nu^k = k\frac{c}{2d}$$

where k is a (large) integer and d is the spacing of the laser cavity (assume $n_{laser} = 1$). The piezo expands or contracts in proportion to e_{FPZ}, so

$$d = d_0 + \beta e_{FPZ} \quad \text{and}$$

$$\nu^k = \frac{kc}{2(d_0 + \beta e_{FPZ})} \simeq \frac{kc}{2d_0}\left(1 - \frac{\beta e_{FPZ}}{d_0}\right)$$

$$\equiv \nu_0^k\left(1 - \frac{\beta e_{FPZ}}{d_0}\right) \quad \text{for } \beta e_{FPZ} \ll d_0$$

Example; the laser Earney has $d_0 \simeq 2.3\ m$ and its fast PZT has

$$\beta \simeq \frac{1\ \text{order}}{550\ V} \simeq 4.7 \times 10^{-10}\ \frac{m}{V} \quad \text{so}$$

$$\frac{\nu^k - \nu_0^k}{e_{FPZ}} \simeq \frac{\beta \nu_0^k}{d_0} = \boxed{120\ \frac{kHz}{V}}$$

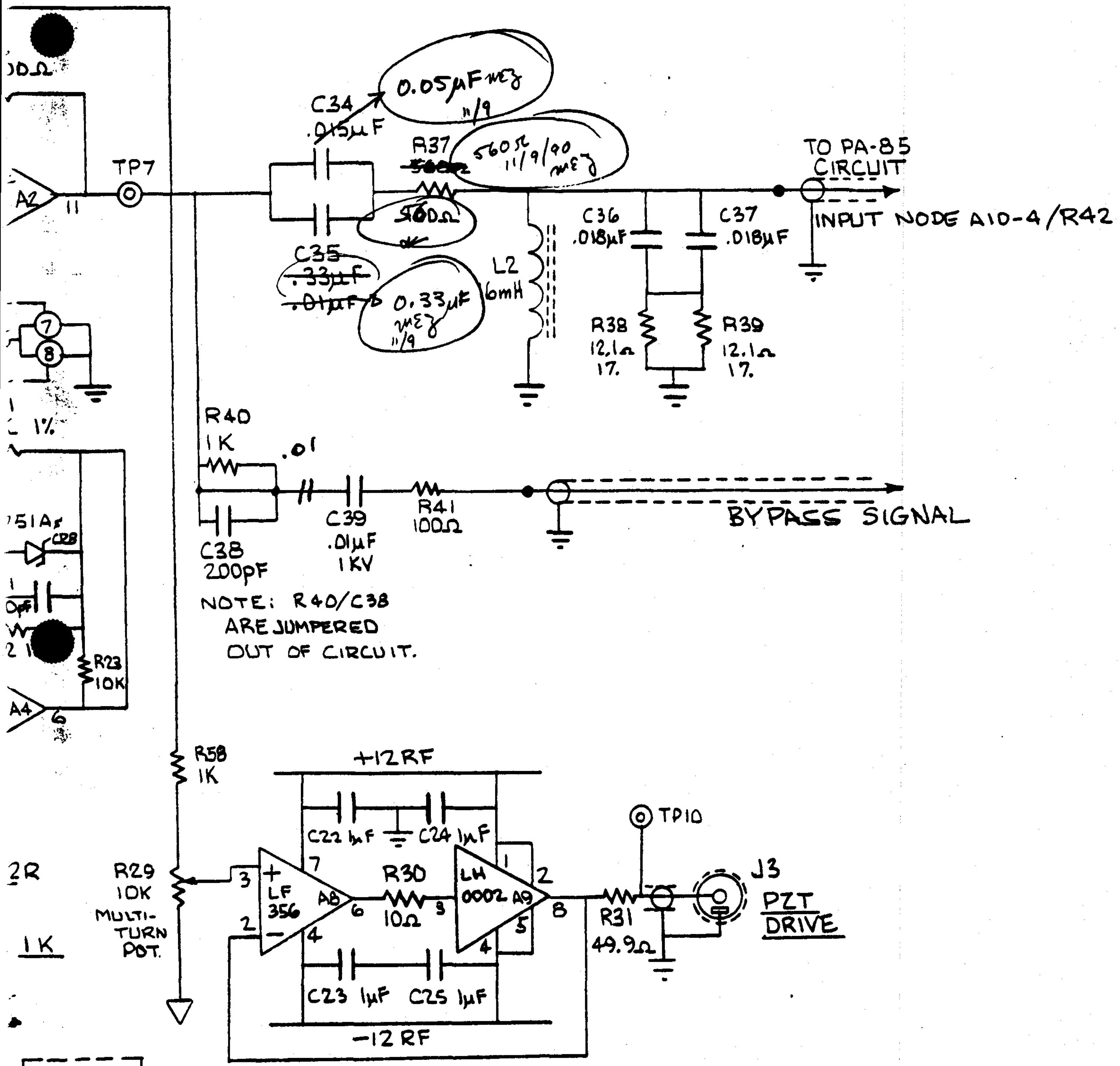
3. Slow PZT mirror; same as fast PZT, different β.

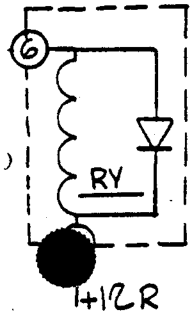
Example; for Earney, $d_0 \simeq 2.3\ m$,

$$\beta \simeq \frac{1\ \text{order}}{70\ V} \Rightarrow$$

$$\frac{\nu^k - \nu_0^k}{e_{SPZ}} \simeq \boxed{930\ kHz/V}.$$

D. LASER LOOP: PROTOTYPE #1





LASER LOOP AMPLIFIER VER. 1 PROTOTYPE 1 VER. 1

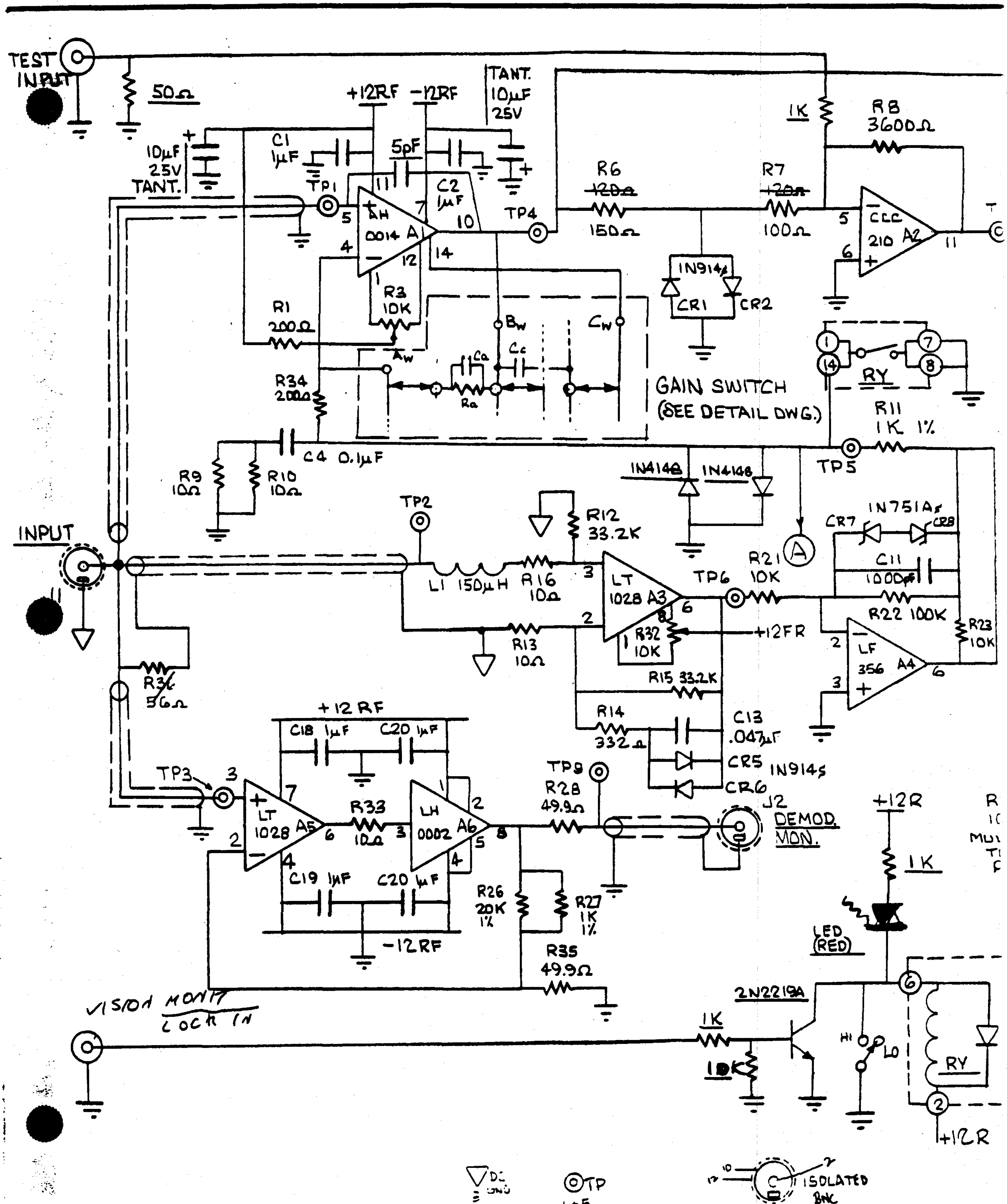
ADDED= COMPONENENTS

REBUILD 11-8-90 B.T. J.C.

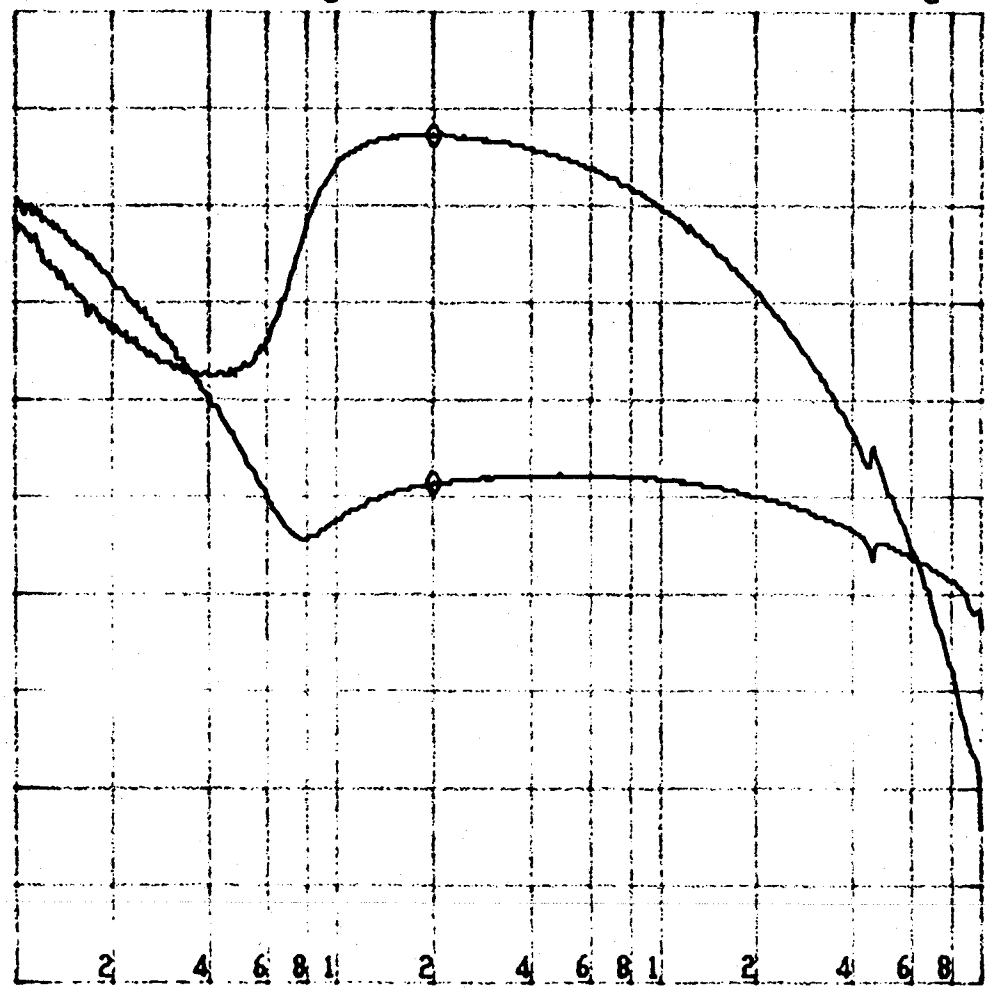
Diagram Revised 11/9/90 MEZ

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
LASER LOOP AMPLIFIER - SECTION 1		
DRAWN BY B.T.	DATE 10-9-89	DRAWING NO
CHECKED BY	SCALE	
APPROVED BY	W.O.	

D1


TEST INPUT
50Ω
+12RF
-12RF
TANT. 10μF 25V
1K
R8 3600Ω
10μF 25V TANT.
C1 1μF
5pF
C2 1μF
TP1
AH 0014 A1
TP4
R6 150Ω
R7 100Ω
CLC 210 A2
1N914
CR1
CR2
R1 200Ω
R3 10K
Bw
Cw
Aw
Ca
Cc
Ra
RY
GAIN SWITCH (SEE DETAIL DWG.)
R34 200Ω
C4 0.1μF
R11 1K 1%
TP5
R9 10Ω
R10 10Ω
1N4148
1N4148
1N751As
CR7
CR8
TP2
R12 33.2K
INPUT
C11 1000pF
R21 10K
L1 150μH
R16 10Ω
LT 1028 A3
TP6
R22 100K
R32 10K
+12FR
R23 10K
R13 10Ω
LF 356 A4
R15 33.2K
R36 56Ω
+12 RF
C18 1μF
C20 1μF
R14 332Ω
C13 .047μF
CR5
CR6
1N914s
TP8
TP3
LT 1028 A5
R33 10Ω
LH 0002 A6
R28 49.9Ω
J2 DEMOD. MON.
+12R
C19 1μF
C20 μF
R26 20K 1%
R27 1K 1%
1K
-12RF
LED (RED)
R35 49.9Ω
2N2219A
VISION MONIT LOCK IN
1K
10K
HI
LO
RY
+12R
DC GND
TP
ISOLATED BNC

NETWORK Cor
A: REF B: REF o MKR 198 380.966 Hz
90.00 225.0 T/R 41.3117 dB
[dB][deg] θ 167.567 deg



DIV DIV START 10 000.000 Hz
10.00 45.00 STOP 10 000 000.000 Hz
RBW: 100 Hz ST: 40.2 sec RANGE: R= 10, T= 0dBm
ATT1= 10 DB

11/14/
14:57

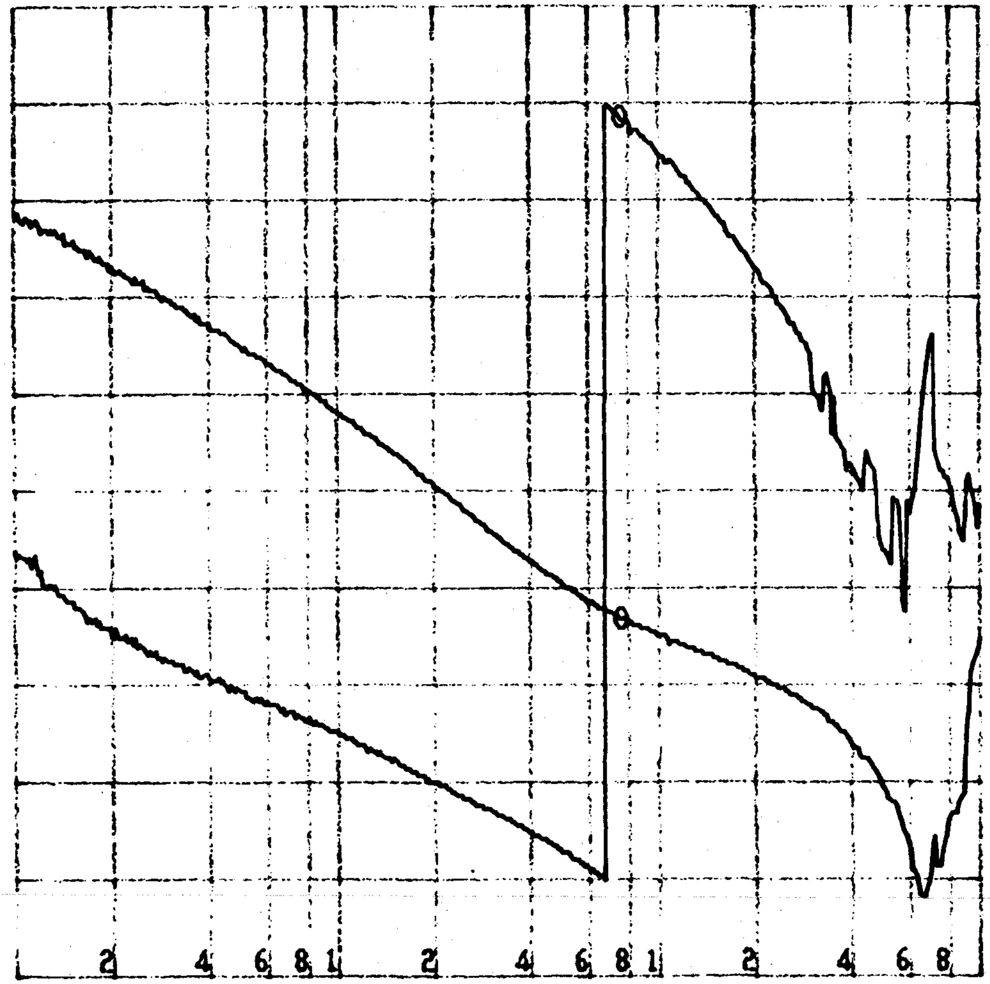
XF, LaserLoop
Proto #1
Demod → A1
DC OUTPUT, END OF CABLE

GAIN "1"
(MIN.)

D3

11/14/90
4:29

NETWORK Cor
A: REF B: REF o MKR 762 956.891 Hz
90.00 225.0 T/R 26.8022 dB
[dB][deg] θ 174.223 deg



DIV DIV START 10 000.000 Hz
10.00 45.00 STOP 10 000 000.000 Hz
RBW: 100 Hz ST: 40.2 sec RANGE: R= 10, T=-10dBm
OSC1= -20.0 DBM

XF, LASER SERVO PROTO #1

DEMOD IN* → A2
PC OUTPUT, AT END OF CABLE (INV.)

GAIN "1" (MIN)

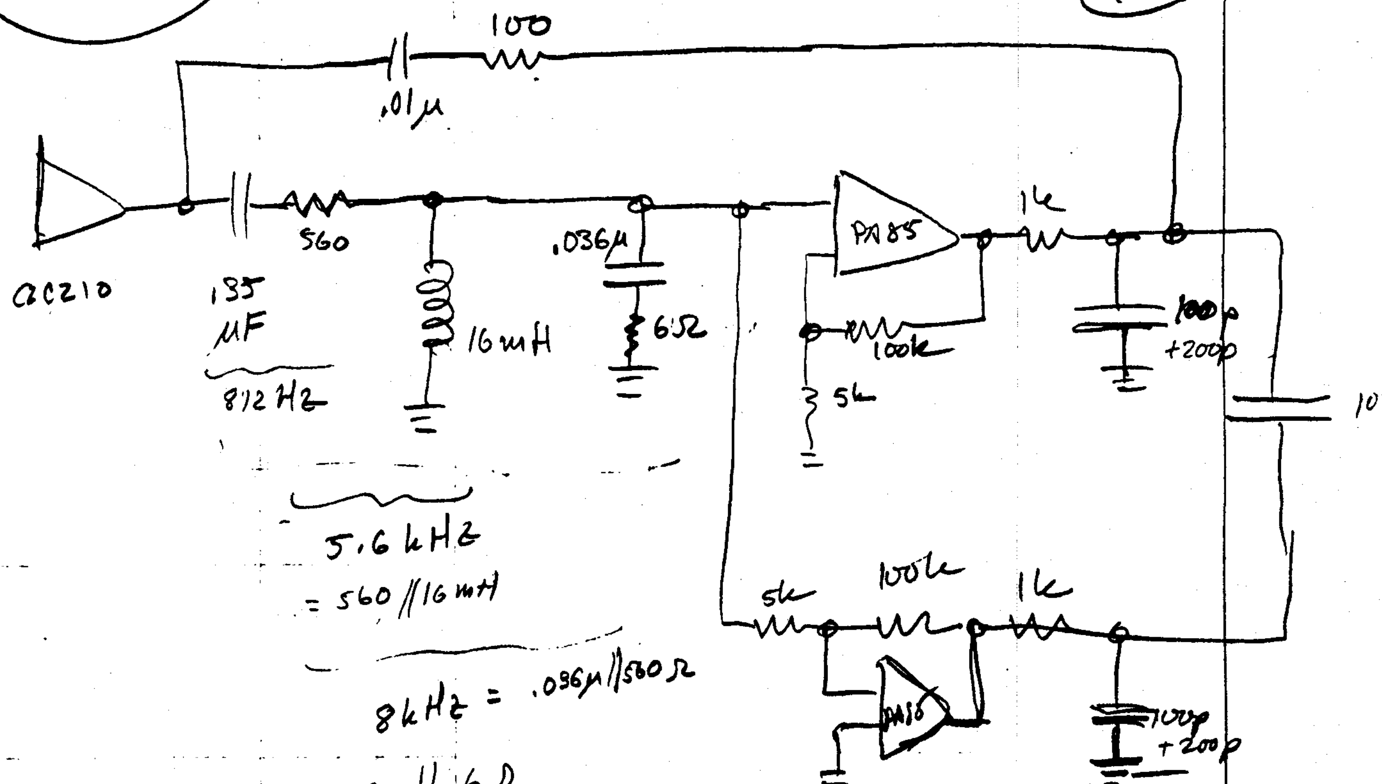
* XF includes 24 + 12 MHz notch filters usually used

D4

LASER SERVO

Proto #1

1k||.01µ = 16kHz

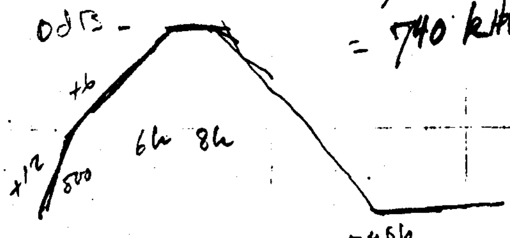


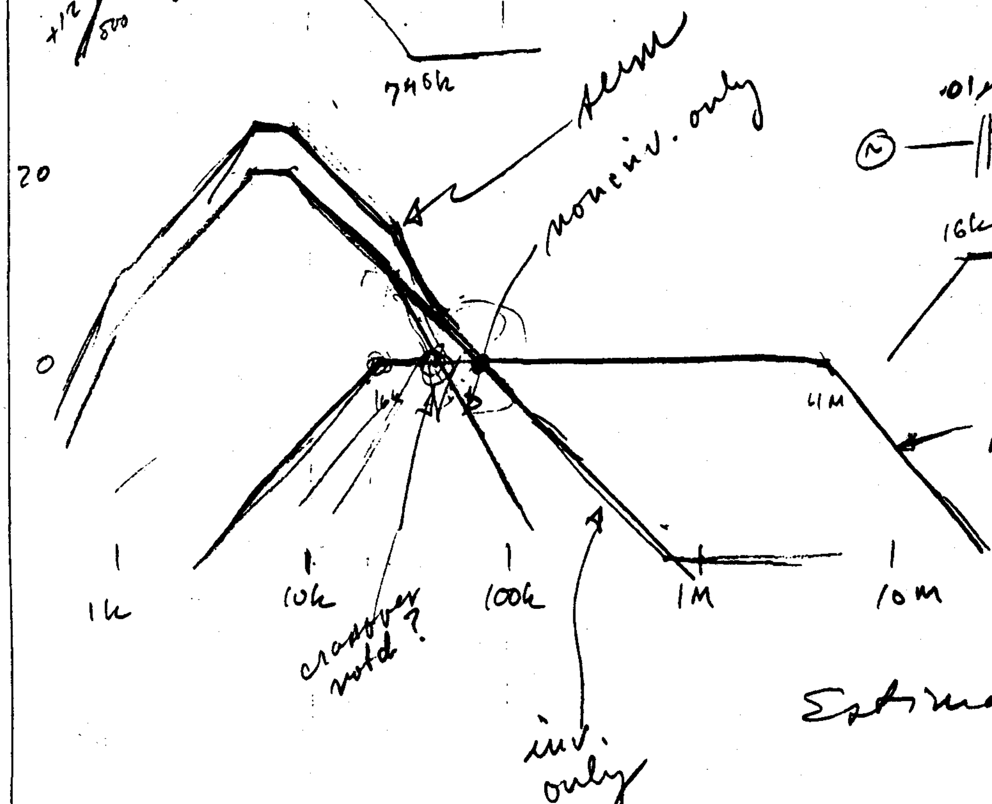
5.6 kHz = 560 || 16mH

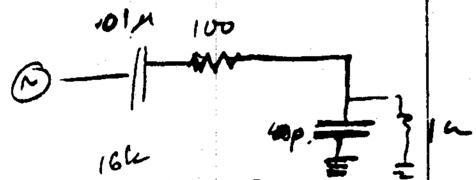
8kHz = .036µ || 560Ω

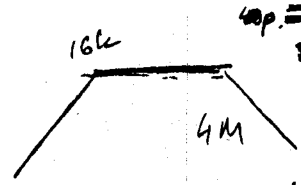
.036µ || 6Ω = 740 kHz

1k || 400pF = 400kHz



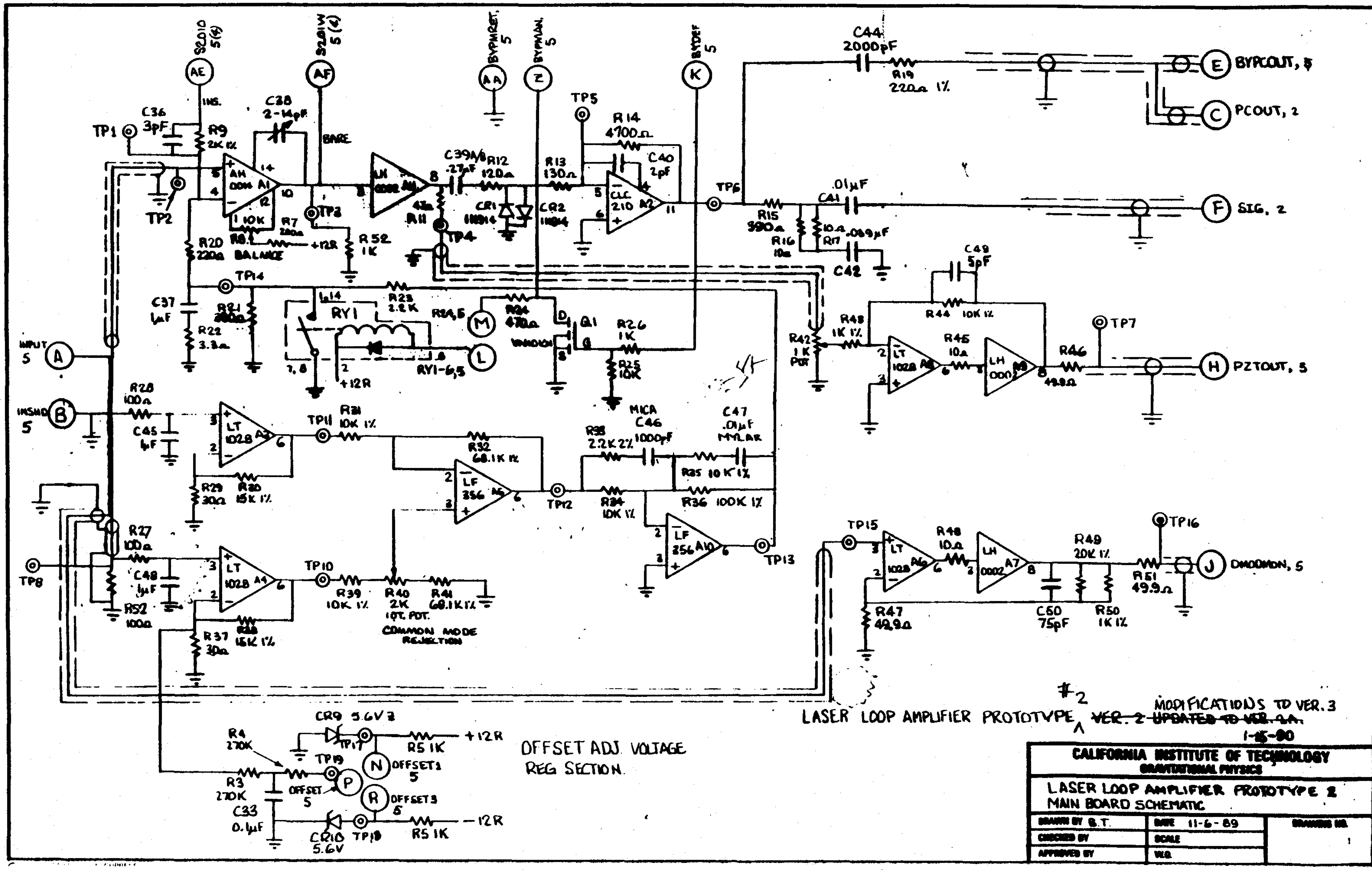




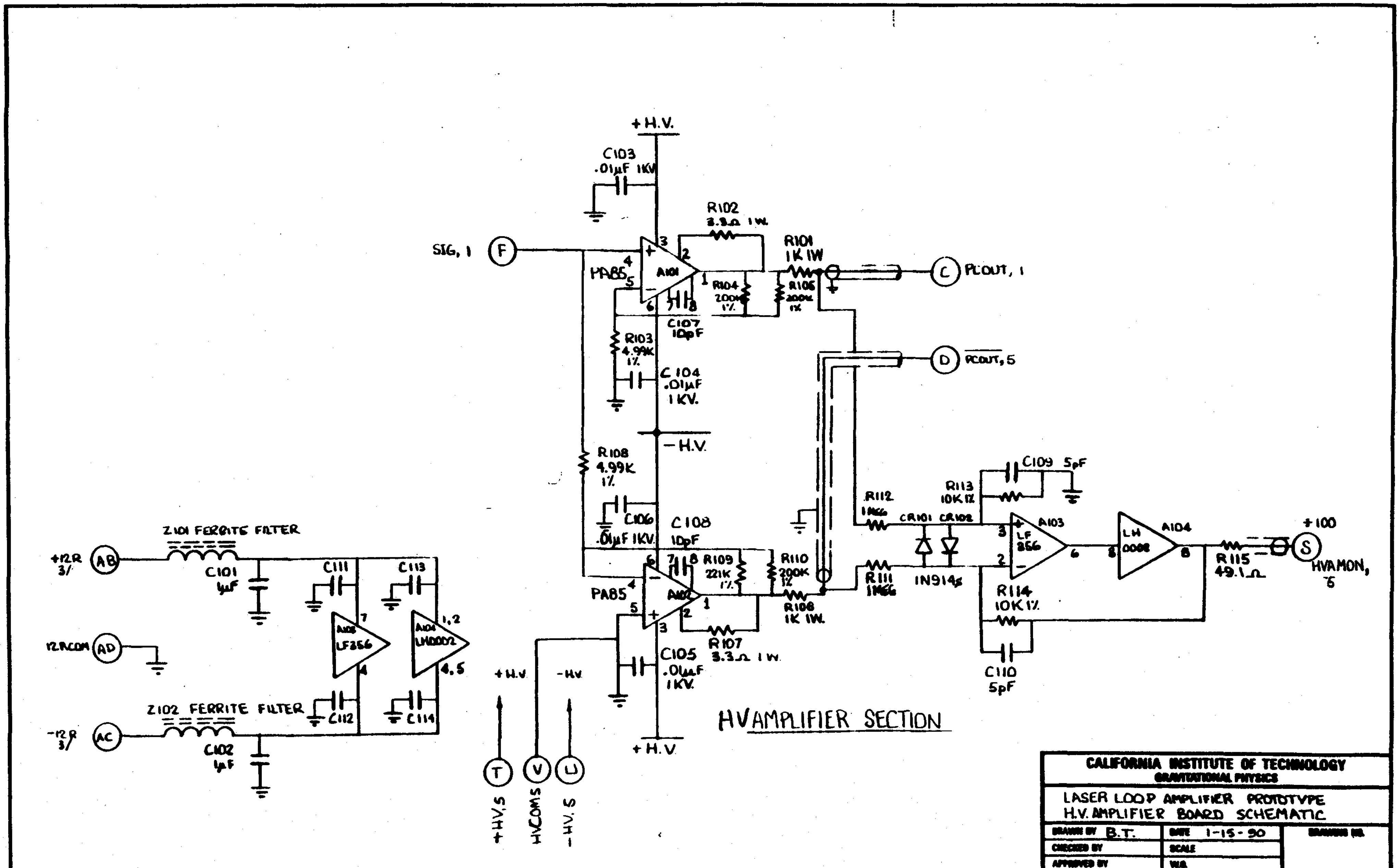


Estimated XF

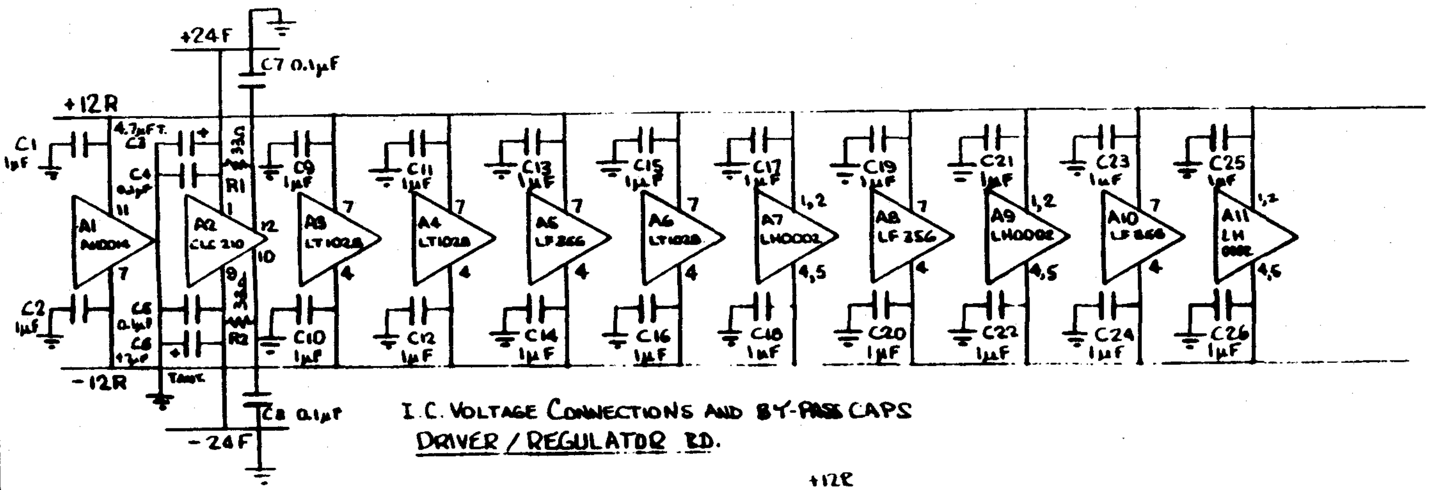
E. LASER LOOP: PROTOTYPE #2



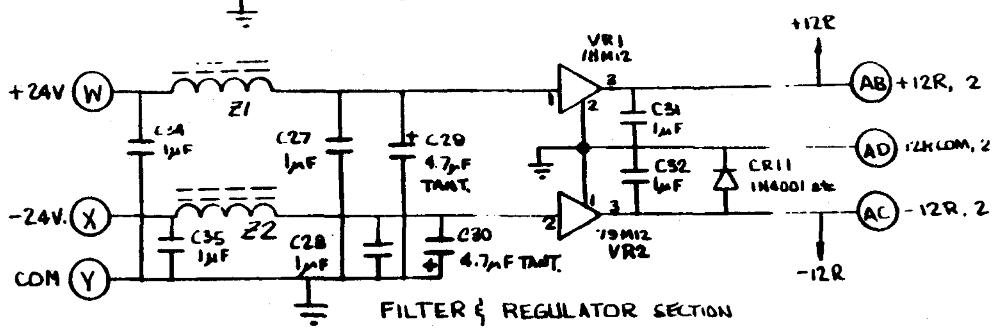
S201D 5(4)
S201W 5(4)
BYPHREF, 5
BYPMAN, 5
BYDEF 5
AE
AF
AA
Z
K
C44 2000pF
R19 220Ω 1%
E BYPCOUT, 5
C PCOUT, 2
F SIG, 2
H PZTOUT, 5
J DHODMON, 5
INPUT 5 A
INSMD B 5
TP1
TP2
TP3
TP4
TP5
TP6
TP7
TP8
TP10
TP11
TP12
TP13
TP14
TP15
TP16
TP17
TP18
TP19
C36 3pF
R9 2K 1%
C38 2-14pF
INS.
BARE
AH 0014 A1
LH 0032 A11
C39A/B .27µF
R12 120Ω
R13 130Ω
R14 4700Ω
C40 2pF
CLC 210 A2
CR1 1N914
CR2 1N914
R11 47Ω
R7 200Ω
R8 10K
BALANCE
+12R
R52 1K
R20 220Ω
C37 1µF
R21 200Ω
R22 3.3Ω
RY1
R23 2.2K
R24,5
M
R24 470Ω
Q1
VN10KM
R26 1K
R25 10K
RY1-6,5
L
+12R
R15 390Ω
R16 10Ω
R17 10Ω
C41 .01µF
.039µF
C42
C49 5pF
R44 10K 1%
R42 1K POT
R48 1K 1%
LT 1028 A8
R45 10Ω
LH 0002 A9
R46 49.9Ω
R28 100Ω
C45 1µF
LT 1028 A3
R29 30Ω
R30 15K 1%
R31 10K 1%
R32 68.1K 1%
LF 356 A5
R33 2.2K 2%
MICA C46 1000pF
C47 .01µF MYLAR
R35 10K 1%
R34 10K 1%
R36 100K 1%
LF 356 A10
R27 100Ω
C48 1µF
R52 100Ω
LT 1028 A4
R39 10K 1%
R40 2K 10T. POT.
R41 68.1K 1%
COMMON MODE REJECTION
R37 30Ω
R38 15K 1%
LT 1028 A6
R43 10Ω
LH 0002 A7
R49 20K 1%
R51 49.9Ω
C50 75pF
R50 1K 1%
R47 49.9Ω
CR9 5.6V Z
R5 1K
+12R
R4 270K
R3 270K
C33 0.1µF
OFFSET 5
P
N OFFSET1 5
R OFFSET3 5
CR10 5.6V
R5 1K
-12R
OFFSET ADJ. VOLTAGE REG SECTION
#2
LASER LOOP AMPLIFIER PROTOTYPE ~~VER. 2 UPDATED TO VER. 2A~~
MODIFICATIONS TO VER. 3
1-15-90
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS
LASER LOOP AMPLIFIER PROTOTYPE 2
MAIN BOARD SCHEMATIC
DRAWN BY B.T.
DATE 11-6-89
DRAWING NO.
CHECKED BY
SCALE
APPROVED BY
W.O.
1


+H.V.
C103
.01μF 1KV
R102
3.3Ω 1W
SIG, 1
F
PA85
A101
R101
1K 1W
R104
200K 1%
R105
200K 1%
C
PLOUT, 1
C107
10pF
R103
4.99K 1%
C104
.01μF
1KV.
D
PLOUT, 5
−H.V.
R108
4.99K
1%
C106
.01μF 1KV.
C108
10pF
R109
221K 1%
R110
200K 1%
PA85
A102
R106
1K 1W.
R107
3.3Ω 1W.
C105
.01μF
1KV.
+H.V
R112
1MEG
R111
1MEG
CR101
CR102
1N914s
R113
10K 1%
C109 5pF
A103
LF 356
A104
LH 0002
R114
10K 1%
C110
5pF
R115
49.1Ω
+100
S
HVAMON, 6
Z101 FERRITE FILTER
+12R 3/
AB
C101
1μF
C111
C113
A105
LF356
A104
LH0002
12RCOM
AD
Z102 FERRITE FILTER
−12R 3/
AC
C102
1μF
C112
C114
+H.V
−HV
T
V
U
+HV,5
HVCOM,5
−HV,5
HV AMPLIFIER SECTION
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS
LASER LOOP AMPLIFIER PROTOTYPE
H.V. AMPLIFIER BOARD SCHEMATIC
DRAWN BY B.T.
DATE 1-15-90
DRAWING NO.
CHECKED BY
SCALE
APPROVED BY
W.A.

E2



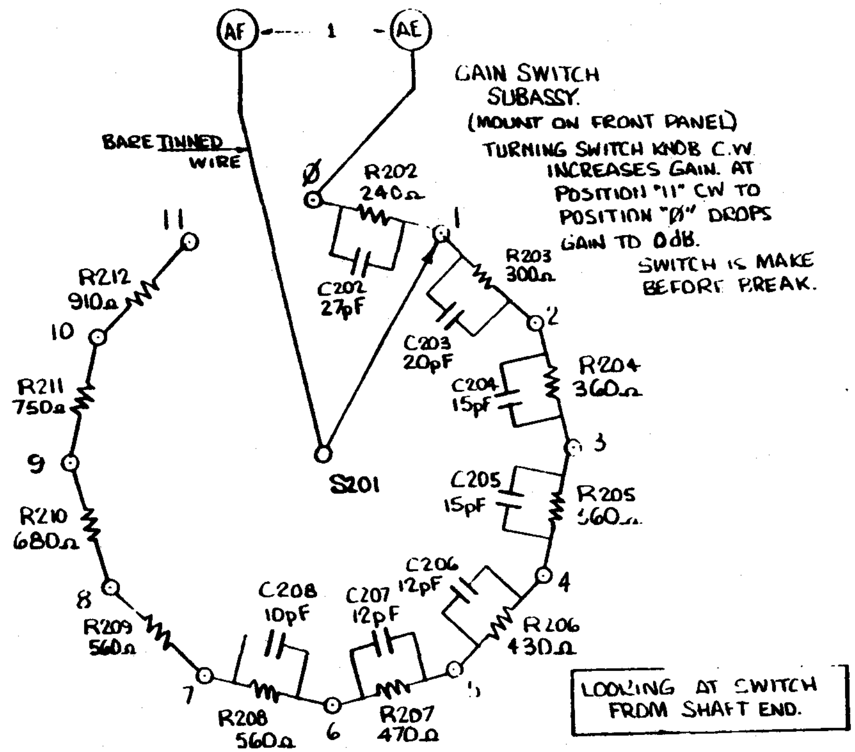
I.C. VOLTAGE CONNECTIONS AND BY-PASS CAPS
<u>DRIVER / REGULATOR BD.</u>



FILTER & REGULATOR SECTION
<u>DRIVER/REGULATOR BD.</u>

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
LASER LOOP AMPLIFIER PROTOTYPE POWER SCHEMATIC		
DRAWN BY B.T.	DATE 1-5-90	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

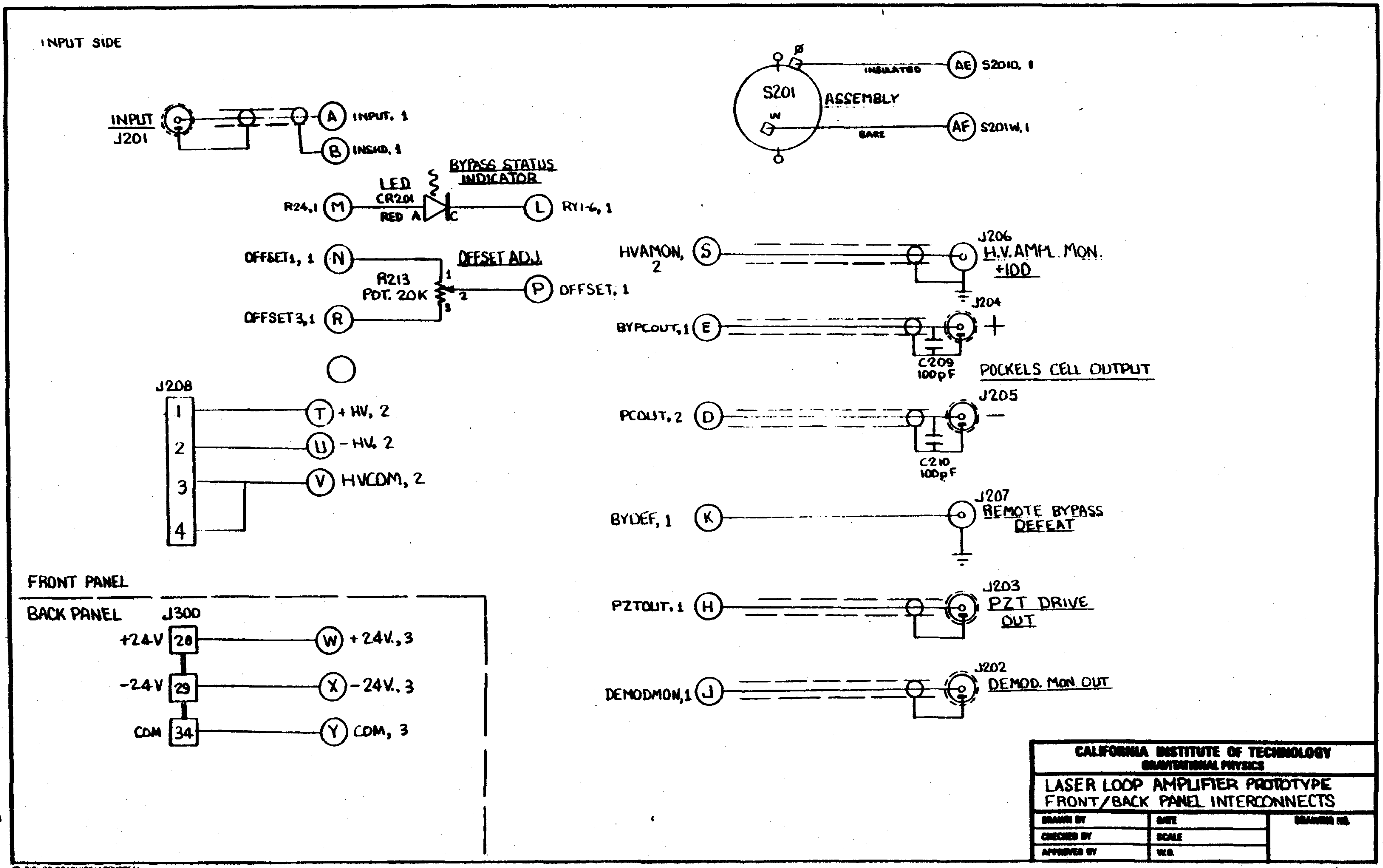
E3



PROTO-TYPE #2

CALIFORNIA INSTITUTE OF TECHNOLOGY GRAVITATIONAL PHYSICS		
LASER LOOP AMPLIFIER PROTOTYPE VER 2A GAIN SWITCH SCHEMATIC LAYOUT		
DRAWN BY B.T.	DATE 1-5-90	DRAWING NO.
CHECKED BY	SCALE	
APPROVED BY	W.O.	

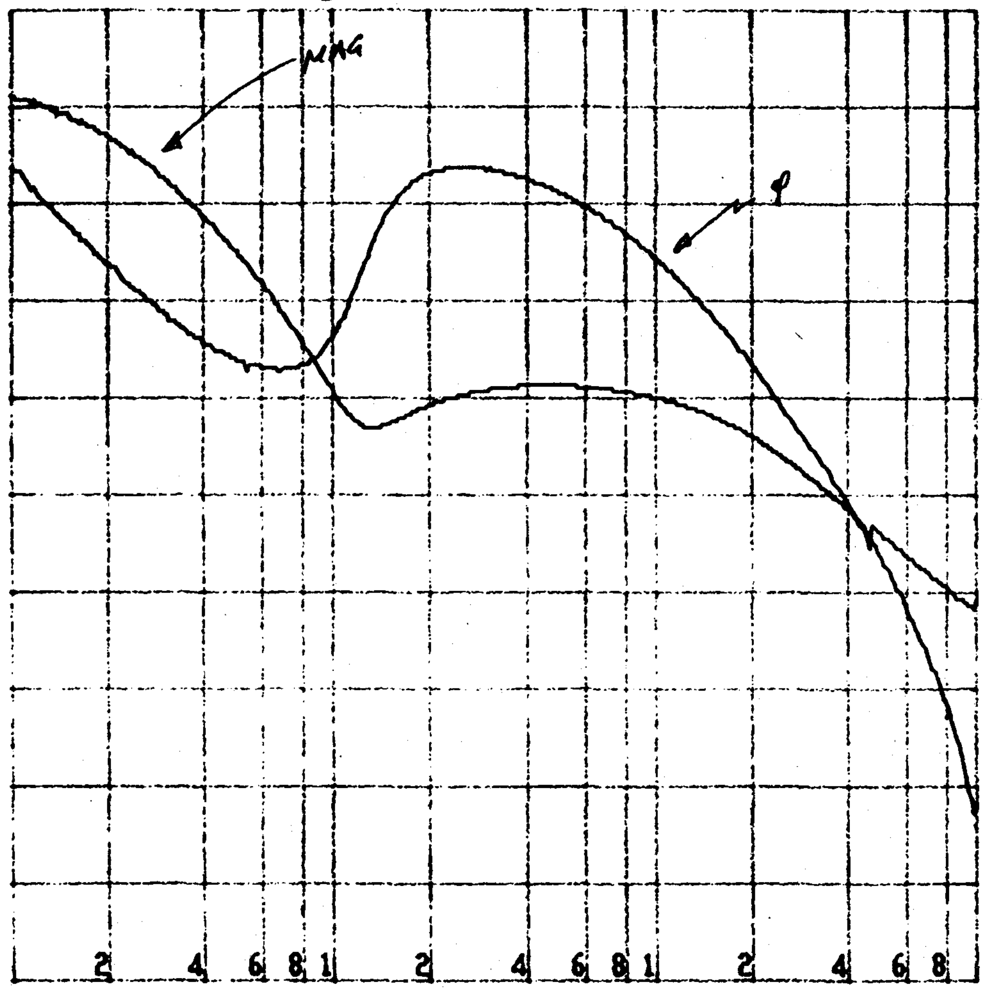
E4


INPUT SIDE
INPUT
J201
A INPUT, 1
B INSHD, 1
BYPASS STATUS INDICATOR
LED
CR201
RED A
C
R24,1 M
L RY1-6, 1
OFFSET1, 1 N
OFFSET ADJ.
R213
POT. 20K
P OFFSET, 1
OFFSET3,1 R
J208
T +HV, 2
U -HV, 2
V HVCOM, 2
FRONT PANEL
BACK PANEL
J300
+24V 28
W +24V., 3
-24V 29
X -24V., 3
COM 34
Y COM, 3
S201
ASSEMBLY
INSULATED
AE S201O, 1
BARE
AF S201W, 1
HVAMON, 2 S
J206
H.V. AMPL. MON. ÷100
BYPCOUT, 1 E
J204
+
C209
100pF
POCKELS CELL OUTPUT
PCOUT, 2 D
J205
—
C210
100pF
BYDEF, 1 K
J207
REMOTE BYPASS DEFEAT
PZTOUT, 1 H
J203
PZT DRIVE OUT
DEMODMON, 1 J
J202
DEMOD. MON OUT
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS
LASER LOOP AMPLIFIER PROTOTYPE
FRONT/BACK PANEL INTERCONNECTS
DRAWN BY
DATE
DRAWING NO.
CHECKED BY
SCALE
APPROVED BY
W.O.

10/7/9? [illegible]

BP off

NETWORK Cor
A: REF B: REF
90.00 225.0
[dB][deg]



DIV 10.00 DIV 45.00 START 10 000.000 Hz
STOP 10 000 000.000 Hz
RBW: 1 KHz ST: 12.8 sec RANGE: R= 20, T= 0dBm

XF, LASER LOOP AMP
PROTO #2,

INPUT → PC "+" OUT
(AT END OF CABLES,
PC INSTALLED, 10 MΩ ‖ 13 pF
PROBE, OPPOSITE SIDE
CONNECTED + DRIVEN
AS OPERATED)

SAME DATA AS 10:45,
LOGBOOK #20, P.039 Y

GAIN = "11" (MAX.)

RF TRAPS
ON INPUT
INCLUDED

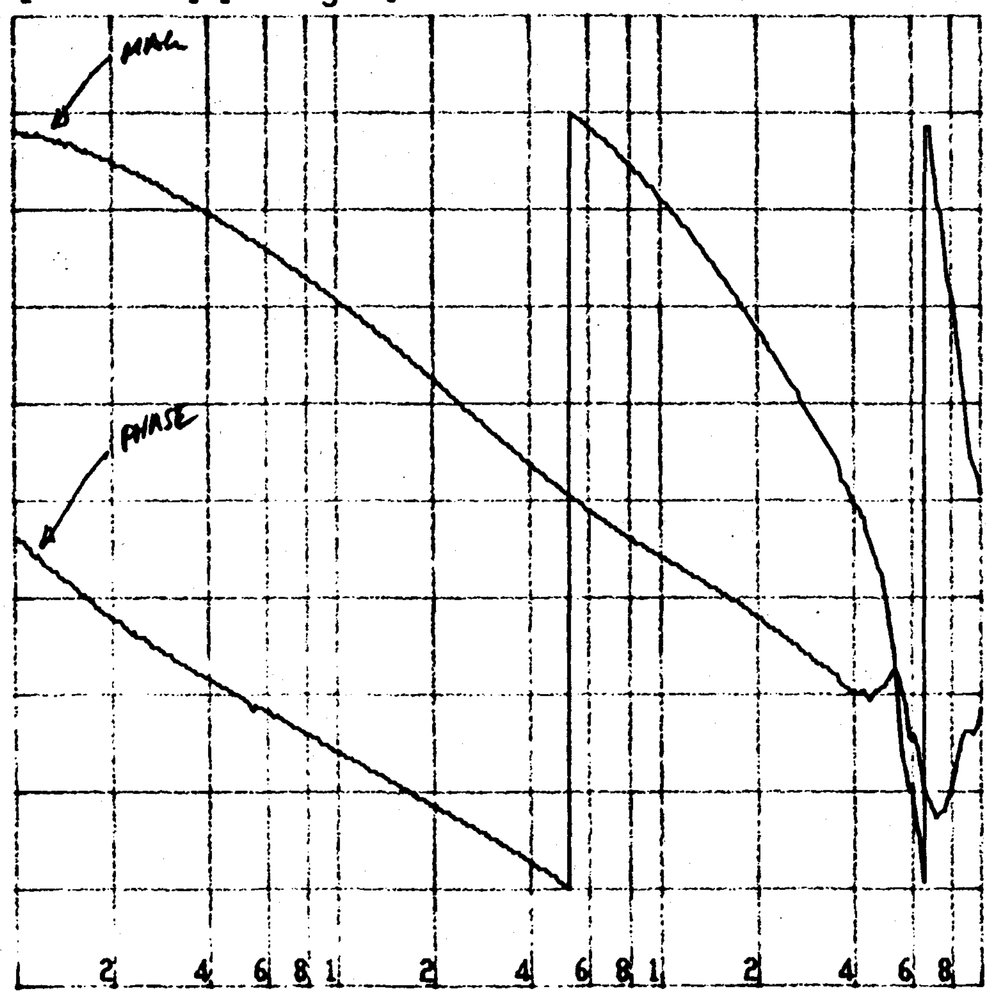
[PROBE SETUP XF
CALIBRATED OUT]

56

10/7/90

BP OFF

NETWORK Cor
A: REF B: REF
90.00 225.0
[dB][deg]



DIV DIV START 10 000.000 Hz
10.00 45.00 STOP 10 000 000.000 Hz
RBW: 1 KHz ST: 12.8 sec RANGE: R= 20, T= 0dBm

XF, LASER LOOP AMP
PROTO #2
INPUT → PC "−" OUT
(SEE 10:50 FOR
OTHER INFO)

GAIN = "11" (MAX)

RF TRAPS
ON INPUT
INCLUDED

[PROBE SETUP XF
CALIBRATED OUT]

10/7/90
11:15

BP OFF

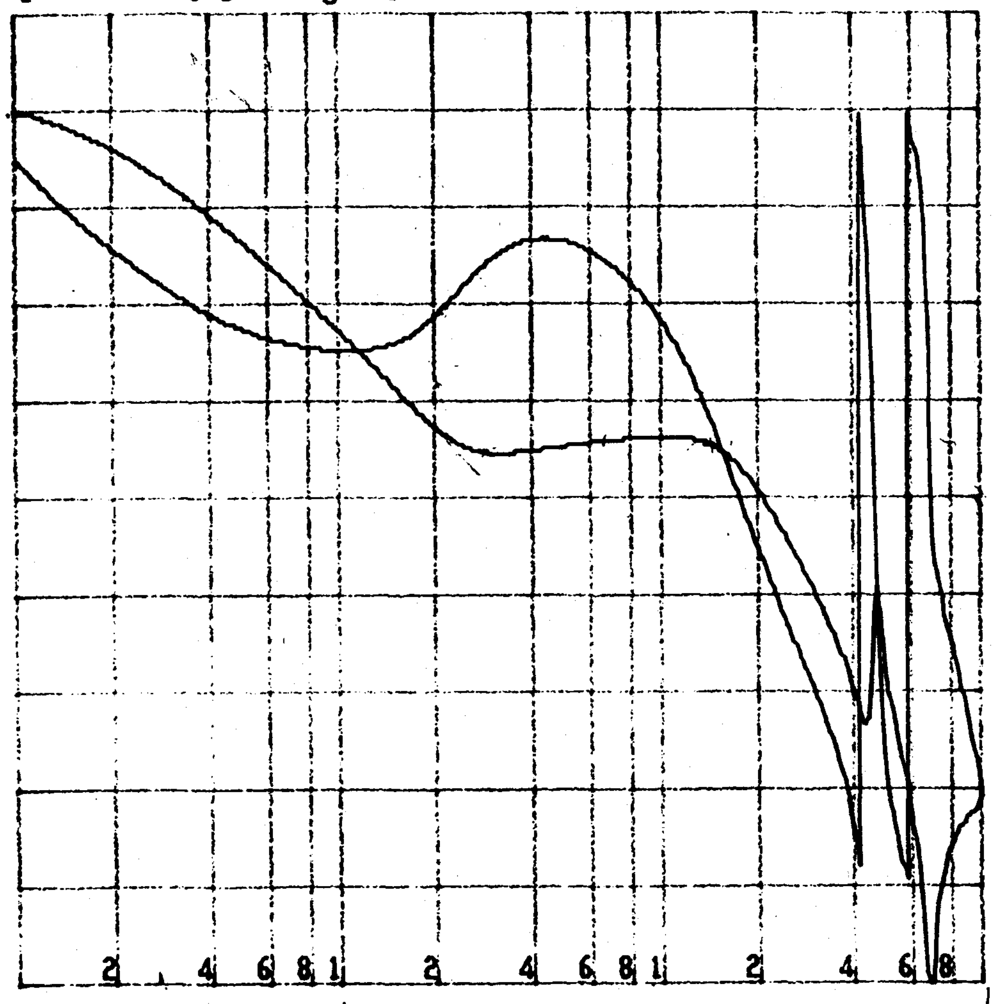
XF, LASERLOOP AMP PROTO #2

INPUT → PC MON ÷ 100
GAIN = "11" (MAX)
INCL. RF TRAPS AT INPUT

DIRECTLY INTO T1 OF ANALYZER

NETWORK

A: REF B: REF
50.00 225.0
[dB] [deg]



DIV DIV START 10 000.000 Hz
10.00 45.00 STOP 10 000 000.000 Hz
RBW: 1 KHz ST: 12.8 sec RANGE: R= 20, T= 10dBm
REF= 5.00000E+01

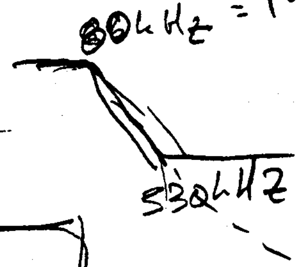
E8

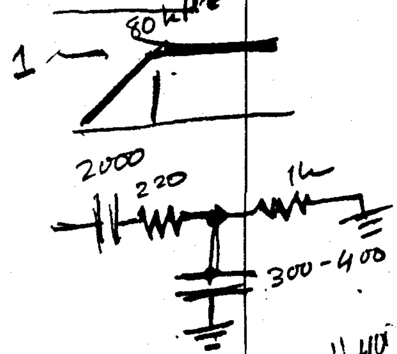
11/6/90

Prototype #2

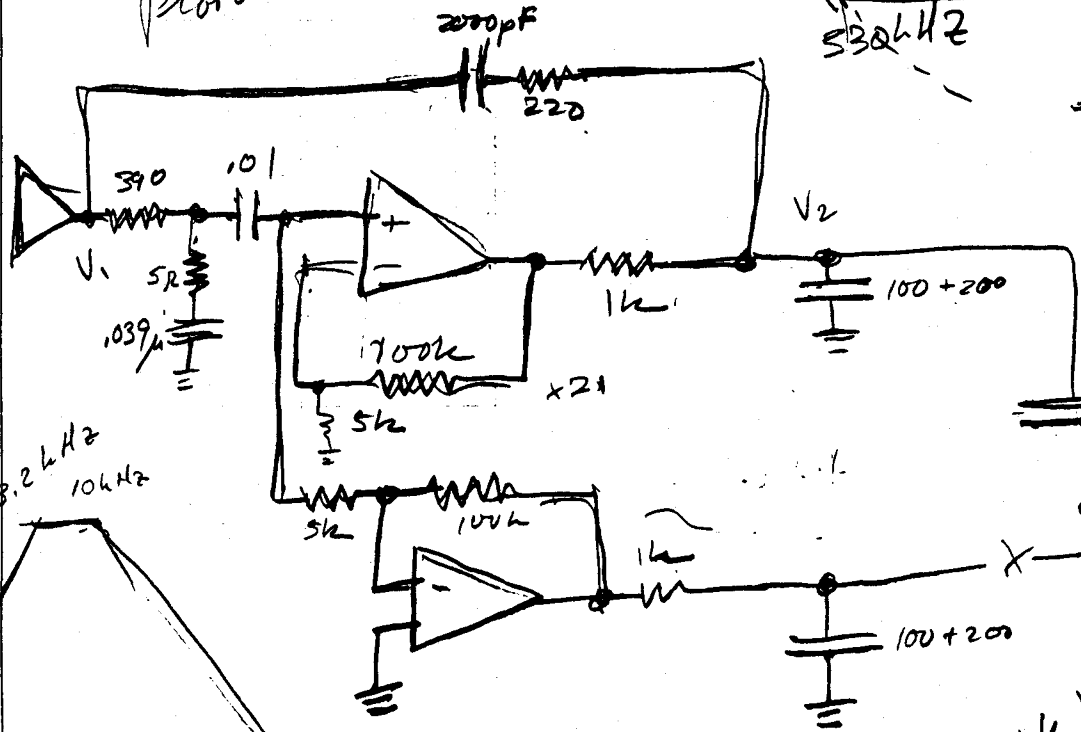
LASERSERVO

80kHz = 1kΩ | 2000pF

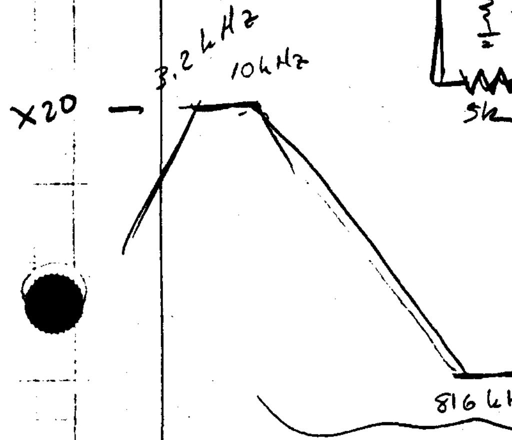




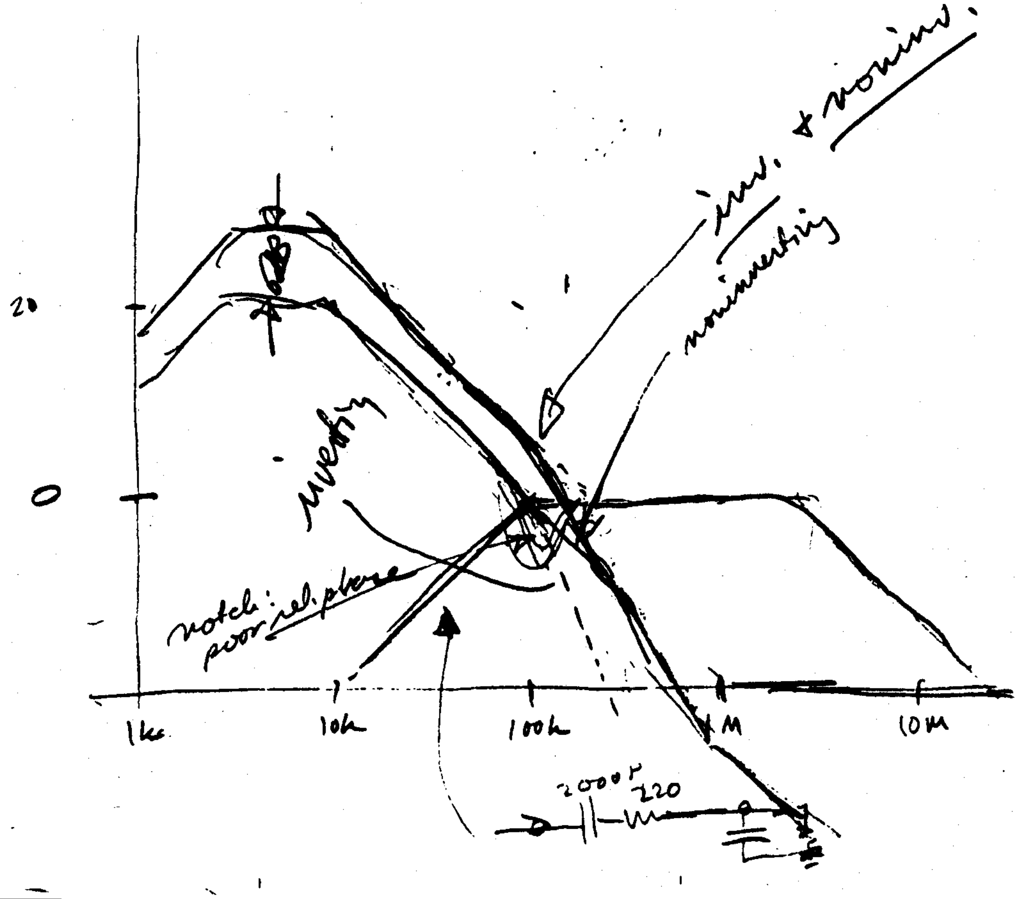
Proto #2



220||400 = 1.8



1k || 400pF = 400kHz

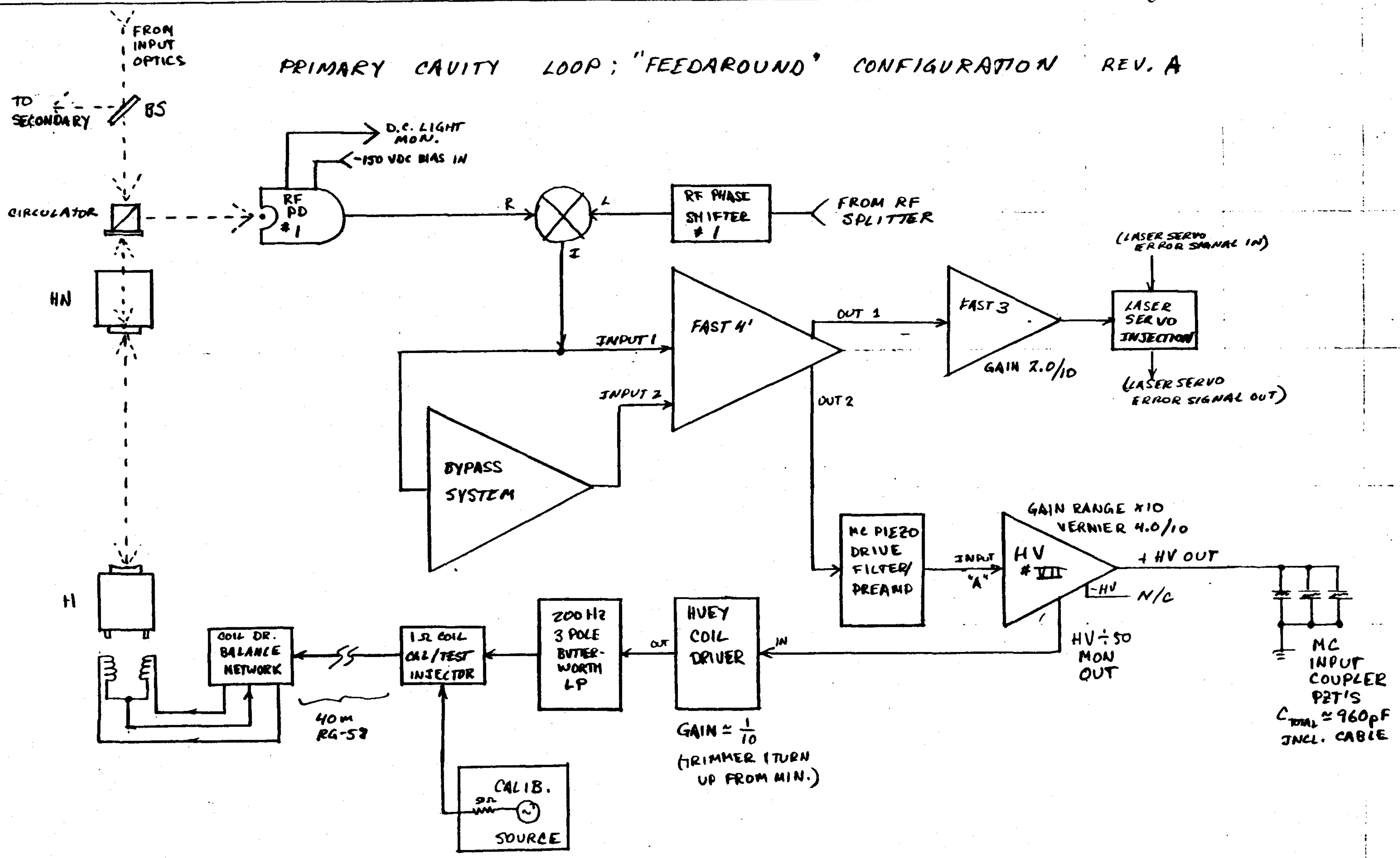


E9

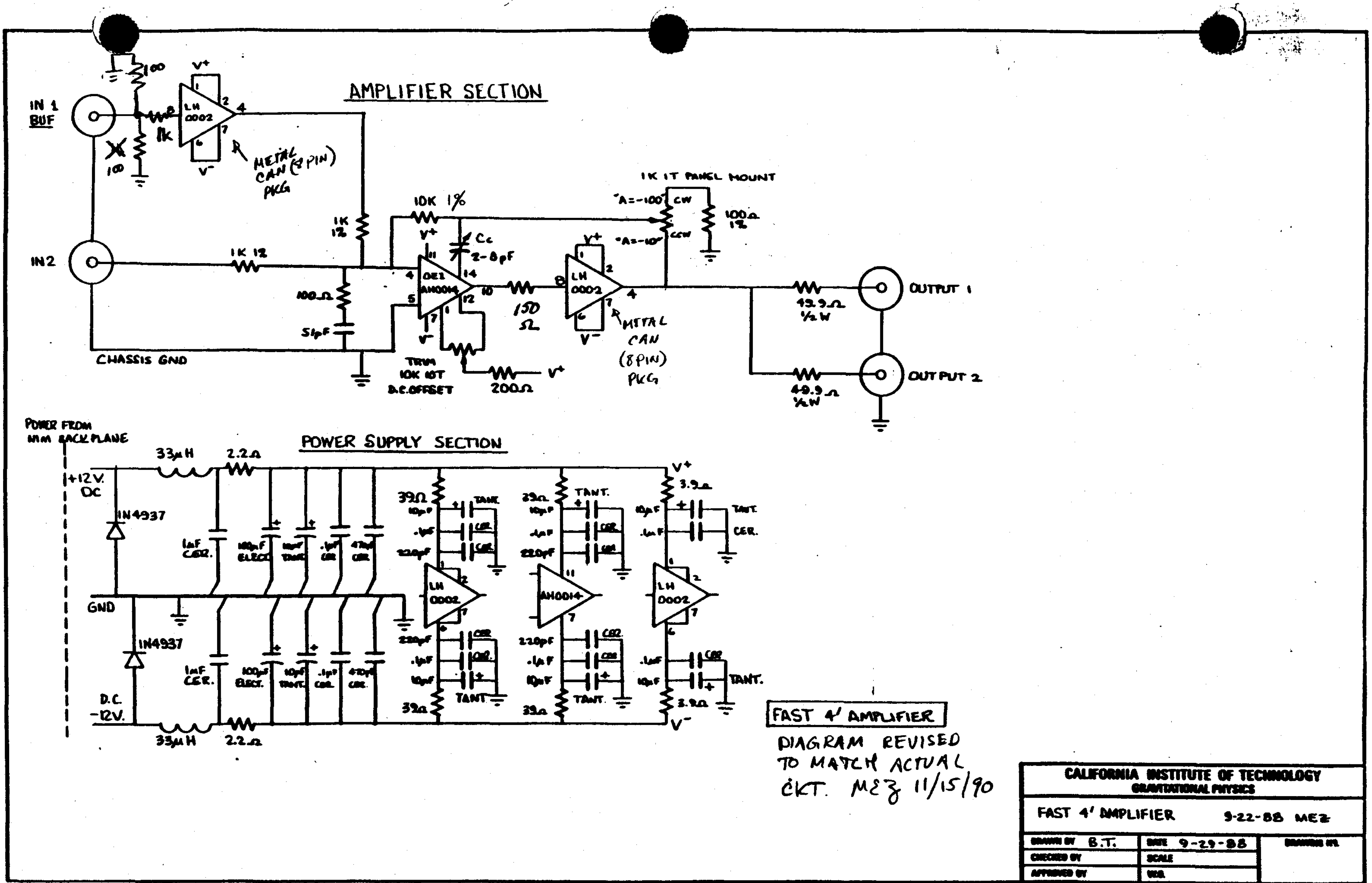
F. PRIMARY CAVITY LOOP

11/20/90 ME

PRIMARY CAVITY LOOP; "FEEDAROUND" CONFIGURATION REV. A



F1



AMPLIFIER SECTION
IN 1 BUF
IN2
100
1k
LH 0002
V+
V-
METAL CAN (8 PIN) PKG
1K 1%
1K 1%
100Ω
51pF
CHASSIS GND
10K 1%
Cc 2-8pF
OEI AH0014
TRIM 10K 10T D.C. OFFSET
200Ω
150 Ω
1K 1T PANEL MOUNT
"A=-100" CW
"A=-10" CCW
100Ω 1%
49.9Ω ½W
OUTPUT 1
OUTPUT 2
POWER FROM NIM BACKPLANE
POWER SUPPLY SECTION
+12V. DC
1N4937
GND
D.C. -12V.
33μH
2.2Ω
1mF CER.
100μF ELECT.
10μF TANT.
.1μF CER.
470pF CER.
39Ω
3.9Ω
TANT.
CER.
10μF
.1μF
220pF
AH0014
FAST 4' AMPLIFIER
DIAGRAM REVISED TO MATCH ACTUAL CKT. MEZ 11/15/90
CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS
FAST 4' AMPLIFIER 9-22-88 MEZ
DRAWN BY B.T.
DATE 9-29-88
CHECKED BY
SCALE
APPROVED BY
DRAWING NO.

88-0929-1

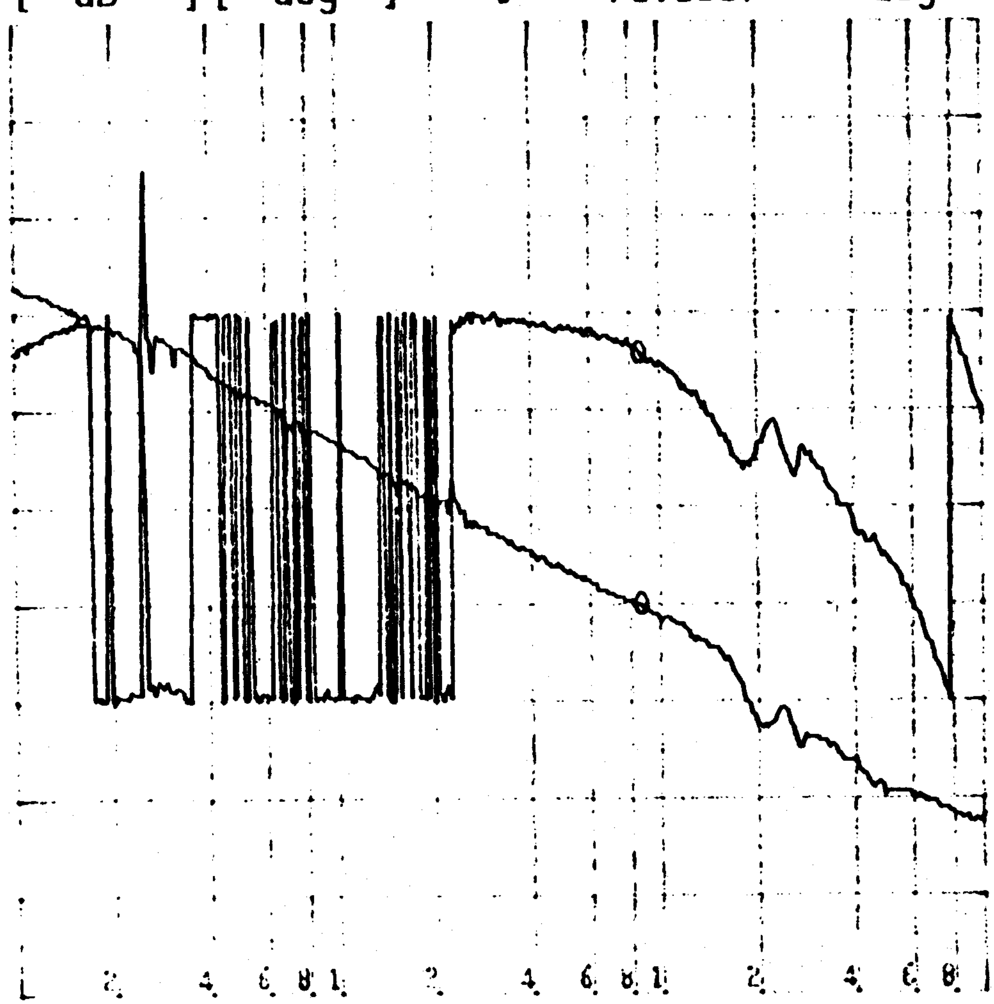
F2

Loop Gain of Primary Cavity Feedaround Servo (NO PC feedback active)

NETWORK Cor

A: REF	B: REF	0 MKR	86 099.375 Hz	
60.00	225.0	T/R	16.3404m	dB
[dB]	[deg]	θ	71.1657	deg

FILE "A1LGFA2"
DISK # 1
(START 10/10/90)



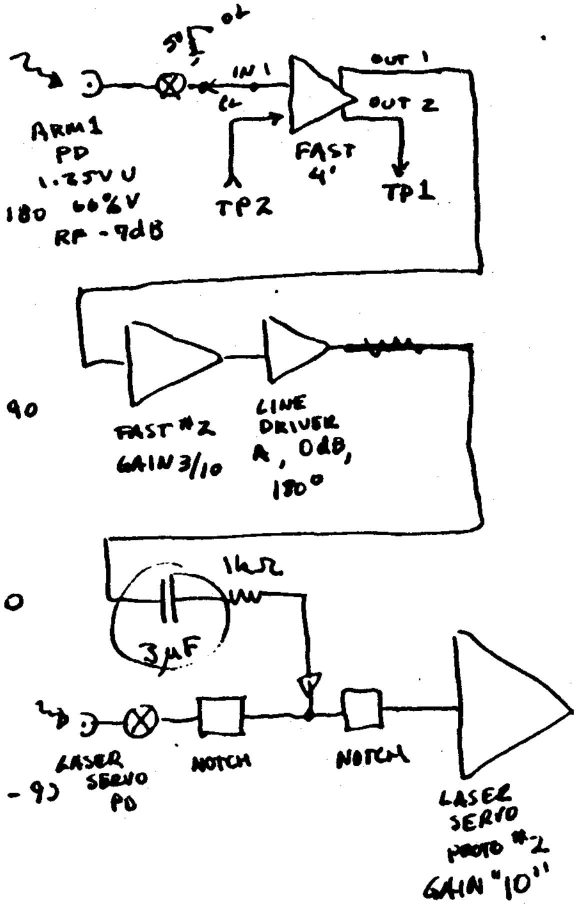
DIV	DIV	START	1 000.000 Hz
10.00	45.00	STOP	1 000 000.000 Hz

RBW: 300 Hz ST: 40.9 sec RANGE: R= 0, T=-10dBm

THIS PLOT DIFFERS FROM 17:00 BECAUSE 3μF AC COUPLING CAP WAS MOVED FROM INPUT OF FAST #2 TO OUTPUT OF LINE DRIVER A

=> HP POLE MOVED DOWN, FROM 3μF || 50Ω = 1kHz TO 3μF || 1kΩ = 50Hz (better Gain @ 1kHz, probably better xover w/ MCPZT)

TW



THIS PLOT:

$$\left[\frac{\left(\frac{TP_1}{TP_2}\right)_{OL}}{\left(\frac{TP_1}{TP_2}\right)_{CL}} - 1 \right] \equiv G_{OL}$$

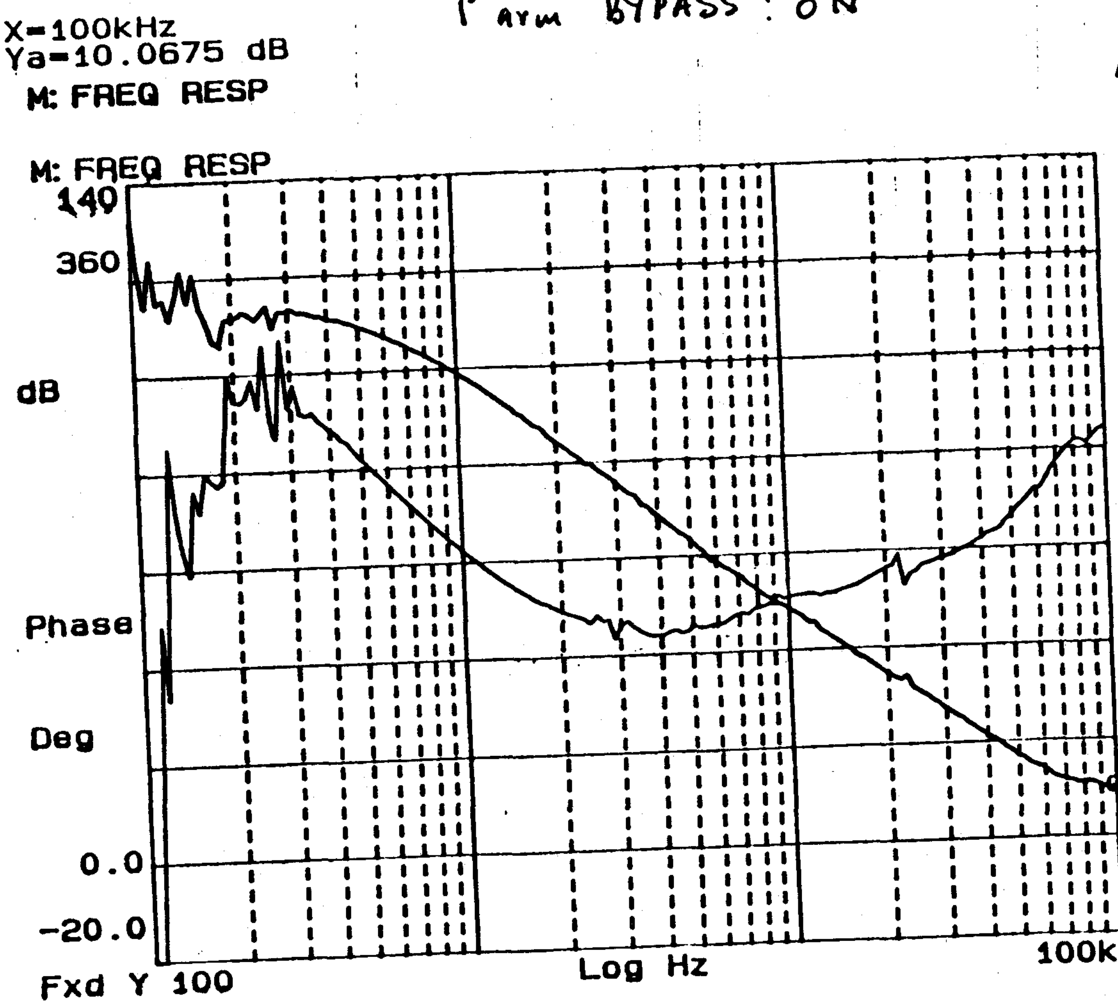
1st - open loop gain with feed-around

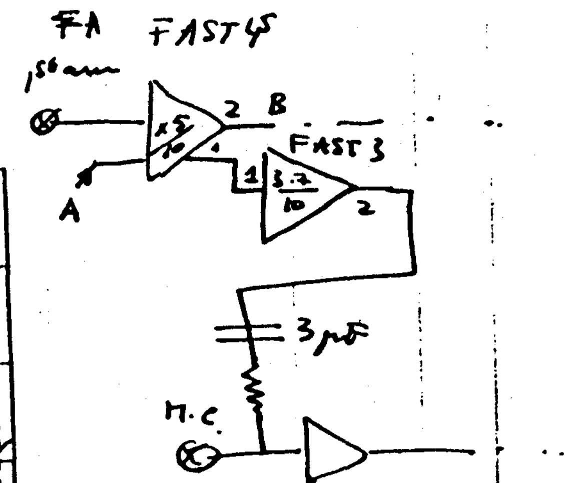
6-NOV-90 17:10

Light levels: 1.4V unlocked
0.4V locked

fn: A1FA
DISC B

1st arm BYPASS : ON





1. Gain without bypass

$$G_{NB} = \frac{\left(\frac{e_B}{e_A}\right)_{\text{open loop}}}{\left(\frac{e_B}{e_A}\right)_{\text{closed loop}}} - 1$$

2. Gain with bypass (shown)

$G_B = G_{NB} \times (1 +$ Bypass gain
measured previously as "BYPASS"

NOT TO BE TRUSTED BELOW 300 Hz

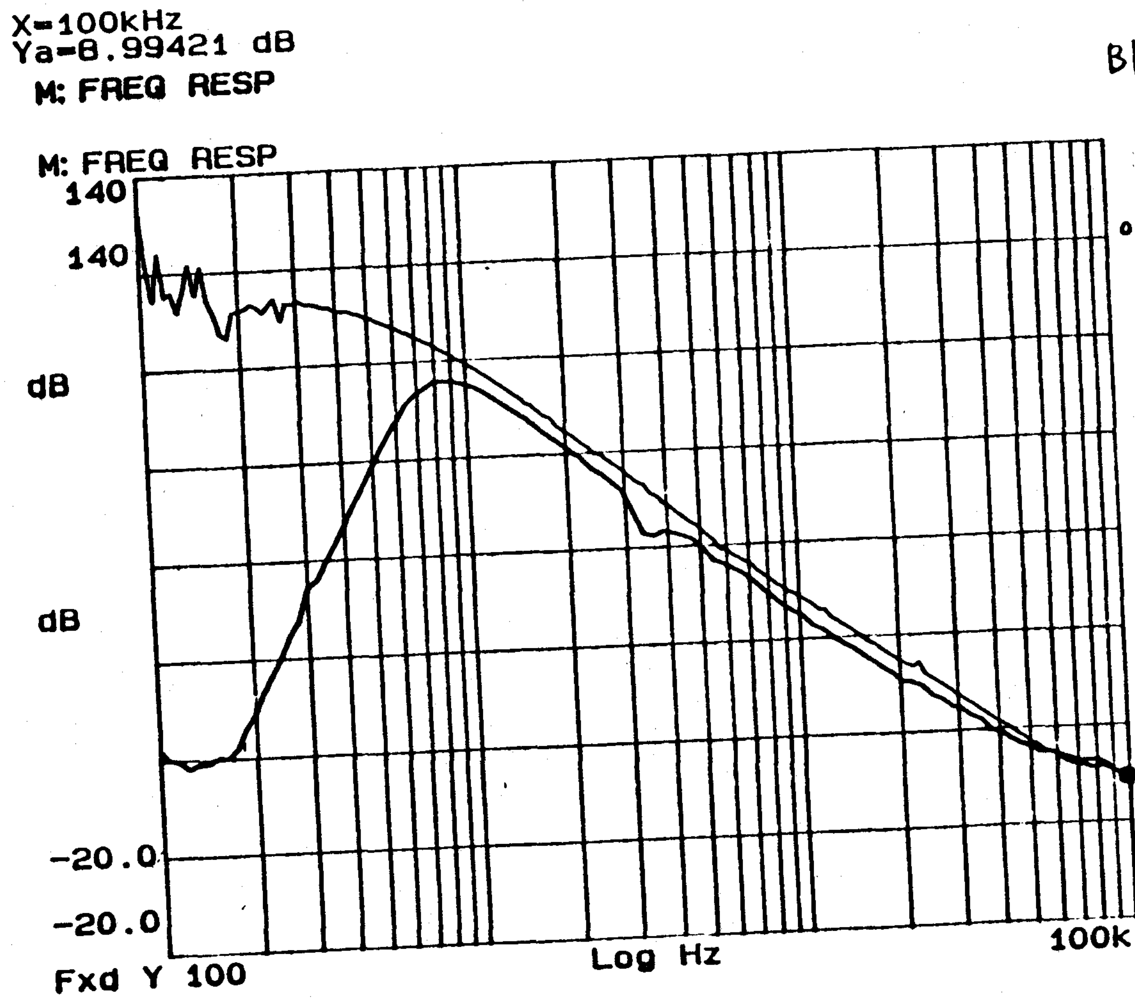
F4

11-6-90 18

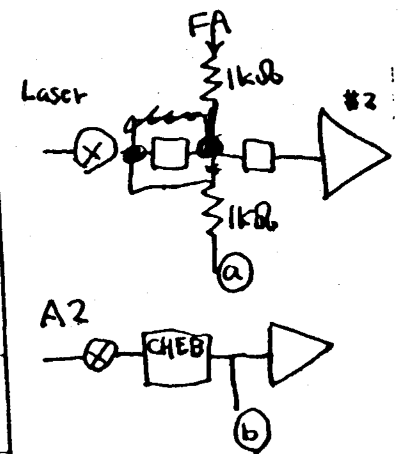
1st arm servo performance, with feed-around

Blue: "Nominal" loop gain of the arm 1 with FA.
(same as 6-NOV-90, 17:10

Black: "Effective" loop gain of the arm 1 with FA
≡ SUPPRESSION OF ARTIFICIAL ν NOISE AS MEASURED BY SECONDARY CAVITY



- FA set-up same as 17:10



$$\text{"Black"} = \frac{\left(\frac{b}{a}\right)_{no\ A1}}{\left(\frac{b}{a}\right)_{w/A1}}$$

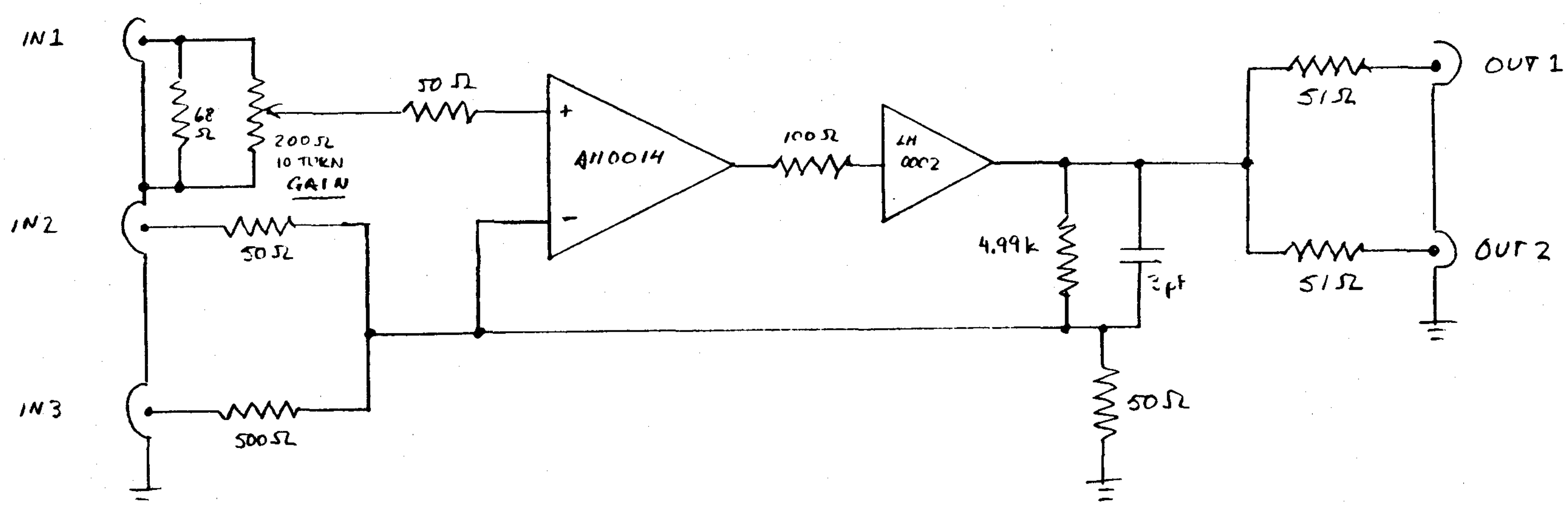
Black : A1FAEFF in Disk B

FU

11/20/90 MS

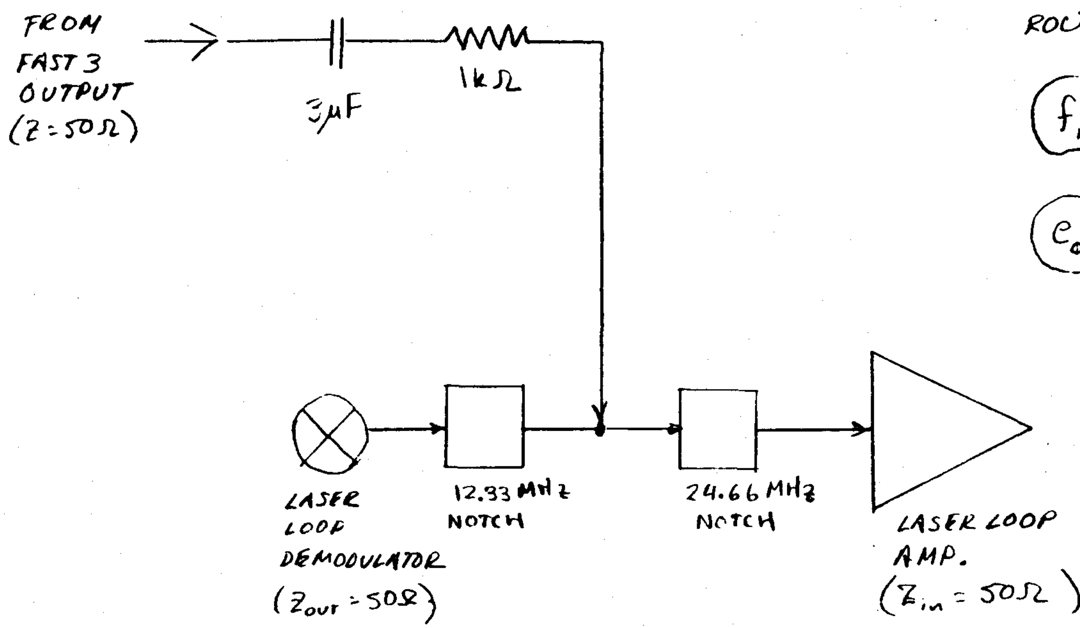
PRIMARY CAVITY SERVO: "FAST #3" AMPLIFIER

[NOTE: ROUGH CKT. ONLY, COPIED FROM 11/14/88 LASER LOOP DRAWING SET, OLD BLUE "LOCKING SERVO HANDBOOK"]

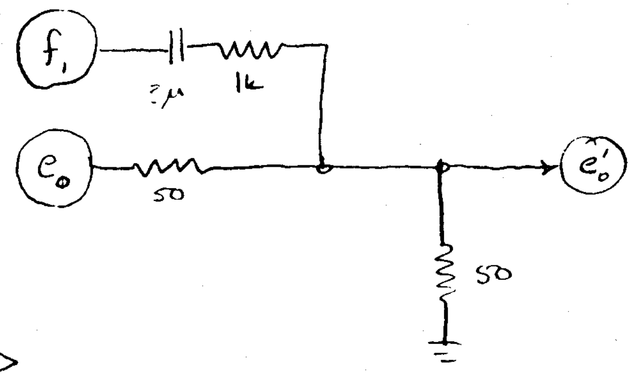


F6

PRIMARY CAVITY LOOP; LASER SERVO INJECTION NETWORK



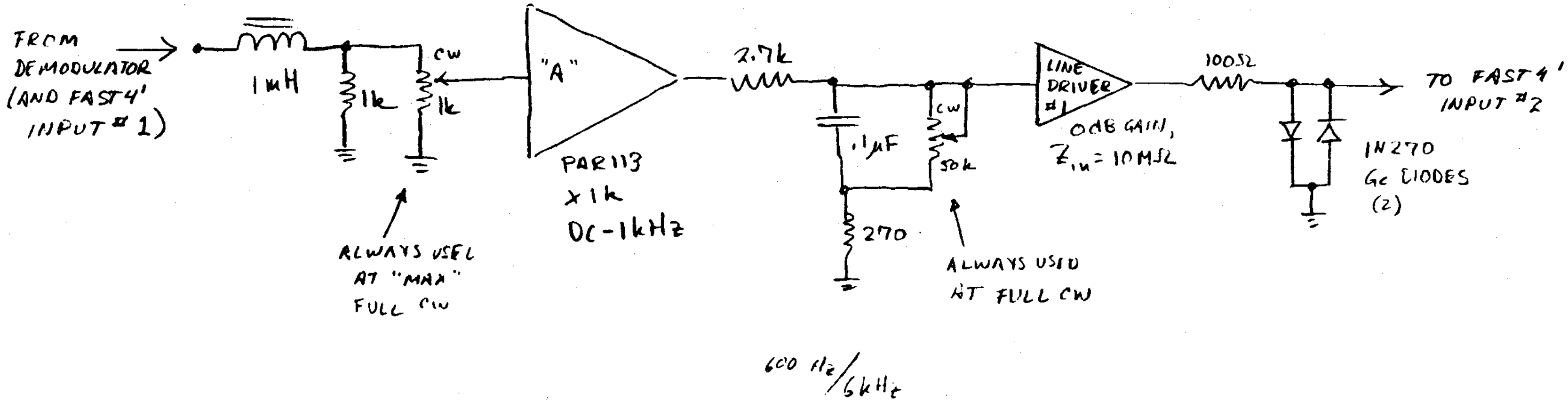
ROUGH EQUIVALENT CIRCUIT;



F7

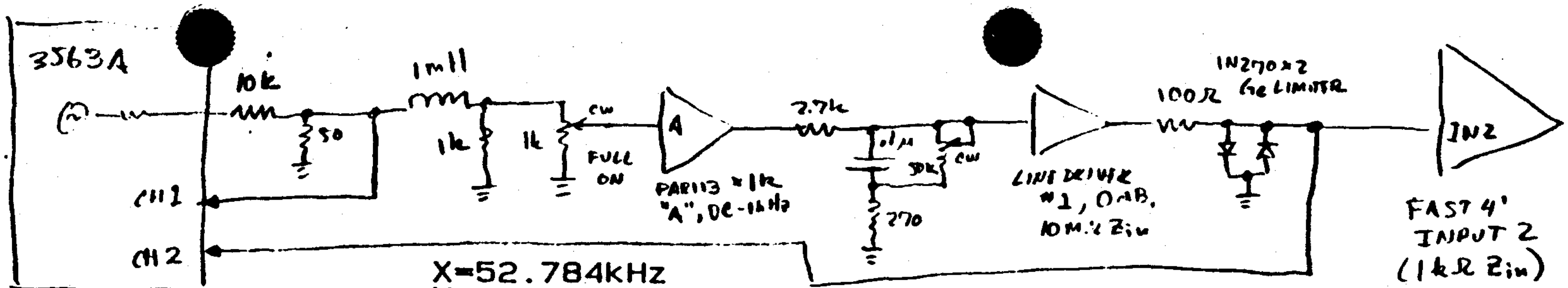
11/20/90 MEZ

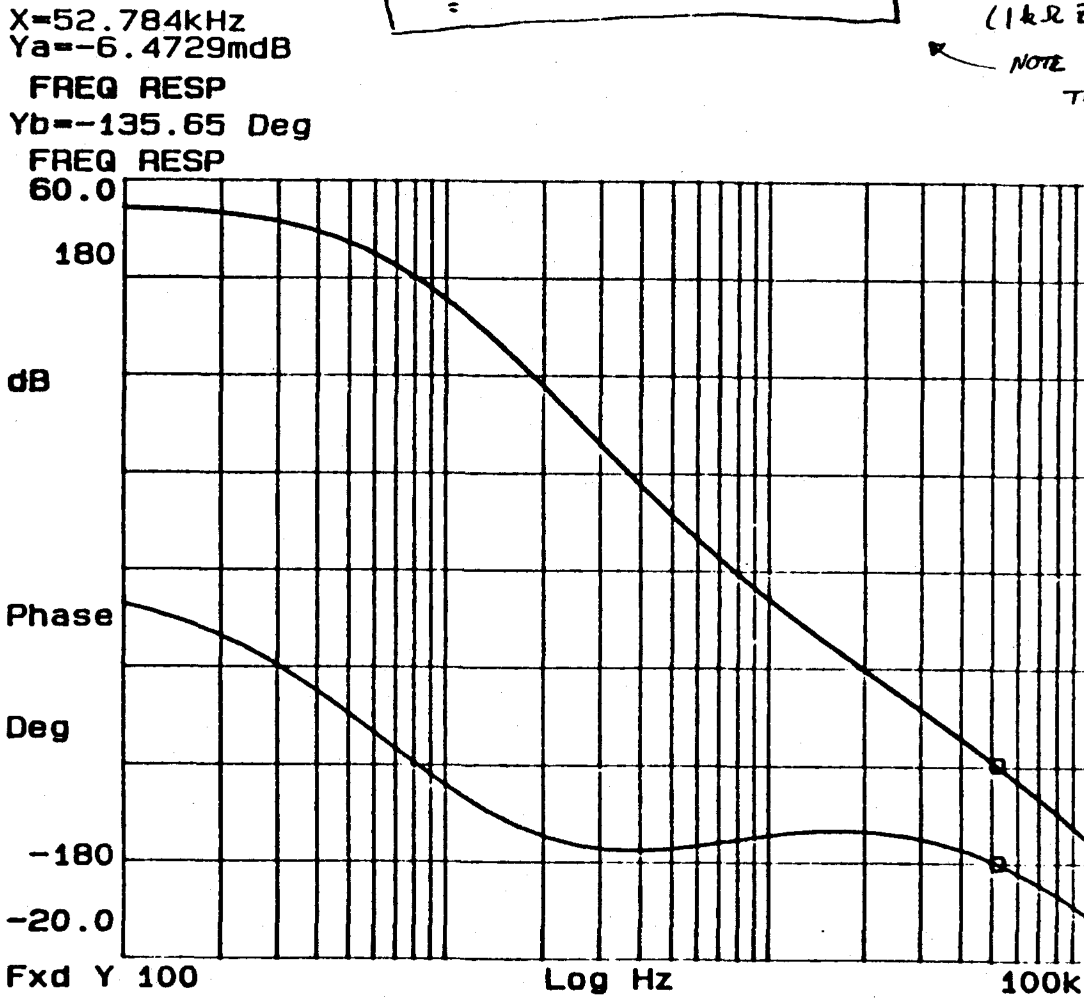
PRIMARY CAVITY LOOP ; BYPASS SYSTEM



T1
8

11/1/90 #20





ARM 1 BYPASS TRANSFER F'N

LOGBOOK #20 p.028W

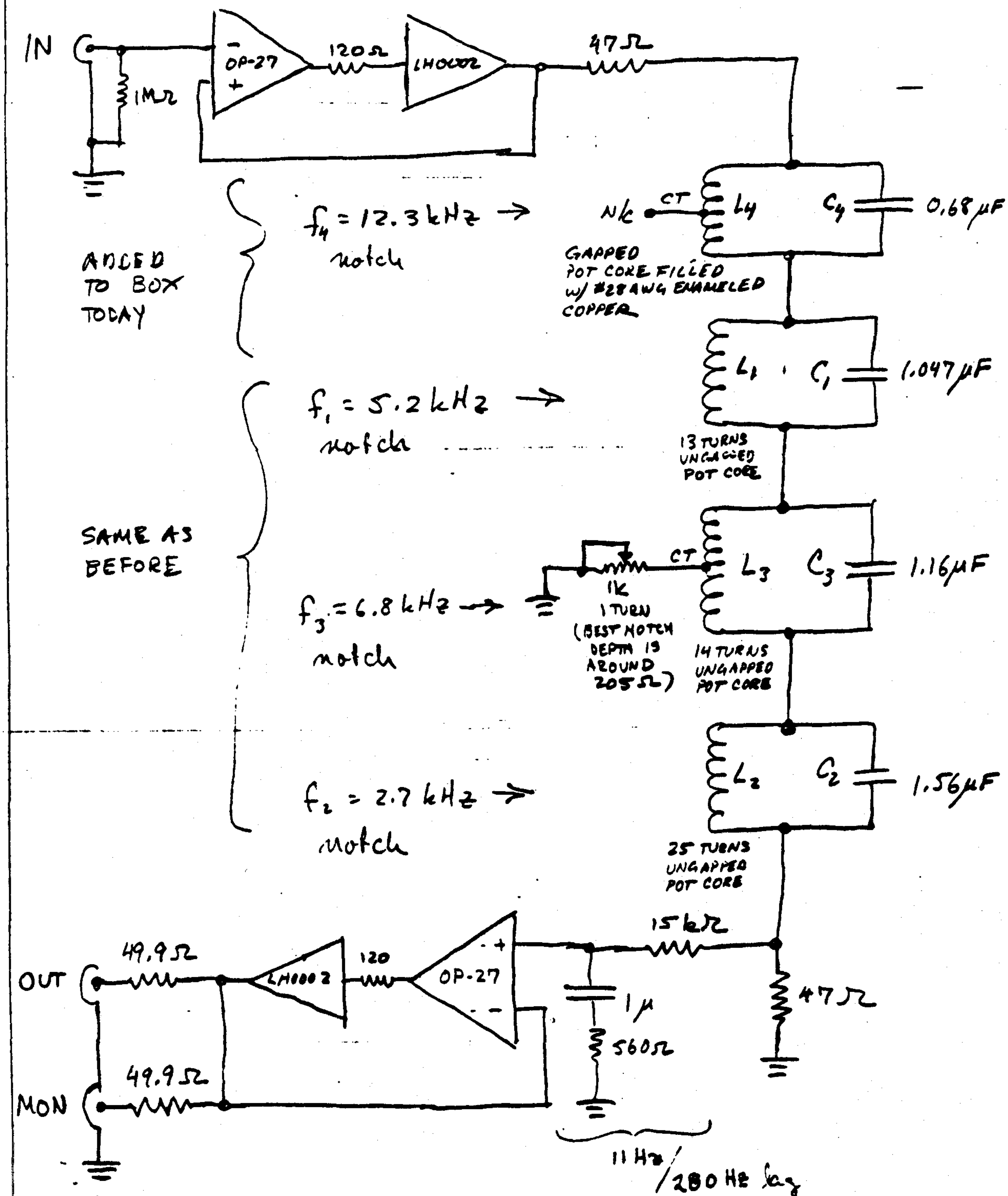
FILE "BYPASS", DISK B, PAGE 1

F9

5/15/90 MEZ 16:30

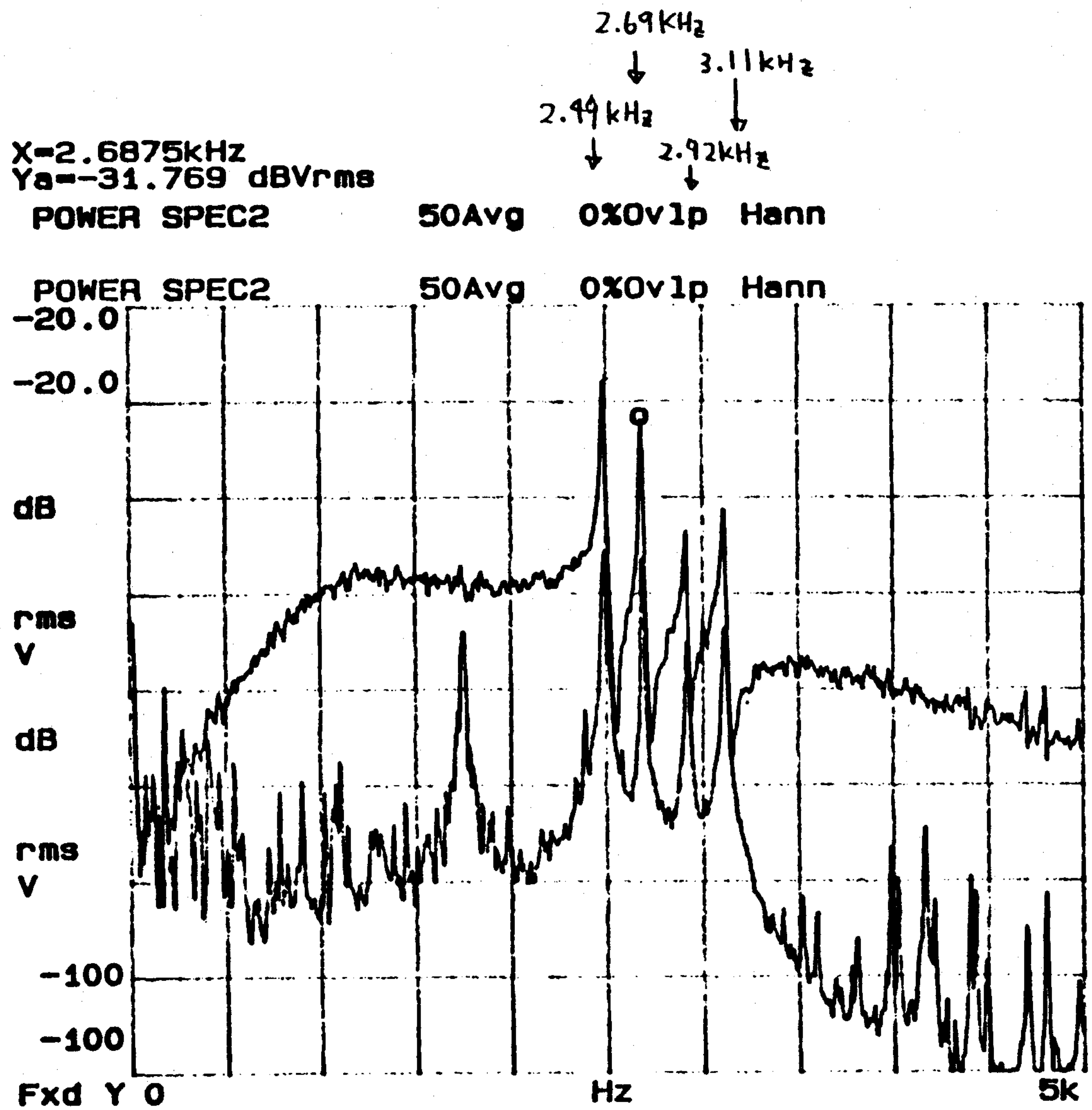
New 12.3 kHz Notch Filter Installed Permanently in MC PIEZO DRIVE FILTER / PREAMP Box

Circuit is now as follows.

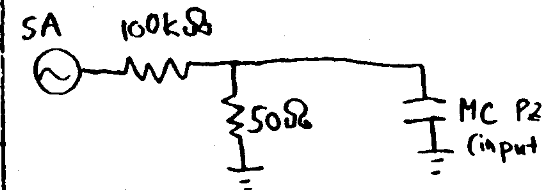


POWER SUPPLY COMMON ON NIM BACKPLANE
CIRCUIT IS NOT GROUNDED TO CHASSIS
(ALL BNC'S ISOLATED)

10-23-90 15:30



Arm 2 error signal with and without white noise applied to MC PZT



Orange : random noise applied (300mVrms in SA)

Green : without

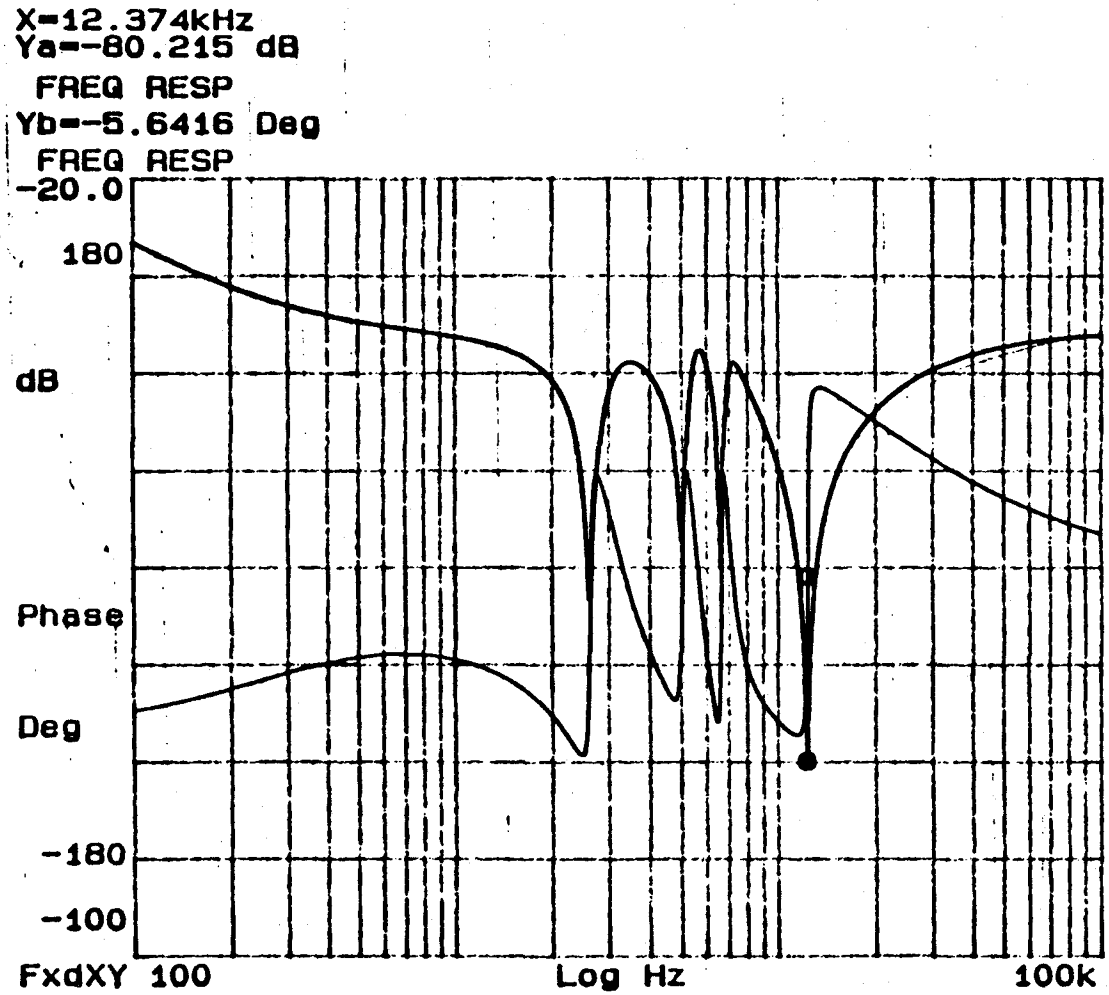
The four peaks were identified in (17) 092 Y (opposite)

5/15/[illegible] 17:30

AFTER

TRANSFER FUNCTION OF "MC PIEZO DRIVE FILTER/ PREAMP" MODULE AFTER MODIFICATION [ADDED AN ADDITIONAL NOTCH AT 12.37 kHz INSIDE CIRCUIT]

SUPERCEDES XFER F'N ON P. 077 OF BOOK # 17

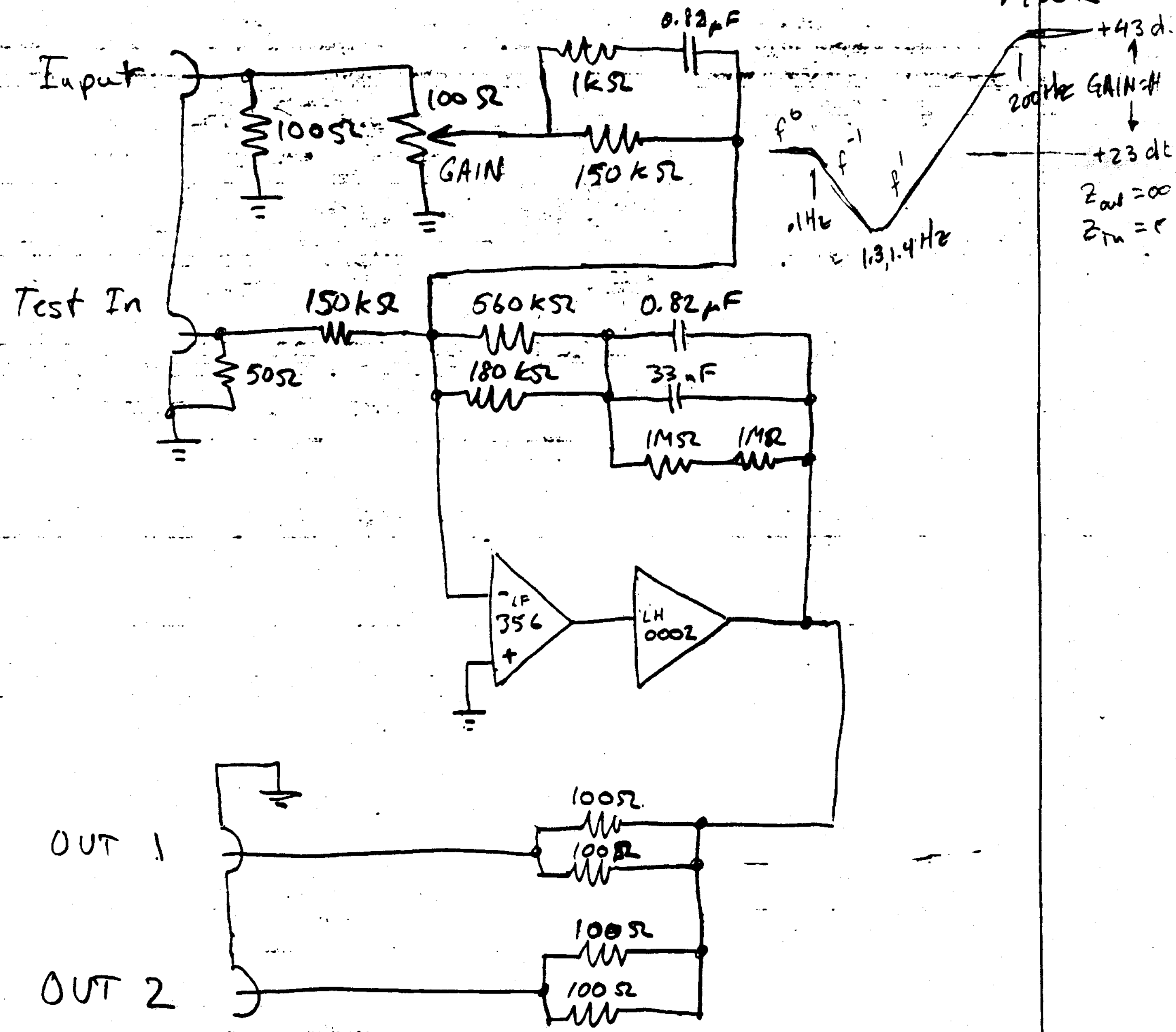


← note 6dB increase, due to placing notch between existing buffers in module rather than outside; compensated by cutting gain of HV # VII back down.

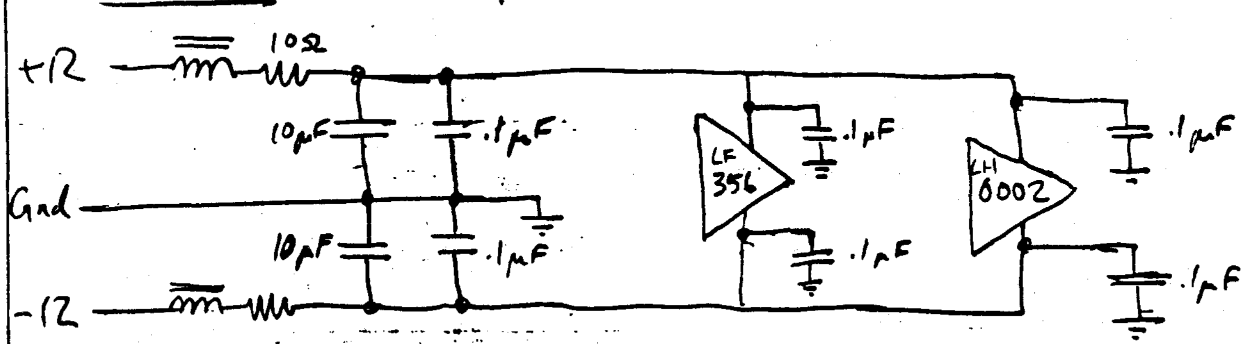
Huey Coil Driver

891020

MWR



POWER



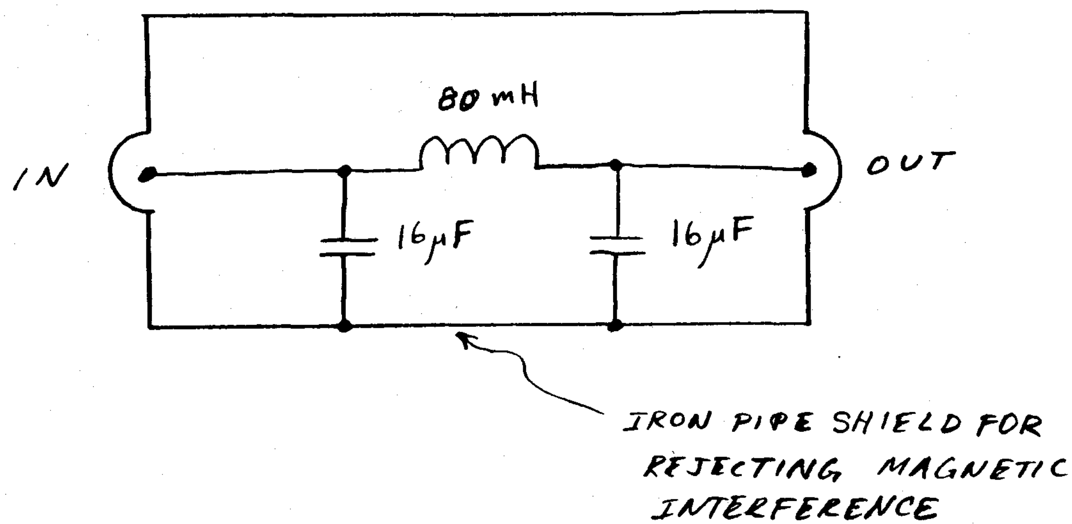
F13

10/10/90 MEZ

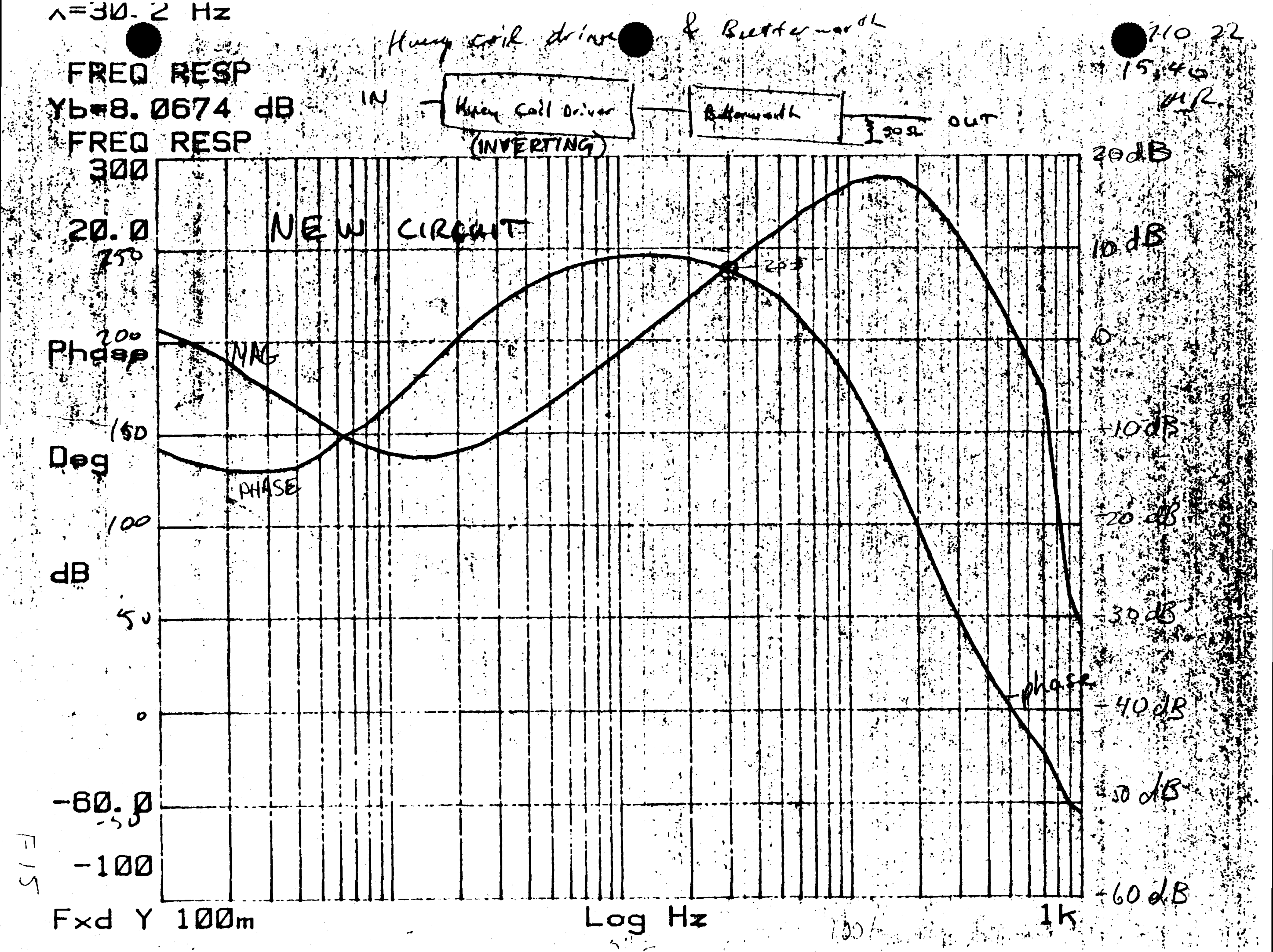
PRIMARY CAVITY SERVO;

200Hz 3-POLE BUTTERWORTH LOWPASS FILTER

$Z_{in} = 50\Omega = Z_{OUT}$



F14

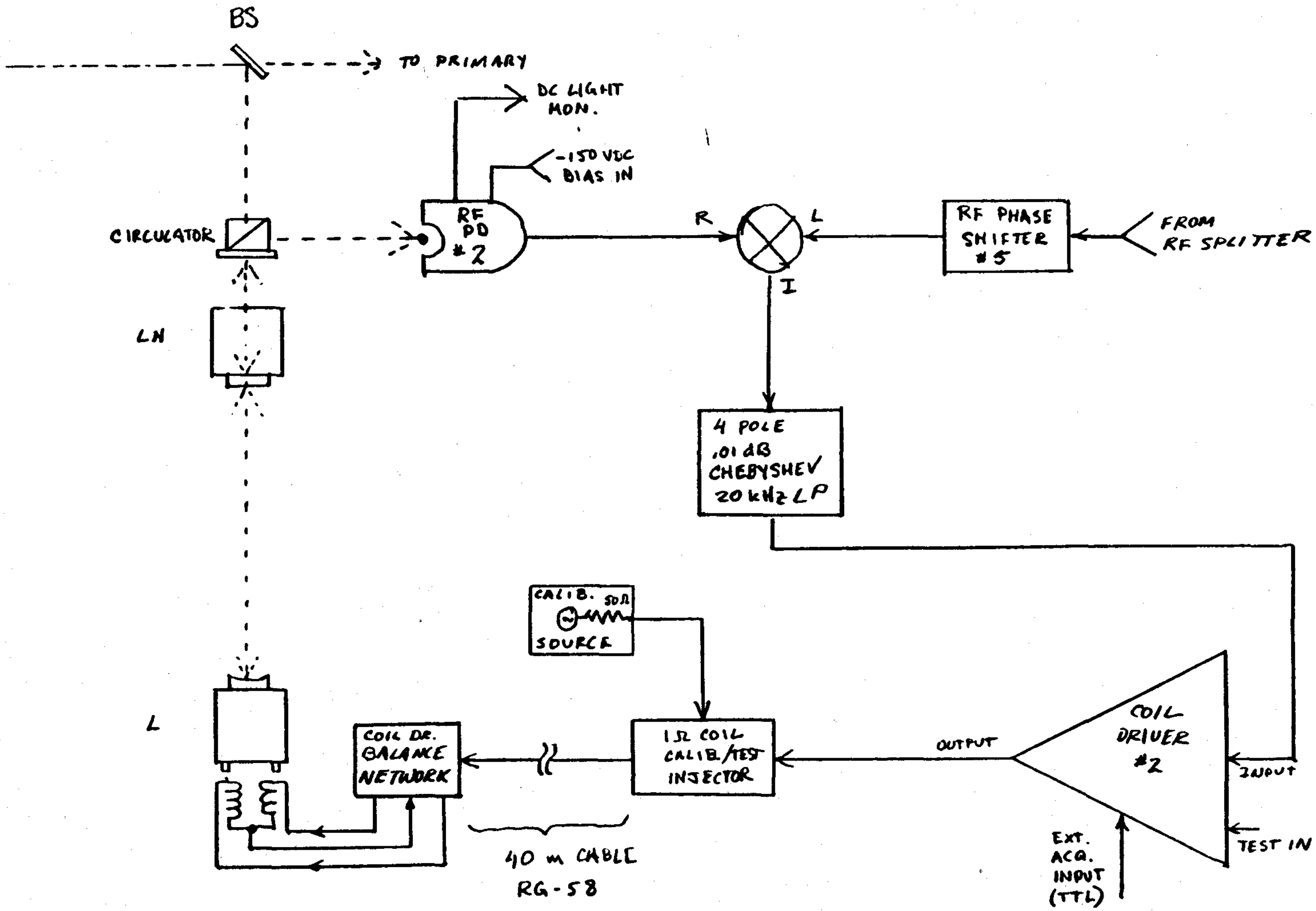


^=30.2 Hz
FREQ RESP
Yb=8.0674 dB
FREQ RESP
300
20.0
-60.0
-100
Phase
Deg
dB
Fxd Y 100m
Log Hz
1k
Huey coil driver & Butterworth
IN
Huey Coil Driver
(INVERTING)
Butterworth
50Ω
OUT
NEW CIRCUIT
MAG
PHASE
phase
20dB
10dB
0
-10dB
-20dB
-30dB
-40dB
-50dB
-60dB
250
200
150
100
50
0
-50

G. SECONDARY CAVITY LOOP

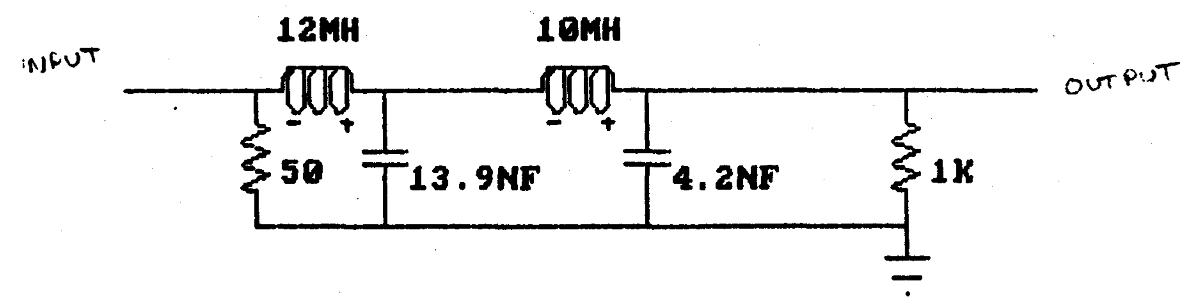
11/20/90 MLZ

SECONDARY CAVITY LOOP BLOCK DIAGRAM

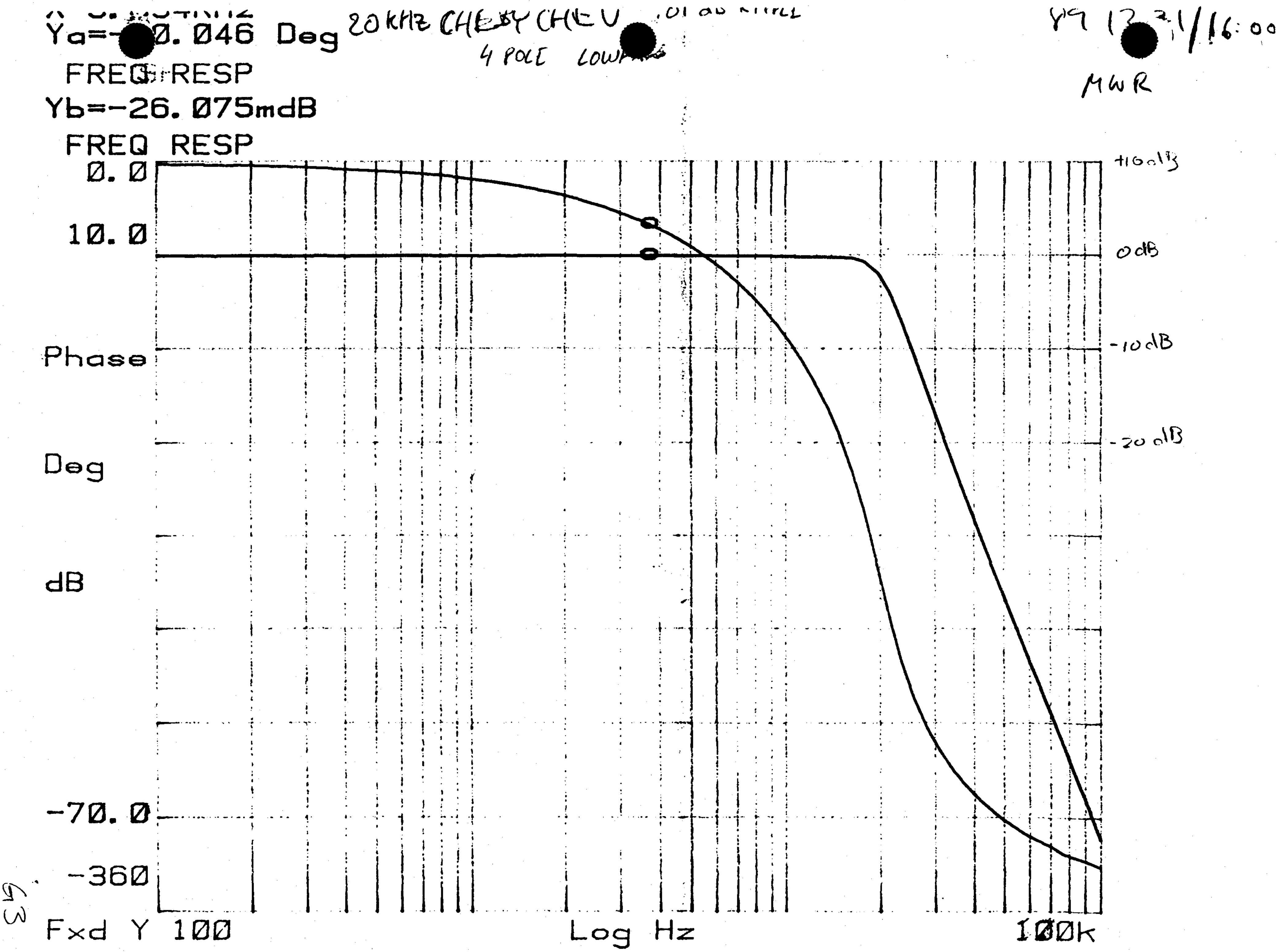


G1

4 POLE CHEBYCHEFF .01 DB 20 KHZ FILTER

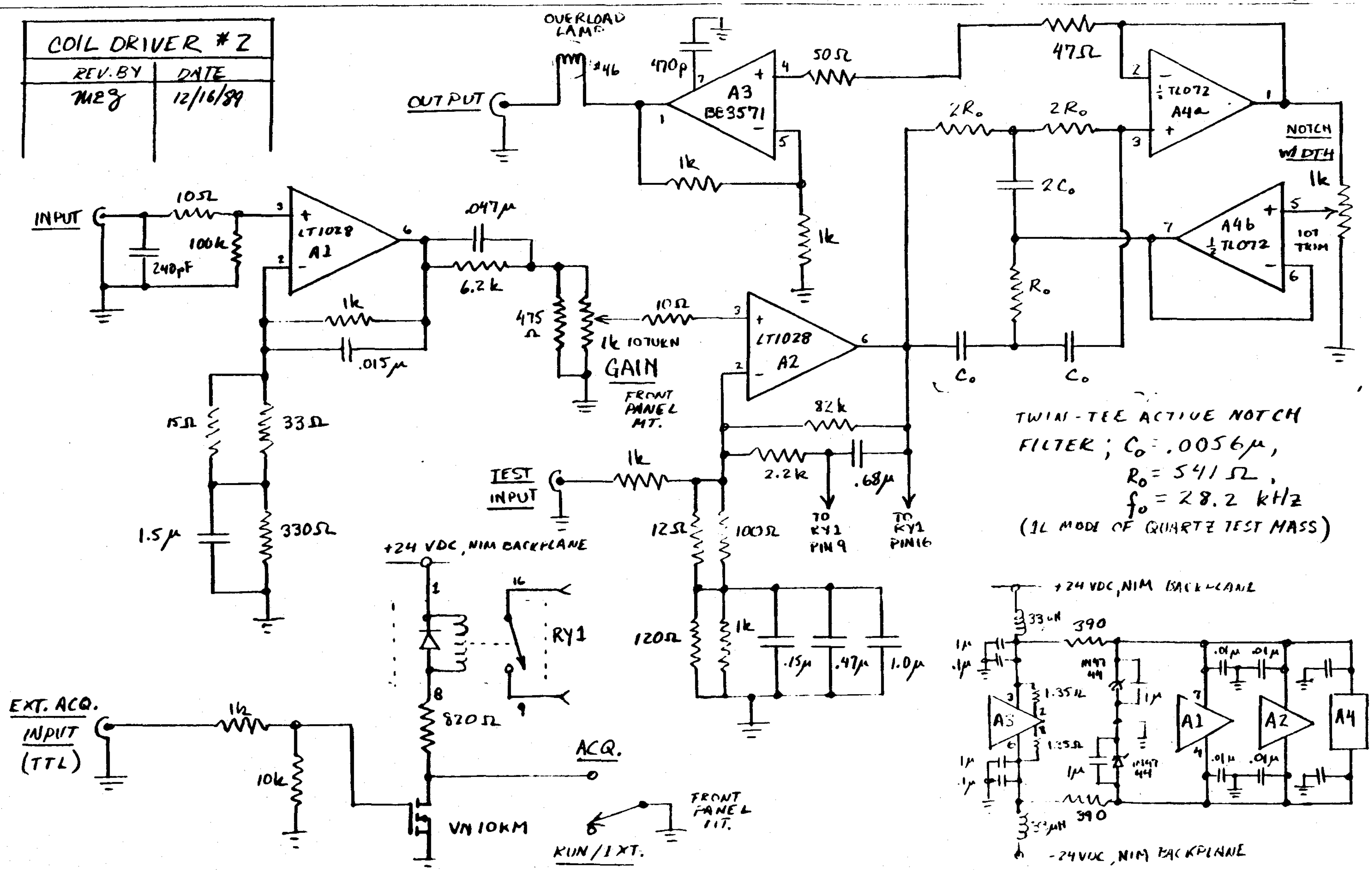


G2



Ya=-0.046 Deg
FREQ RESP
Yb=-26.075mdB
FREQ RESP
20 kHz CHEBYCHEV
4 POLE LOW
MWR
0.0
10.0
Phase
Deg
dB
-70.0
-360
+10 dB
0 dB
-10 dB
-20 dB
Fxd Y 100
Log Hz
100k
63

12/16/89 MEJ

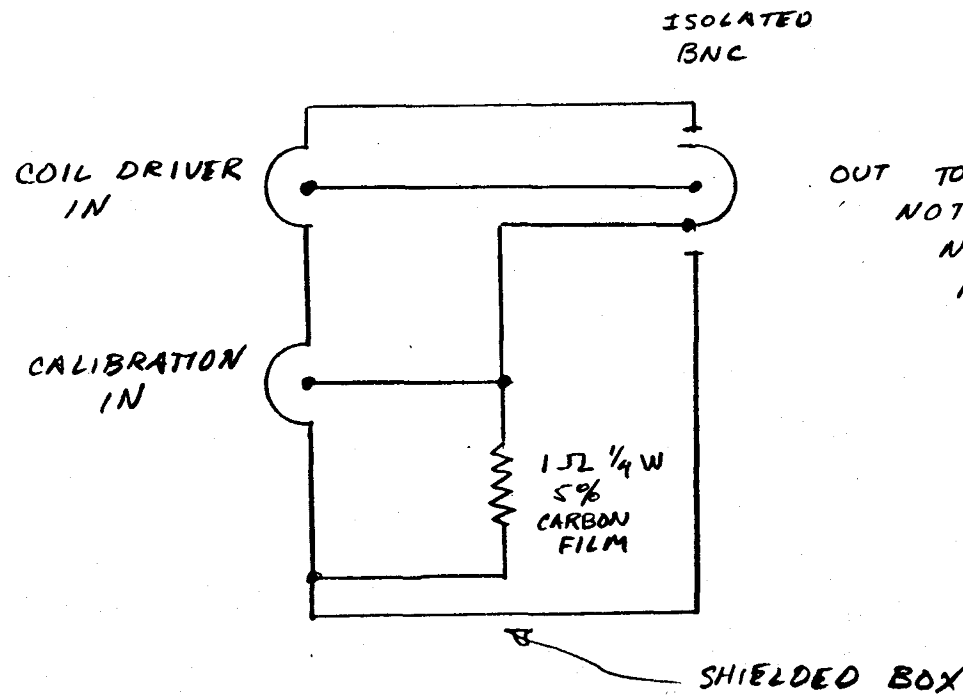


G4

10/10/90 MEZ

PRIMARY, SECONDARY CAVITY SERVOS;

$1\,\Omega$ COIL CALIBRATION/TEST INJECTOR



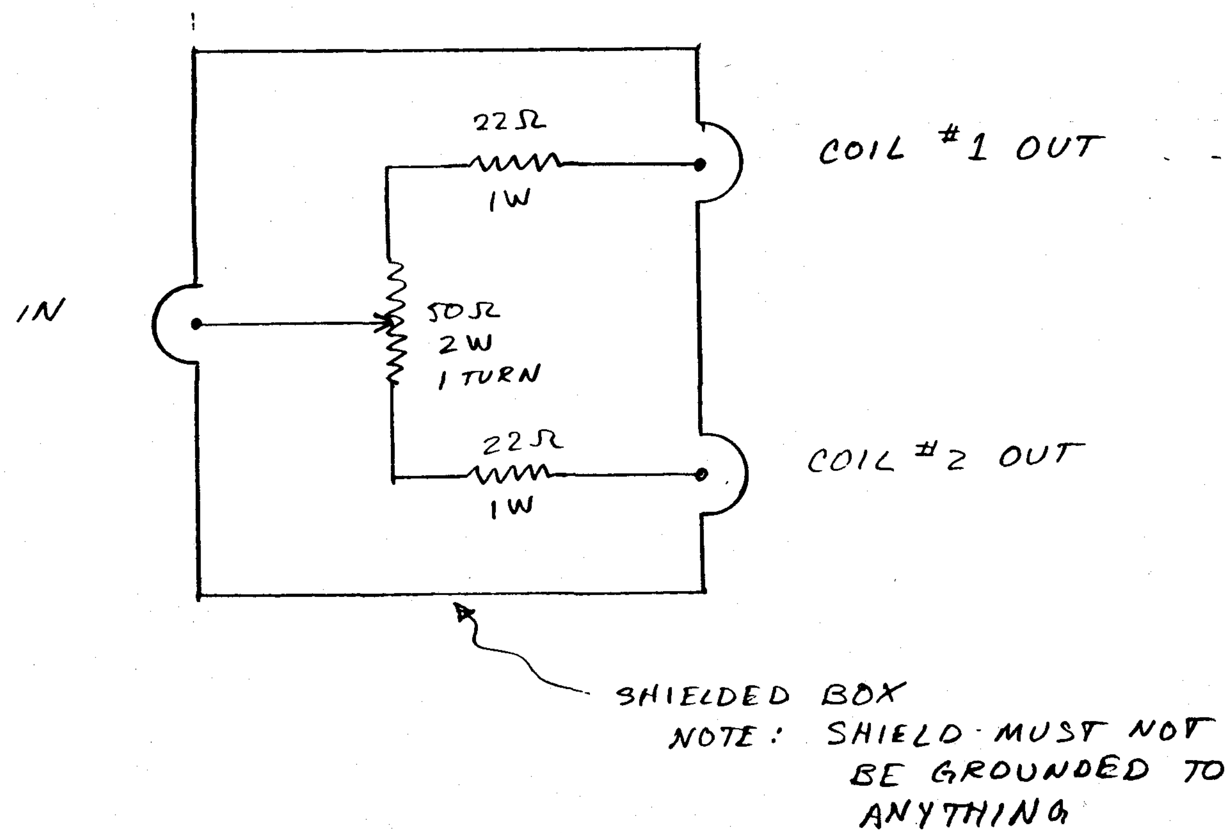
NOTE: SHIELD MUST NOT BE GROUNDED ANYWHERE, OR CALIBRATION WILL BE IN ERROR!

59

10/10/90 MEZ

PRIMARY, SECONDARY CAVITY SERVOS;

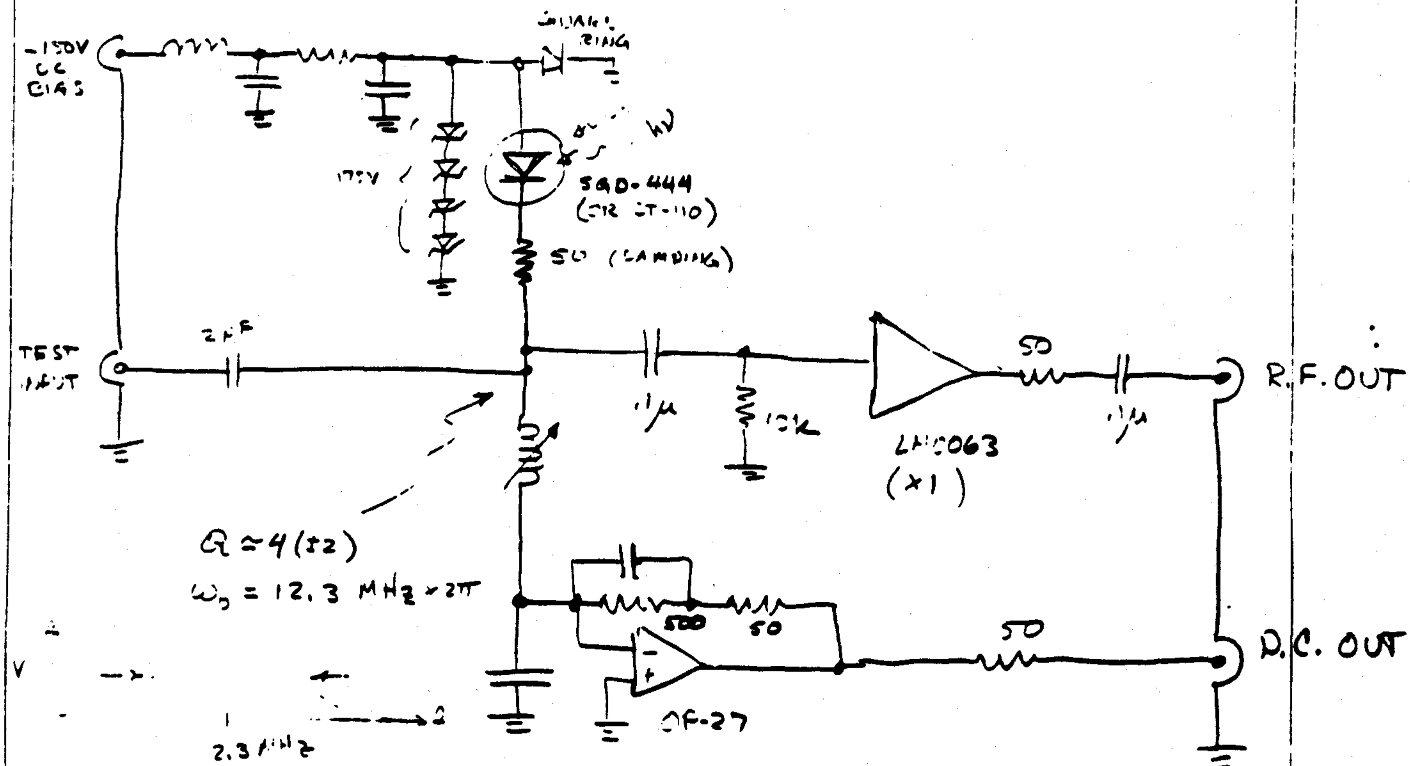
COIL DRIVE BALANCE NETWORK, END TEST MASS



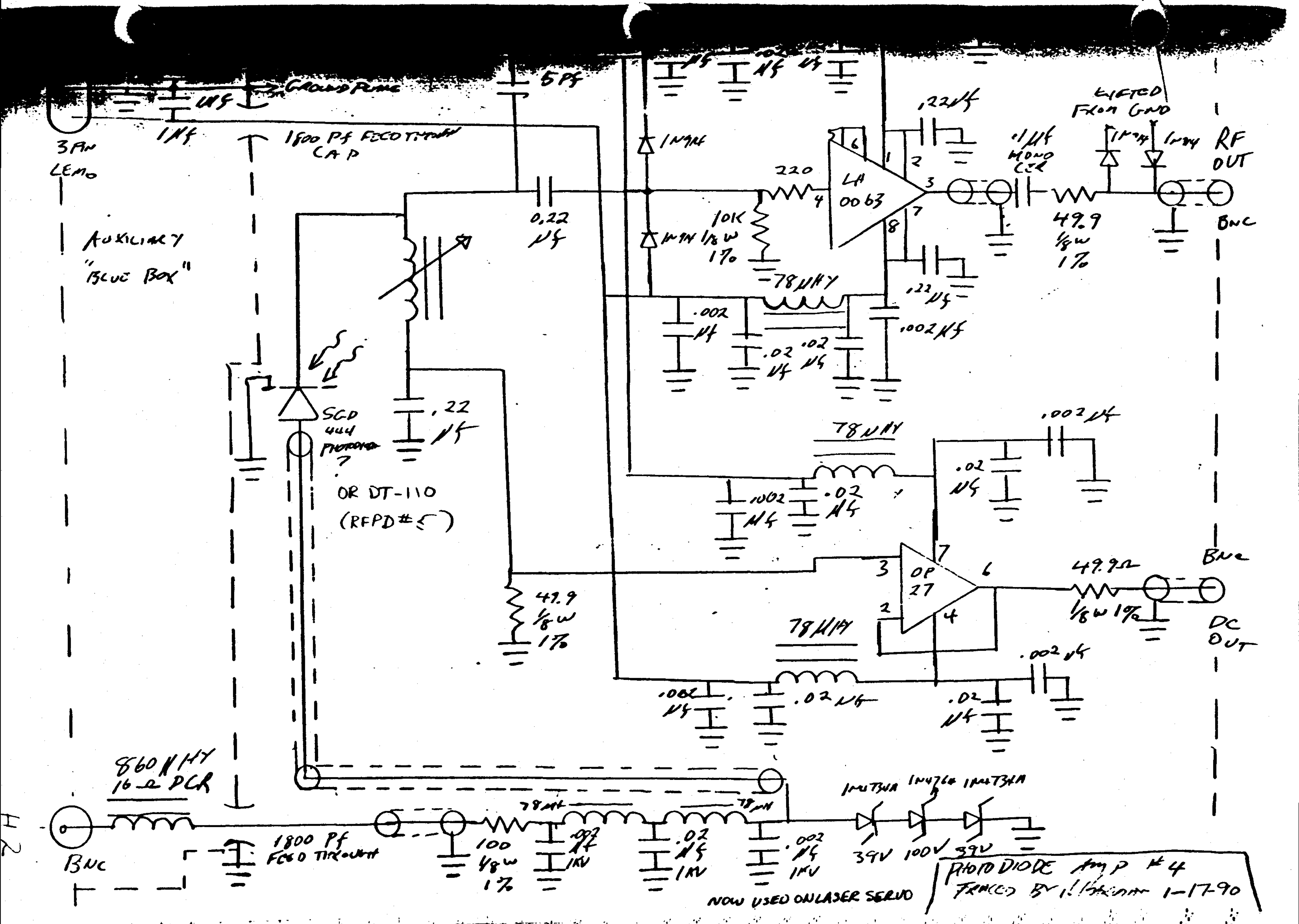
H. PHOTODETECTORS

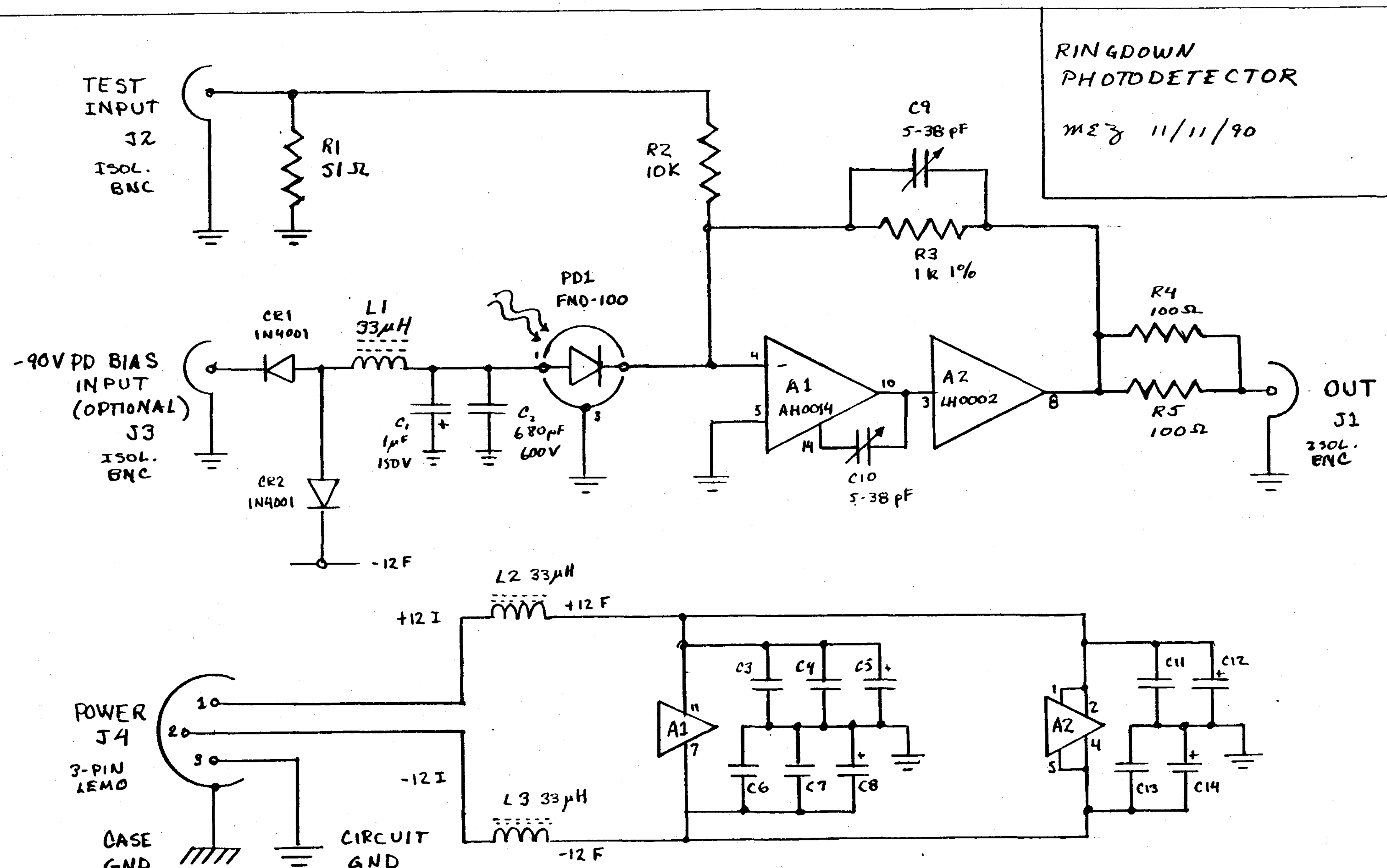
11/14/88 MEZ

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



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


GROUND PLANE
5 pF
.22 µf
LIFTED FROM GND
1N914
RF OUT
3 PIN LEMO
1800 PF FEEDTHROUGH CAP
220
LH 0063
.1 µf MONO CER
49.9 1/8 W 1%
BNC
0.22 µf
10K 1/8 W 1%
AUXILIARY "BLUE BOX"
78 µHY
.002 µf
.02 µf
.002 µf
SGD 444
OR DT-110 (RFPD #5)
.22 µf
78 µHY
OP 27
49.9 Ω 1/8 W 1%
DC OUT
49.9 1/8 W 1%
860 µHY 16 Ω DCR
BNC
1800 Pf FEED THROUGH
100 1/8 W 1%
.002 µf 1KV
.02 µf 1KV
39V 100V 39V
PHOTO DIODE AMP #4
NOW USED ON LASER SERVO



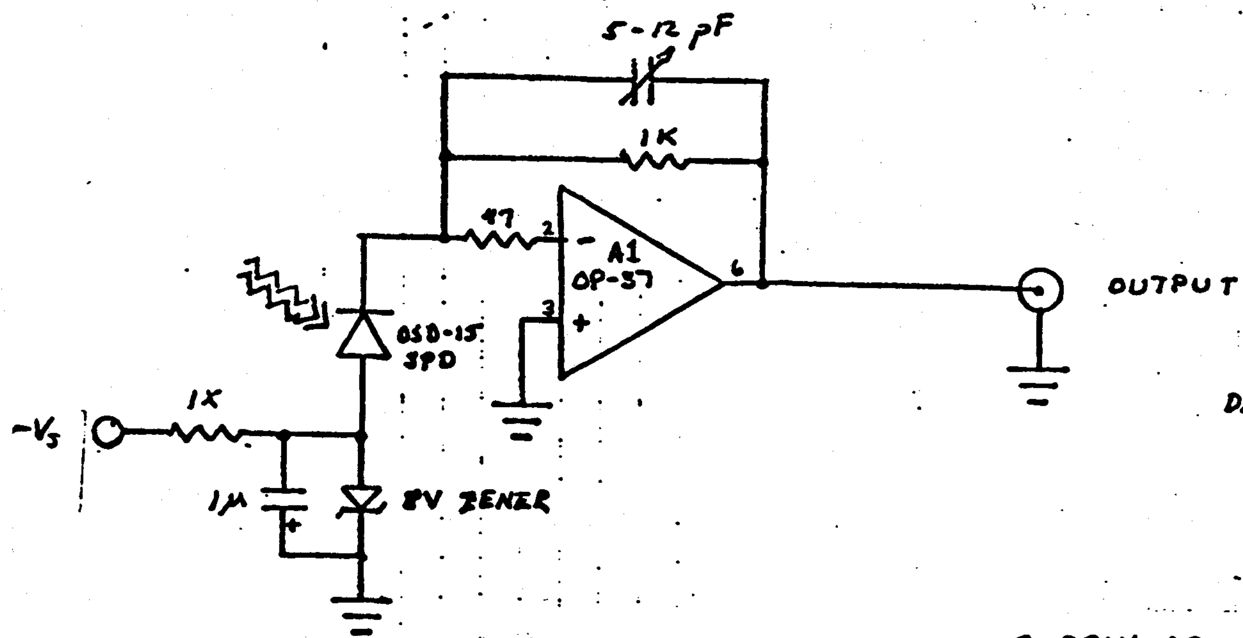
C3, C6 = .1μF CERAMIC; C4, C7, C11, C13 = 1μF CERAMIC; C5, C8, C12, C14 = 10μF TANT.

H3

NOISE EATER SENSING DIODE

2/27/85 MEZ

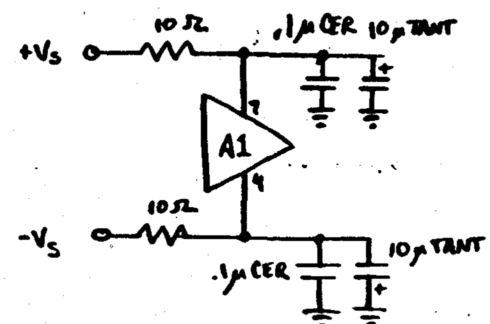
DIODE #73



0.33 V/mW

DARKNOISE ≈ 5 nV/$\sqrt{Hz}$ (TYP.)

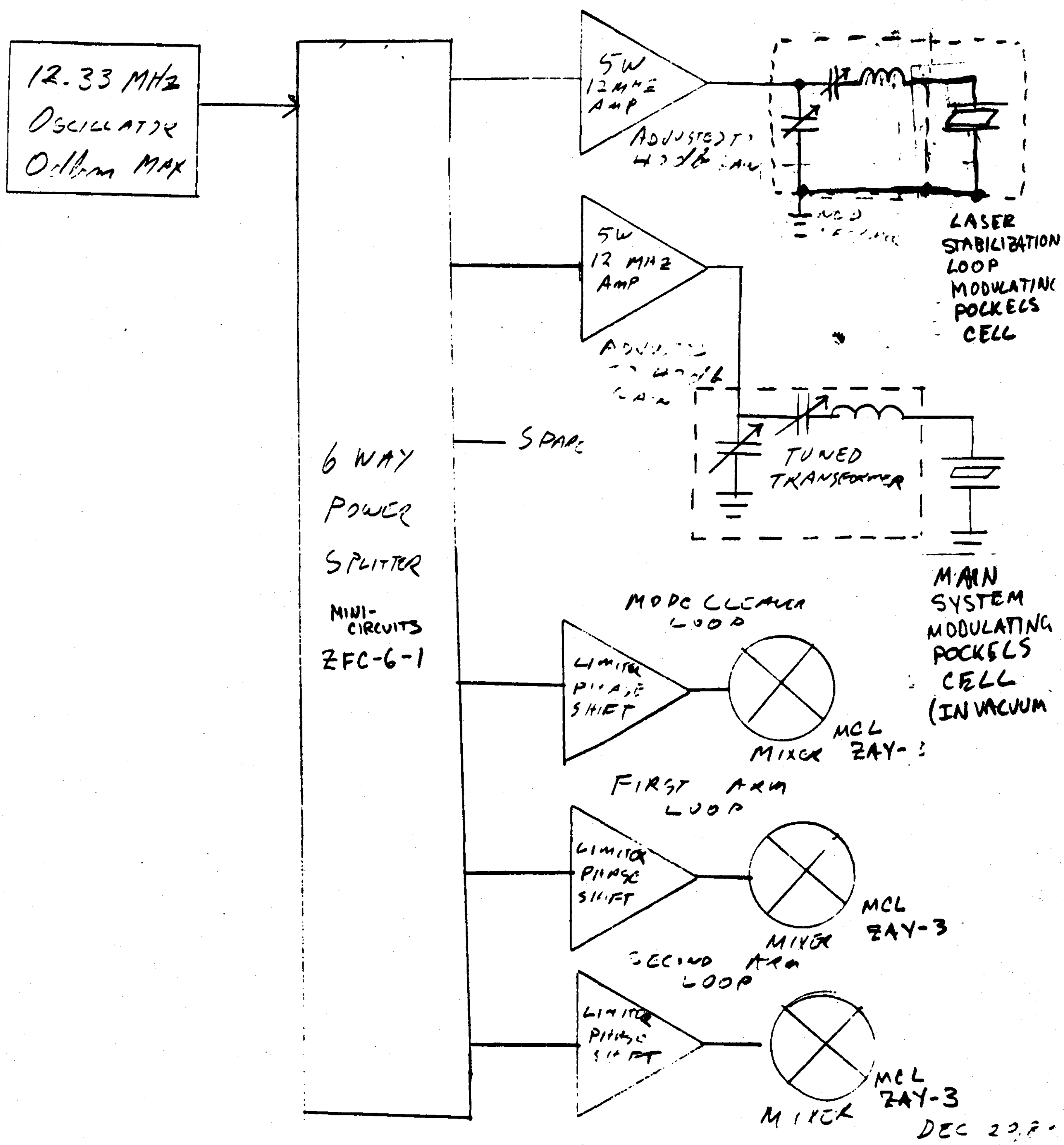
SUPPLY DECOUPLING



I. RF MODULATION

12 MHz RF DISTRIBUTION

REV.
10/10/90 MEZ



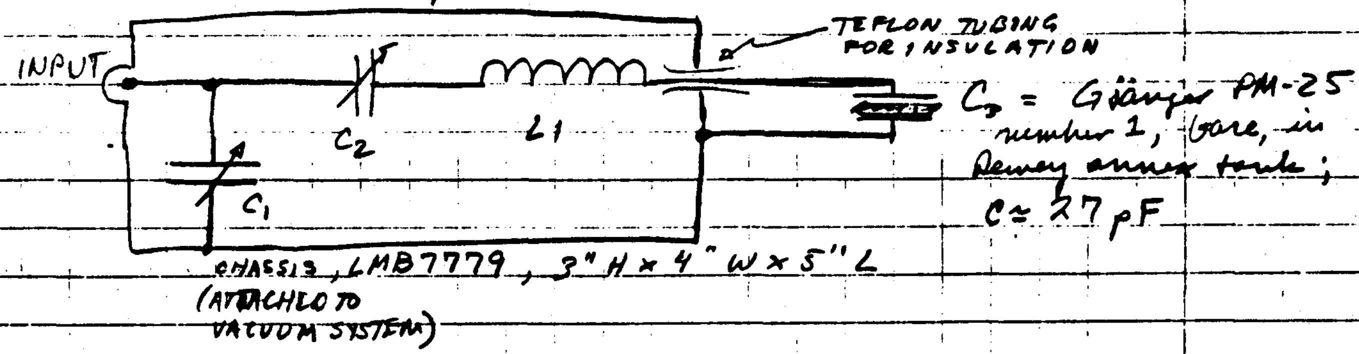
DEC 2?

T1

11/21/89 cont'd

After much effort, arrived at the following ferrite-less design for the RF stepup network

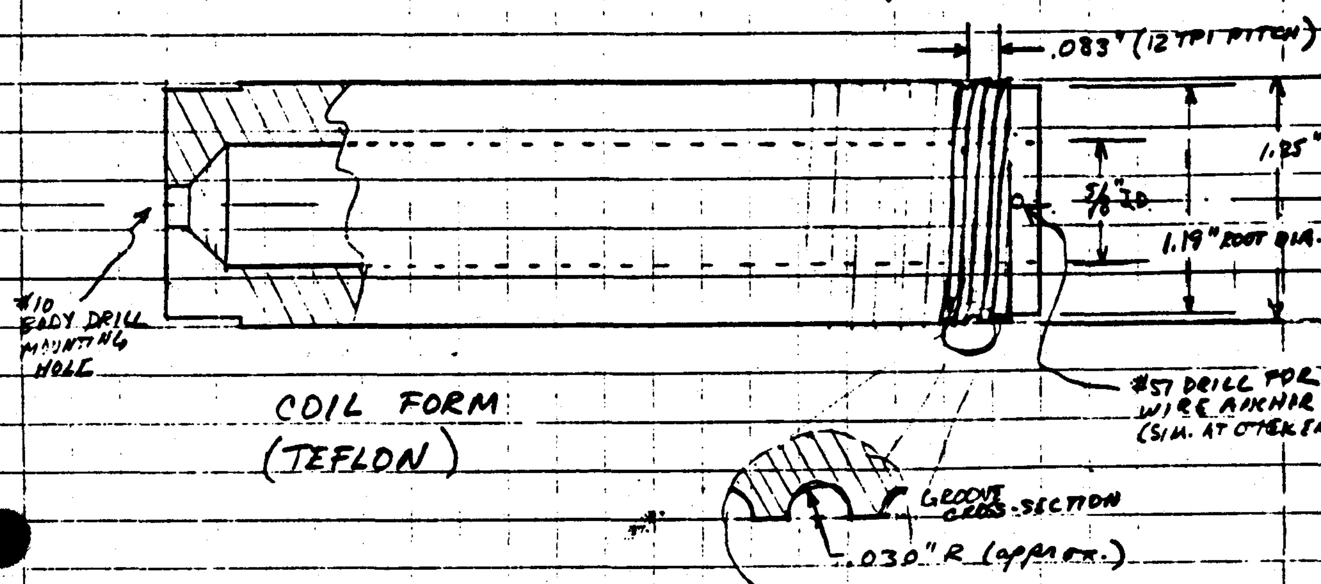
Electronic Diagram of New RF Stepup Network



C_1 = 50-500 pF air variable, 3 gangs in ||, about 1½" H × 2" W × 3" L (surplus, same as in old circuit but cleaned ultrasonically in strong detergent to remove grease, then in Methanol)

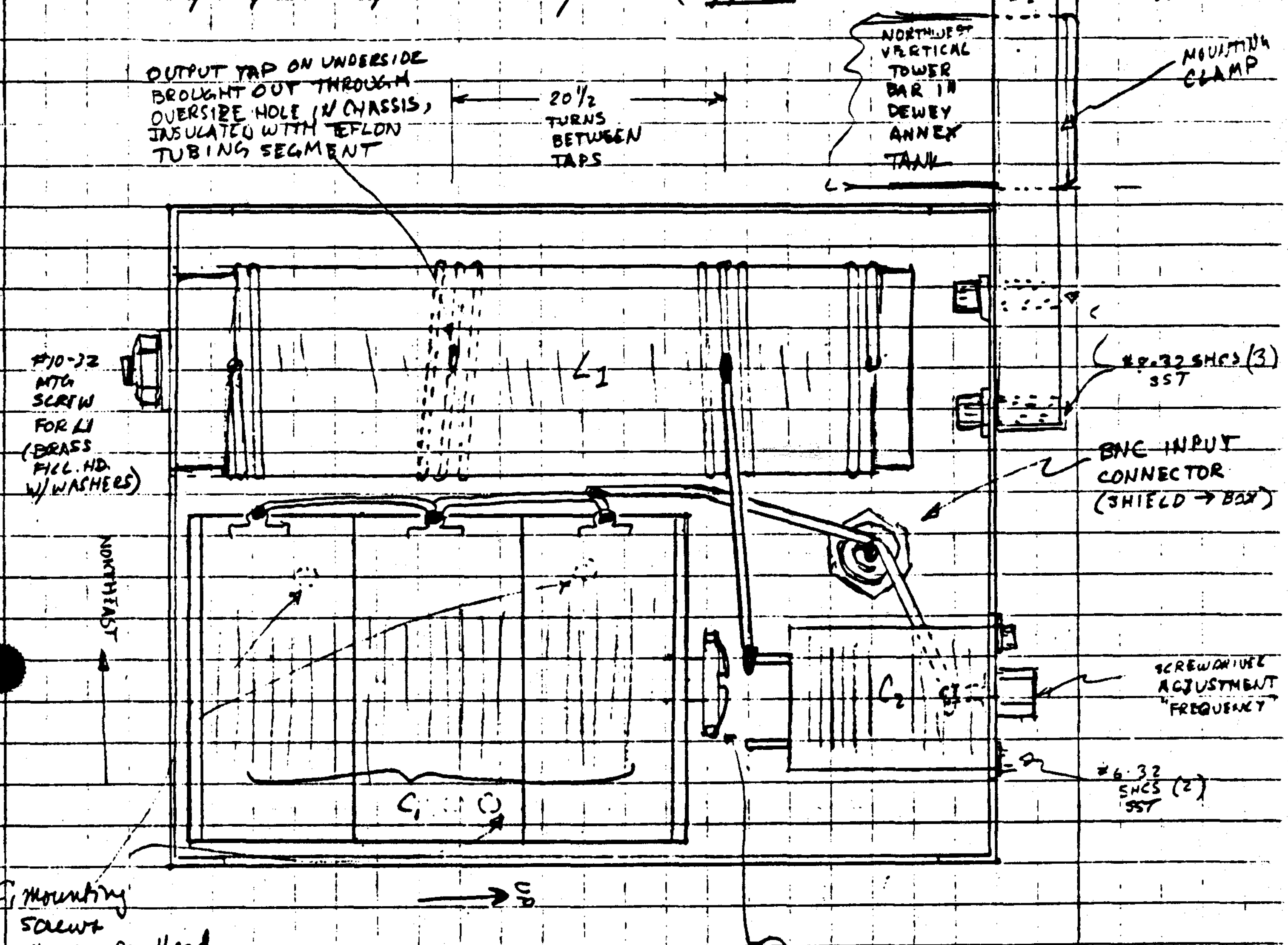
C_2 ≈ 10-120 pF air variable tuning cap, about 1" H × 7/8" W × 1½" L (surplus, also cleaned as above)

L_1 = 20½ turns of a 48-turn coil of #14 gauge bare copper wire (stripped ordinary AC power wire) wound in a .032" deep semicircular cross-section groove cut at a pitch of 12 threads per inch into a 1.25" O.D. Teflon rod 4.5" long:

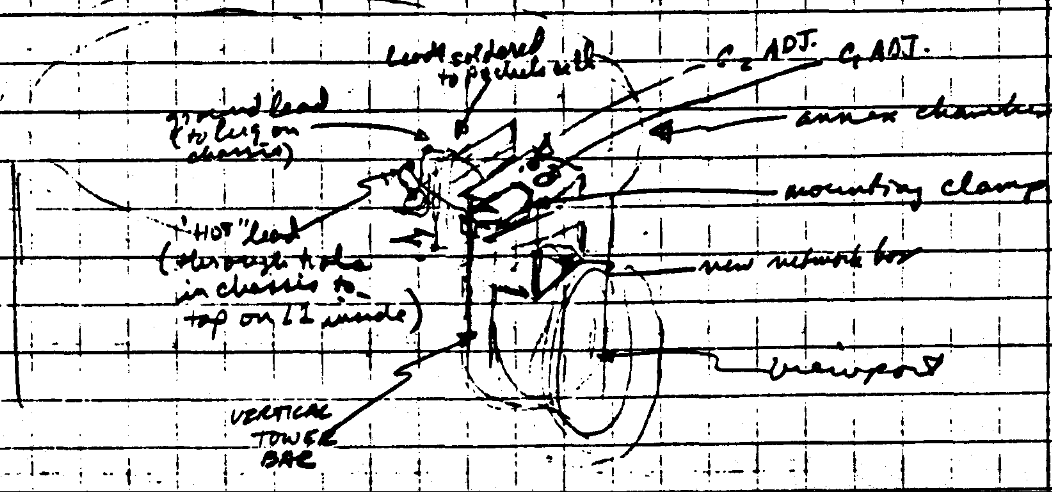


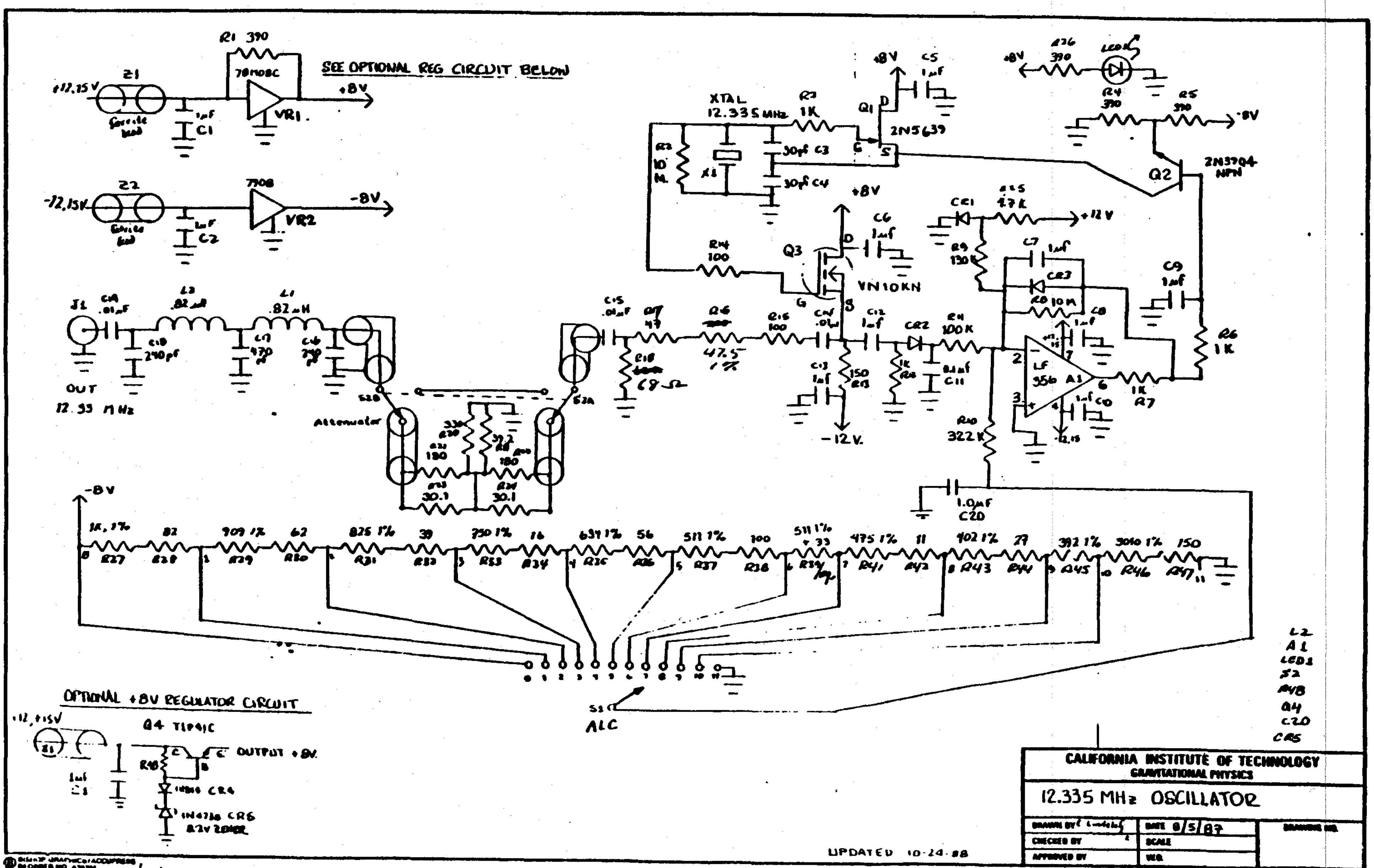
11/21/89

New step-up transformer layout (approx. 1:1 scale)



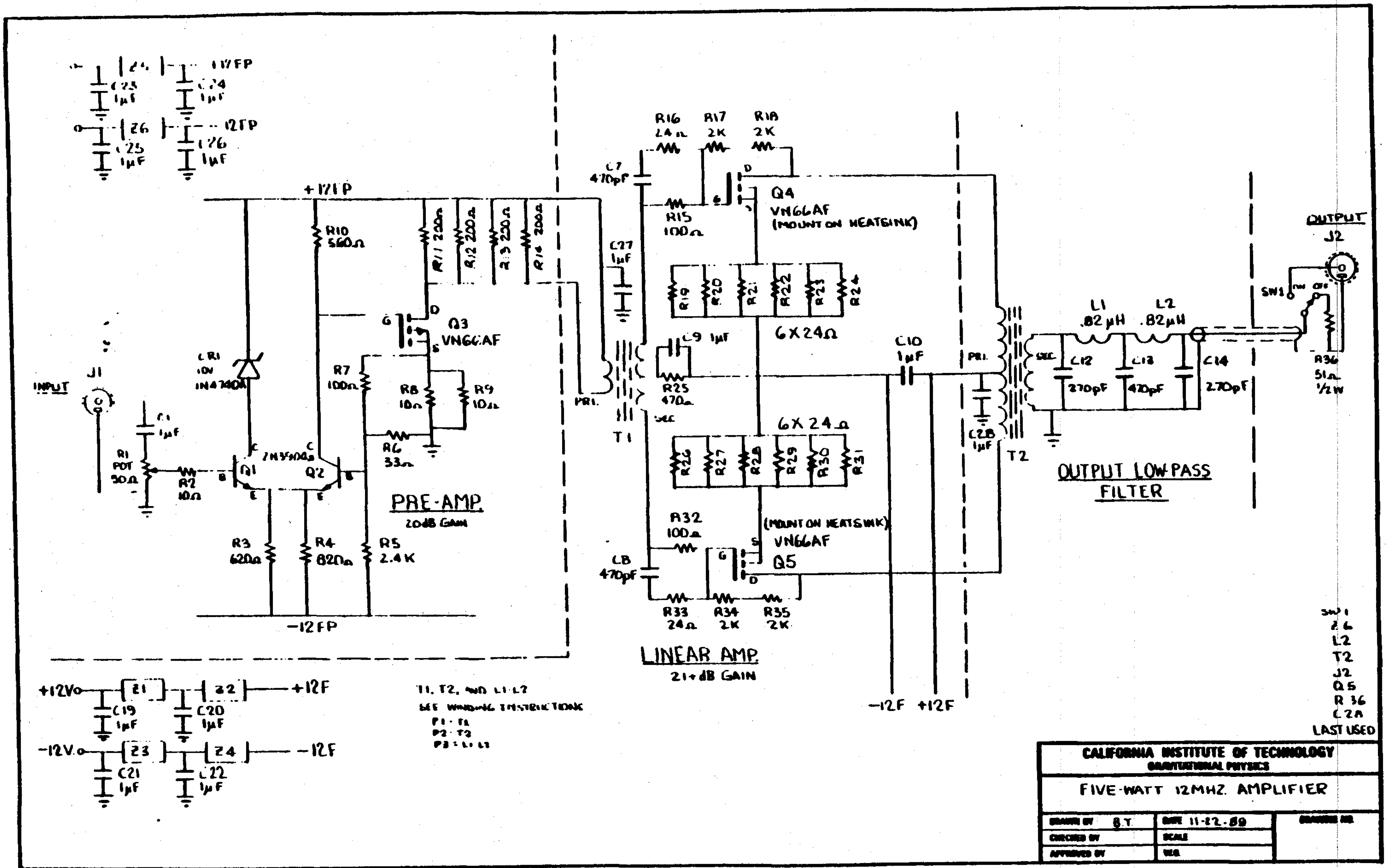
"BACK" VIEW
(LOOKING TOWARD PC)




SEE OPTIONAL REG CIRCUIT BELOW
R1 390
78M08C
VR1
+8V
+12,15V
Z1
C1
Z2
7908
VR2
-8V
-12,15V
C2
XTAL
12.335 MHz
R3 1K
Q1
2N5639
30pf C3
30pf C4
Q2
2N3904 NPN
Q3
VN10KN
+8V
C5
C6
C7
C9
R6 1K
R7 1K
LF 356 A1
CR2
CR3
R10 322K
C20 1.0µF
-12V
+12V
OUT
12.33 MHz
Attenuator
S2A
S2B
ALC
S1
OPTIONAL +8V REGULATOR CIRCUIT
Q4 TIP41C
OUTPUT +8V
CR4
1N4738 CR6
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
DATE 8/5/87
CHECKED BY
APPROVED BY
SCALE

87-0805-1

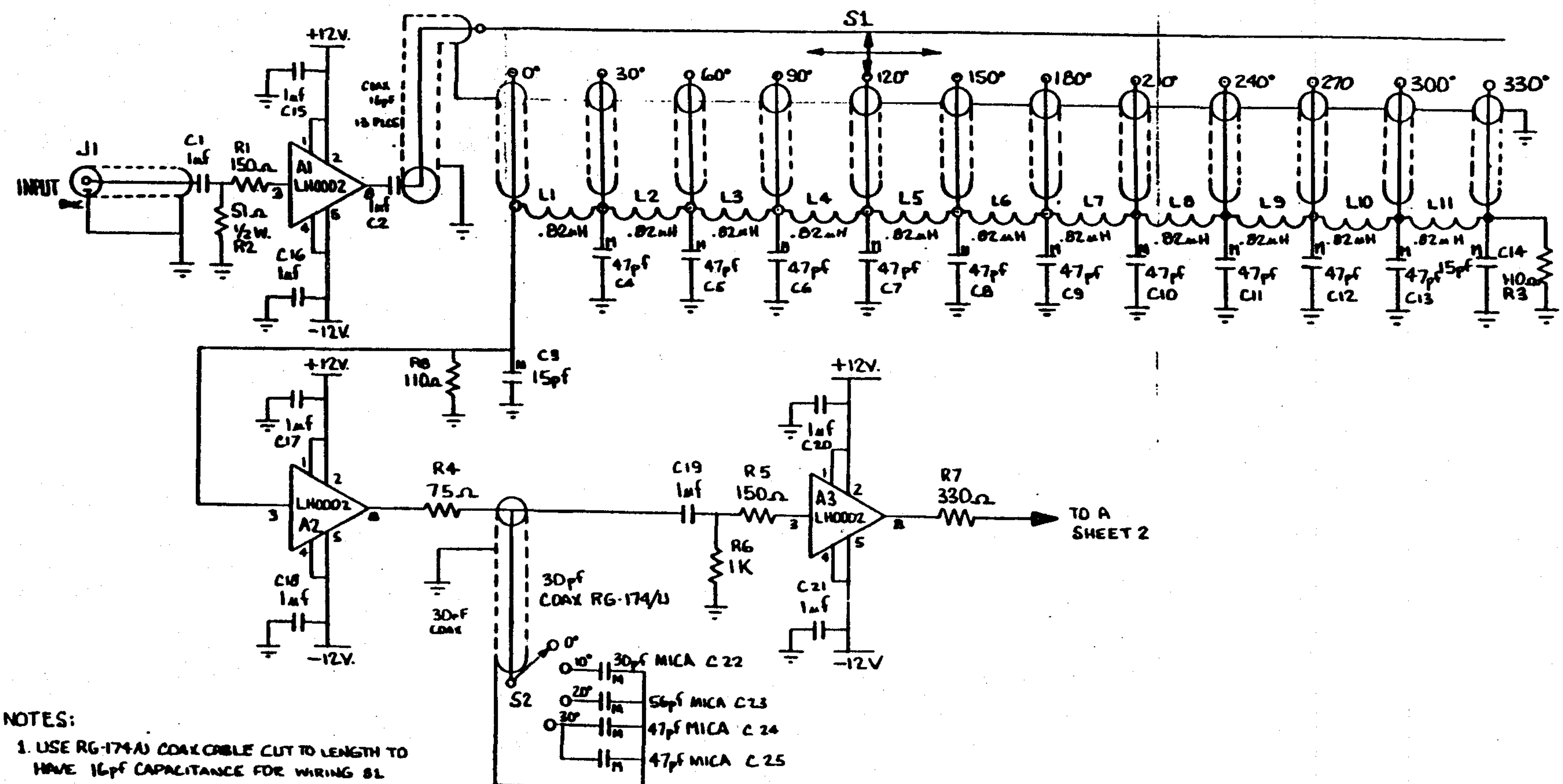
I4



+12FP
R10 560Ω
R11 220Ω
R12 220Ω
R13 220Ω
R14 200Ω
D
G
Q3 VN66AF
S
R7 100Ω
R8 10Ω
R9 10Ω
R6 33Ω
CR1 10V 1N4740A
INPUT
J1
C1 1μF
R1 POT 50Ω
R2 10Ω
2N3904s
Q1
Q2
R3 620Ω
R4 820Ω
R5 2.4K
PRE-AMP.
20dB GAIN
-12FP
C23 1μF
C24 1μF
C25 1μF
C26 1μF
Z6
12FP
C7 470pF
C27 1μF
PRI.
T1
SEC
R16 24Ω
R17 2K
R18 2K
R15 100Ω
Q4
VN66AF
(MOUNT ON HEATSINK)
R19
R20
R21
R22
R23
R24
6X24Ω
C9 1μF
R25 470Ω
C10 1μF
6X24Ω
R26
R27
R28
R29
R30
R31
R32 100Ω
(MOUNT ON HEATSINK)
VN66AF
Q5
C8 470pF
R33 24Ω
R34 2K
R35 2K
LINEAR AMP.
21+dB GAIN
-12F
+12F
PRI.
SEC
C28 1μF
T2
L1 .82μH
L2 .82μH
C12 270pF
C13 470pF
C14 270pF
OUTPUT LOW-PASS FILTER
OUTPUT
J2
SW1
R36 51Ω 1/2W
+12V
Z1
Z2
+12F
C19 1μF
C20 1μF
-12V
Z3
Z4
-12F
C21 1μF
C22 1μF
T1, T2, AND L1-L2
SEE WINDING INSTRUCTIONS
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
CHECKED BY
SCALE
APPROVED BY
DRAWING NO.

89-1122-1

45



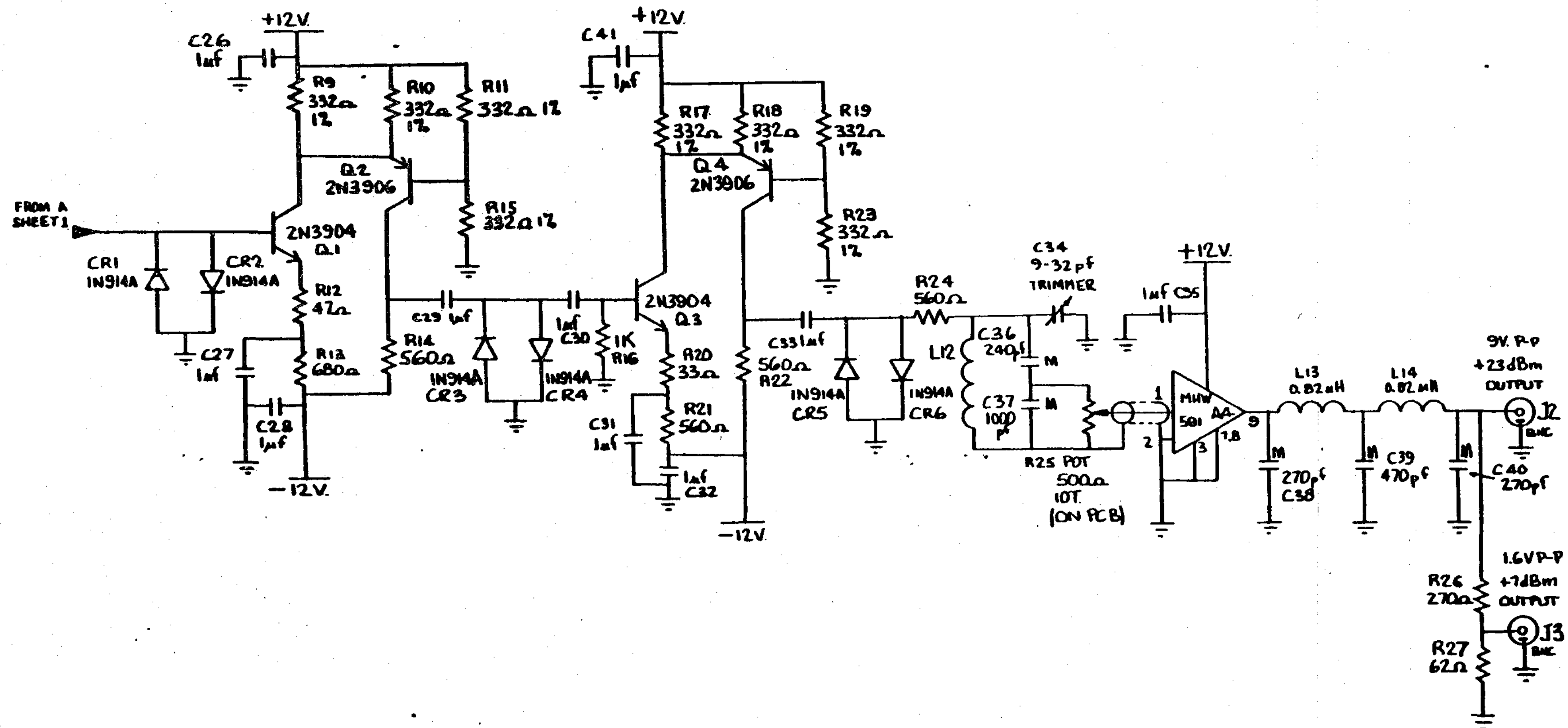
NOTES:

1. USE RG-174/U COAX CABLE CUT TO LENGTH TO HAVE 16pF CAPACITANCE FOR WIRING S1 FROM TERMINALS TO IND. 0.82mH
2. COAX FROM 75Ω/1mf 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.

I6

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



LAST NO. USED

A4
Q4
J3
L14
CR6
C40
R27

CALIFORNIA INSTITUTE OF TECHNOLOGY
GRAVITATIONAL PHYSICS

12.33 MHZ. LIMITER PHASE SHIFTER
SHEET 2

DRAWN BY B.T.	DATE 11-6-87	DRAWING NO. -2
CHECKED BY	SCALE	
APPROVED BY	W.O.	

87-1106-2