Central Mass Damping Electronics 1983 January 10 to 1985 May 30

Society
Note Book

The Coop

2739Q

CENTRAL MASS
DAMPING ELEC.

CM

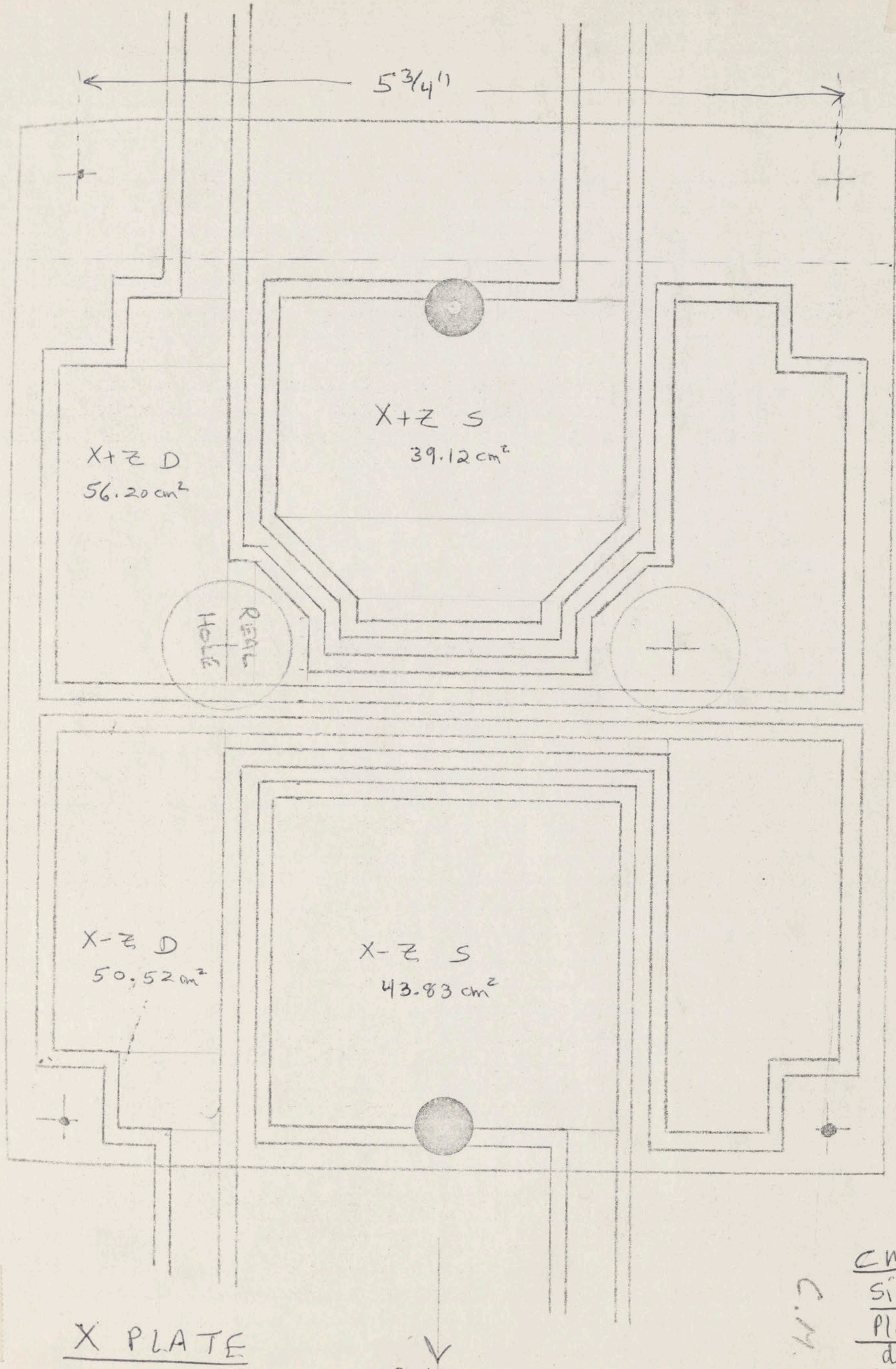
the Coop

1882 — A Century of Service — 1982

Name ______________________

$1.30

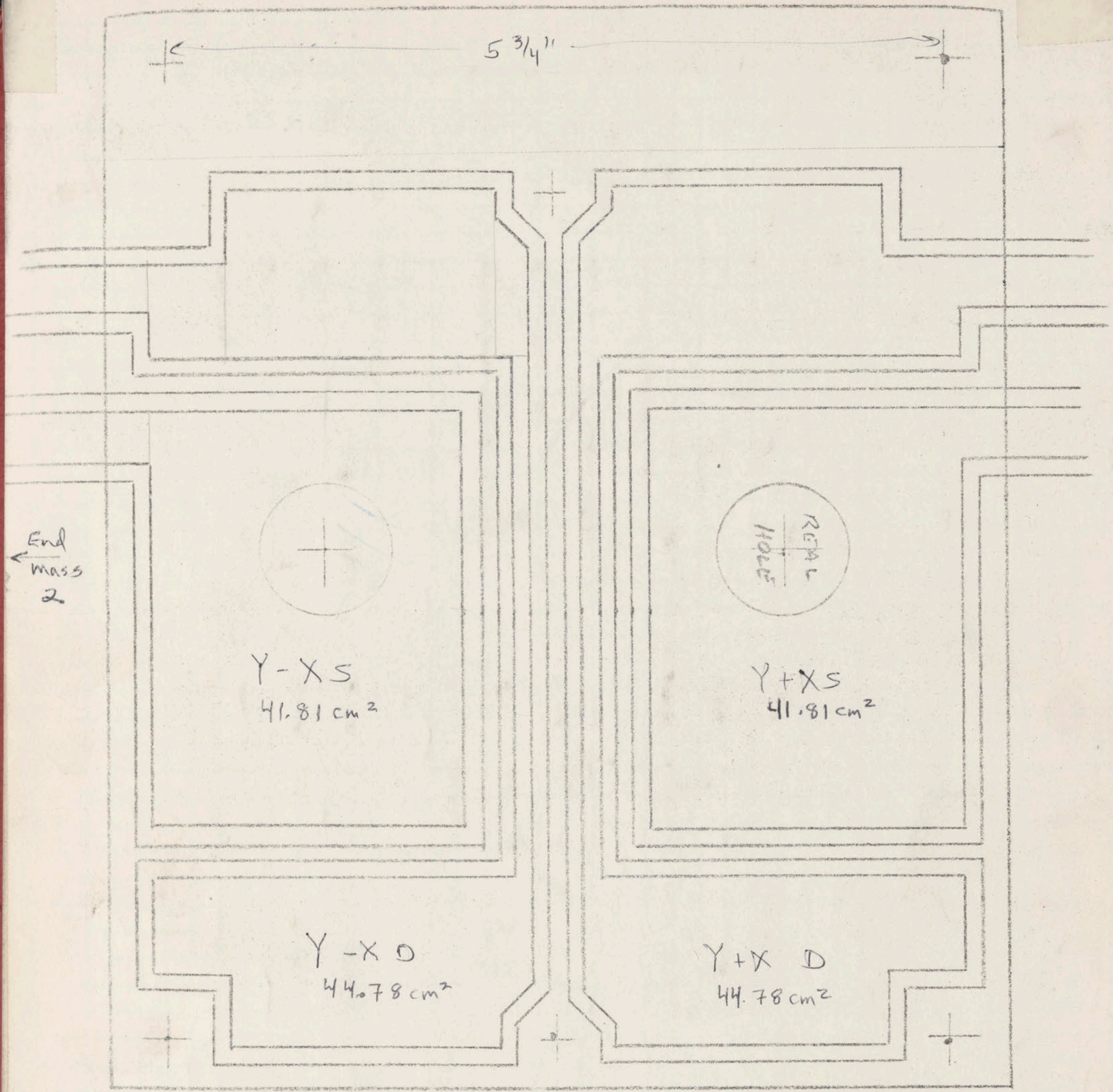
"This book is made with 20lb. paper"



X PLATE

Bottom

CM Side Plate
ds
31/8/82



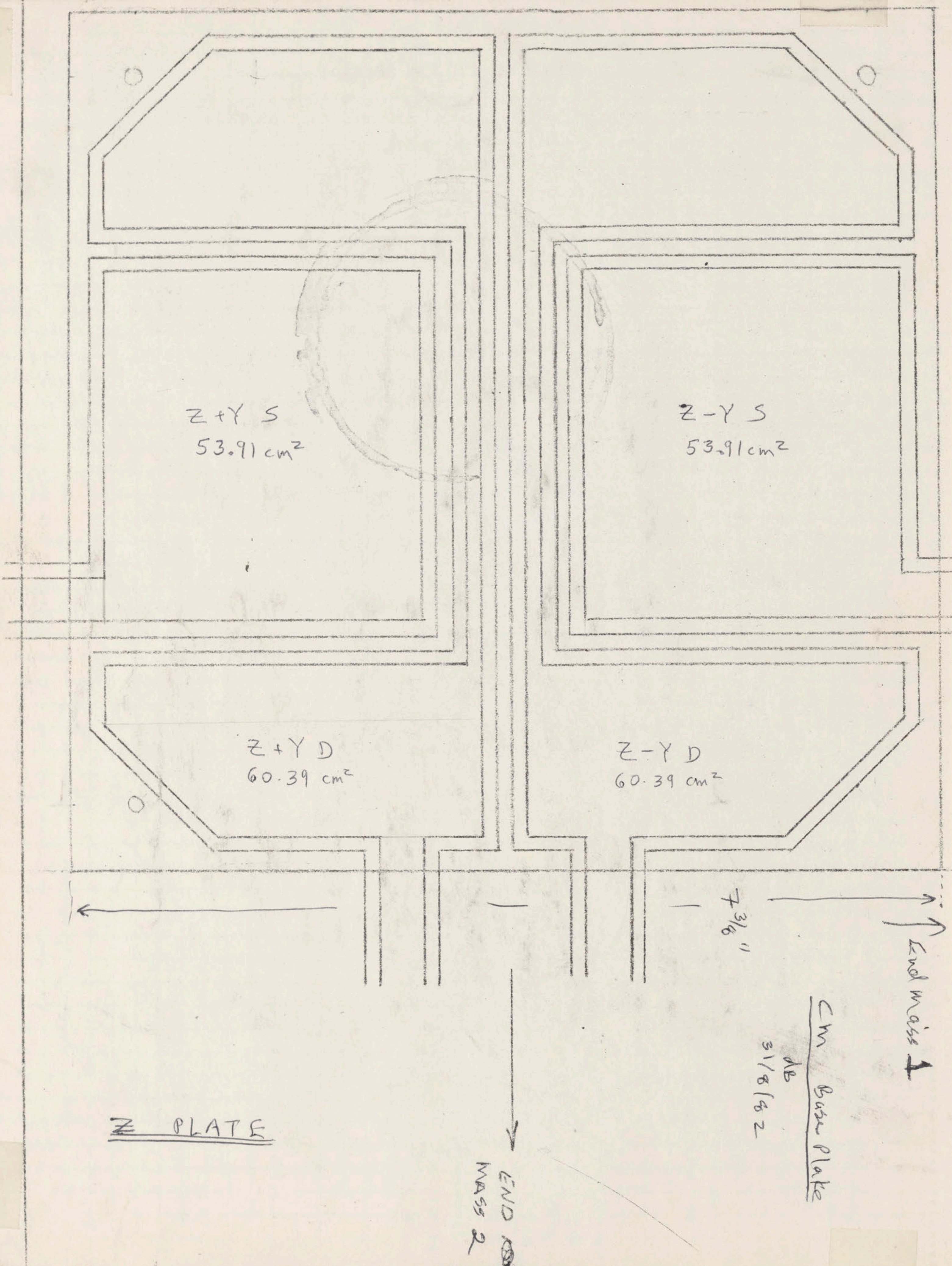
Y PLATE

BOTTOM

Cm side plate

dB
31/8/82

C.M. SIDE

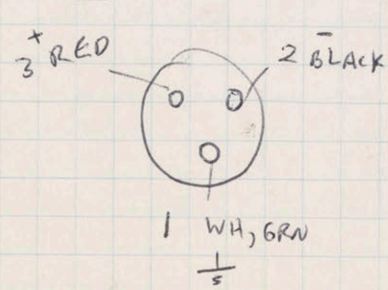

Z+Y S
53.91 cm²
Z-Y S
53.91 cm²
Z+Y D
60.39 cm²
Z-Y D
60.39 cm²
7 3/8"
End mass 1
CM Base Plate
dB
3/8/82
END
MASS 2
Z PLATE

CENTRAL MASS NIM SLOT ASSIGNMENTS :

1/10/83

7.50 MHz BRIDGE Z-Y	7.50 MHz DRIVE
Z-Y HV AMP Z+Y	6.30 MHz DRIVE
6.30 MHz BRIDGE Z+Y	5.16 MHz DRIVE
5.16 MHz BRIDGE Y-X	MATRIX BOX
Y-X HV AMP Y+X	
3.92 MHz BRIDGE Y+X	
2.61 MHz BRIDGE X-Z	3.92 MHz DRIVE
X-Z HV Amp X+Z	2.61 MHz DRIVE
1.01 MHz BRIDGE X+Z	1.01 MHz DRIVE

Power Connector :



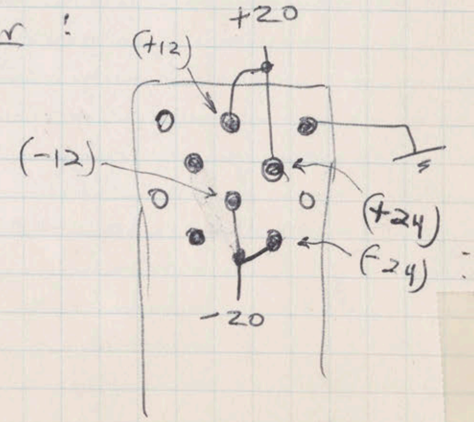
NIM Power :

GRN - ⏚

RED - +20

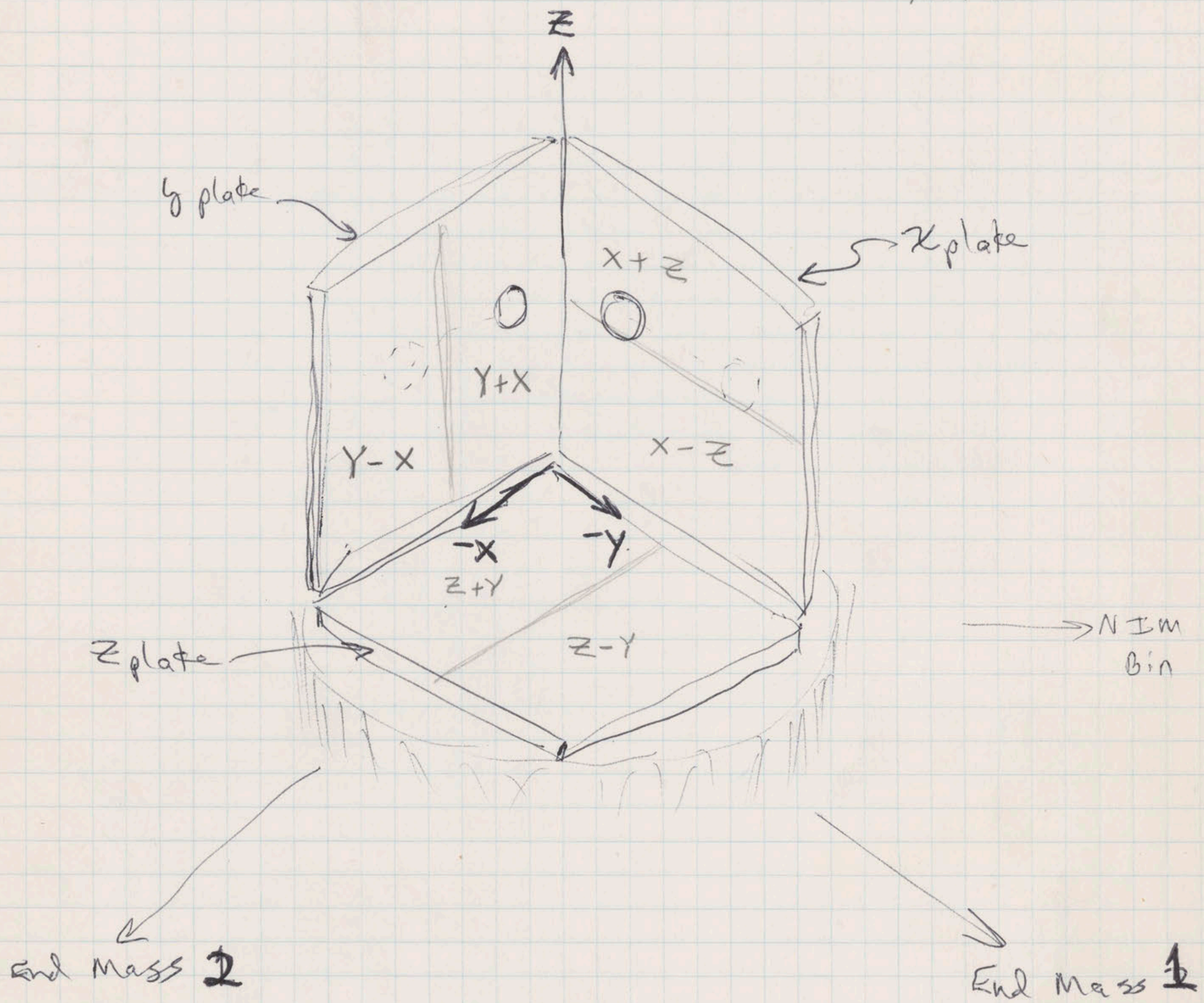
WHT - ⏚

BLK - -20



C.M. CAGE PLATE DESIGNATIONS:

1/10/83



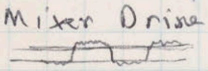
~~DRIVER~~ BOARDS

1/11/83

The driver boards are checked out as follows:

- correct DC voltages
- oscillator output
- Peak two LC's on way to LH0002
- measure Vpp at Drive out across 47Ω
- Check first mixer drive - peak LC
- check first two phase shifters
- check second mixer drive - peak LC
- Set third phase shifter so that mixers are 90° out of phase.
- Gain from RF IN to RF TP using attenuated drive out as signal peak 5539 input filter. - adjust 5539 offset adj.
- Look at mixer output(s) with 1Vpp at RF TP - adjust ϕ_1, ϕ_2 for max output - tweak mixer input filter repeat ↗ ...
- Verify mixer output after LM310N.
- Adjust LOOP output to zero for no RF SN
- Measure LOOP output for 1Vpp on RF TP
- Set ϕ_1 and ϕ_2 to mid-range.

For the six cm Driver boards:

		1.01	2.61	3.92	5.16	6.30	7.50
Drive into 47Ω Vpp		7.0	6.0	5.0	7.0	5.2	7.0
Mixer Drive 		3.3	3.0	3.0	2.6	2.5	2.5
RF IN to RF TP Gain		100	75	100	70	50*	~~17~~ → 43 (1/17/83 (P8))
1Vpp @ RF TP	1C MO1	130 mV	110	80	75	45	32
	1-2 MO1	130 mV	120	80	70	50	32
	1C LOOP1	+3.5	3.0	2.0	2.0	1.05	0.8
	1-2 LOOP1	+3.5	3.2	2.0	1.6	1.25	0.8
a equivalent		40.8	27.1	25.1	15.9	7.5	~~1.7~~ → 4.3 (1/17/83 (P8))

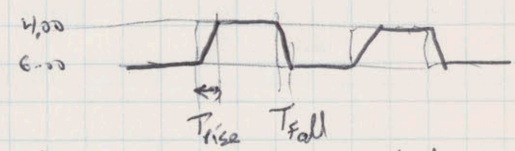
* 1/20/83 Noticed that 5539 input resistor (after B-P filter) is <u>220Ω</u> not 47Ω - This explains the large difference in going to 7.5 MHz (50→17 ...)

HV Amp Boards

1/12/83

For each channel measured:

Vout max : HV mon output for offset turned up to saturation
Vin for 2Vpp : Vpp applied to input to get 5 ± 2V sine wave at output @ 10 Hz
Trise, Tfall : Put in ≈ 30 Hz square wave of HV mon = 2Vpp amplitude about 5V and measure:



Quiescent Current: HV current drawn by box when both outputs are at -5.0 on HV mon's.

Unit	Vout max	Vin for 2Vpp	Trise	Tfall	Quiescent Current
X + Z	8.8 V	7.5 Vpp	6.5 mS	1.0 mS	7.6 mA
X - Z	7.5	"	6.0	2.5	
Y + X	7.4	"	5.0	7.5	7.9
Y - X	7.4	"	6.0	4.0	
Z + Y	7.3	"	6.0	3.0	7.9
Z - Y	7.4	"	6.0	2.5	

Note 8/1/84

Series Resistor added in series with output of all HV amps.

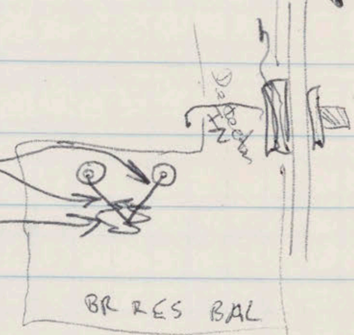
R_{series} = 100K X, Y (beam) plates
one pole ≈ 8 KHz

1 MΩ Z plates
(≈ 800 Hz)

1/14/83

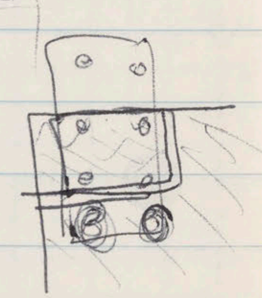
Modifications to 750 MHz board
– probably needed on Remaining Bridge Boards for AM2

- Power Supply Zeners : no header connection
- Solder in ground connection between sides:



TMO 36-1

- ~~[crossed out]~~ Pins: →



- New varactors, 10K resistor, 47pf cap.
- Should be no L_{ring} or $C_{bridges}$ in place

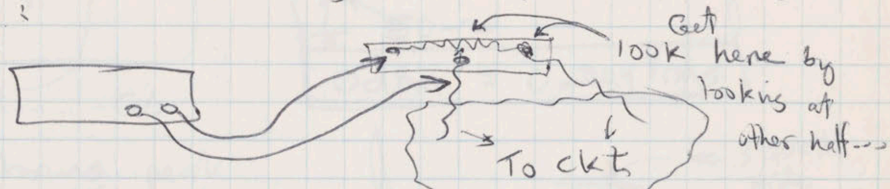
- Remove 1M "CMRR Amp Two" pot
- Remove 4M fixed resistors on Amp 2.
- Add 2 20K bias resistors in place of
- Put in shield between L's of filter
- On 351 MHz and up boards put in 2N5912 buffer stage after amp 2
- On 7 ~~8~~ MHz boards put in fixed L_2 variable C_2
- Install L_3, L_1

- Remove 5539 CMRR ADJ
- Replace 100K 353a resistors by 2K
- Holes for Input Filters
- Input Filters

Bridge Boards

Once modified for present set up :

- Set Ω BAL resistors to a nominal 100K each by measuring resistance of remaining half of pot and making it Max - 100K :

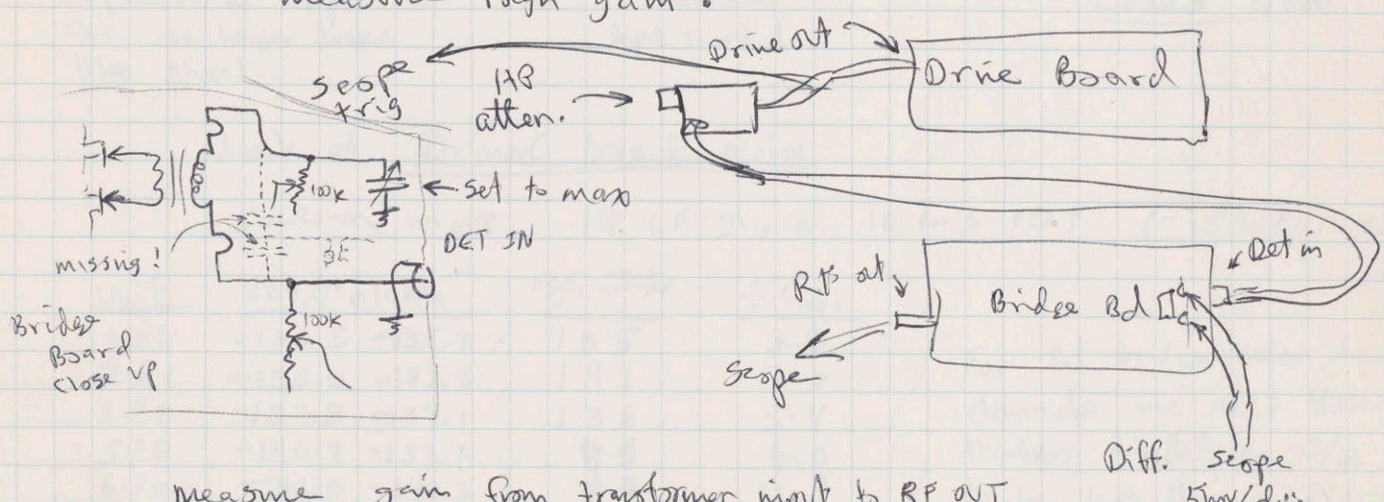


- Put all units in 180° mode for C and Ω fb.
- Check ±15, ±8 supplies
- Check op Amp Ckts - gain from CFB/ΩFB to CMON/ΩMON of -1

  Leave offsets so that CMON = +5V
  ΩMON = -7.5V

RF check :

- Set Bias and Balance pots so U431's have -3.5V on 2K's...
- Use set up below to tweak filter components and measure rough gain :



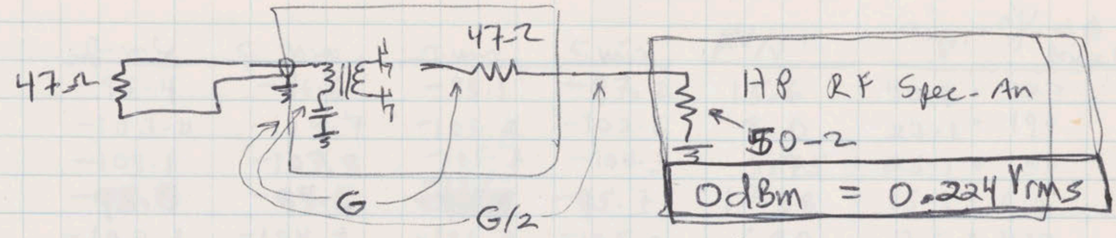
Measure gain from transformer input to RF OUT.

Results :

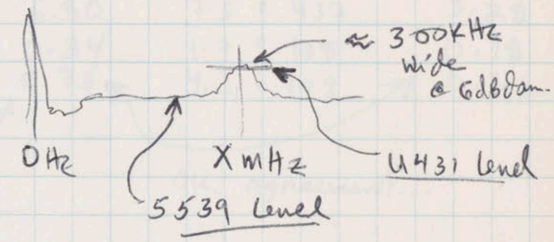
Unit	Diff Scope in mVpp	RF OUT Vpp	Gain (into 1MΩ)	dB
1.01	3.5	1.7	486	54
2.61	3.5	1.1	314	50
3.92	8.5	1.8	212	46
5.16	3.2	3.5	1093	61
6.30	7.0	3.7	529	54
7.50	17.5	2.2	126	42

First Look at Noise & RF Boards as they are now (V_{2K}'s ≈ 3.5V)

1/14/83



Spect analyzer shows peak & U431 noise above 5539 noise:



measure the noise levels:

÷5	Unit	5539	U431	nV/√Hz	÷ (G/2) = FET noise nV/√
5.4 nV/√ / 27 nV/√	1.01	-88.3	-60.0 (-66.7)	327	1.35
	2.61	-87.8	-57.2 (-71)	199	1.27
	3.92	-88.3	-72.0 (-73.5)	150	1.42
	5.16	-88.5	-60.0 (-61.2)	610	1.12
	6.30	-88.5	-63.5 (-64.2)	437	1.65
	7.50	-90	-76 (-76.3)	108	1.71

Level, dBm, BW = 100KHz

as above ↑

Capacitor in input ckt. no longer looks like short---

Transformer input shorted

Looks Good!

Look at Driver Board Noise

50Ω on input   HP LF sig on 16 rms FLAT. (-153dBV/√ noise flr)

Unit	dBV/√ @10KHz		nV/√ Ω,C averaged	÷ a_{eqv}
1.01	-136.5	-135.9	155	3.8
2.61	-135.0	-133.8	191	7.0
3.92	-137.5	-137.1	136	5.4
5.16	-140.9	-139.7	98	6.0
6.30	-142.0	-140.3	89	11.9
7.50	-145.7	-142.4	63	37.1
	↑ Ω mixer	↑ C mixer		

For RF Bridge noise to dominate we need these numbers divided by G/2 to be less than ≈ 1nV/√ which is easy!

1/17/83

Bridge Transformer input shorted and Bridge RF OUT attached to Driver Board RF IN — look at mixer noise:

Unit	R mix	C mix	R mix	C mix	nV/√	$a_{equ.}$ · nV/√ out of Bridge band =	nV/√
1.01	−95.4	−96.6	−95.1	−97.2	15.6	40.8 · 327 =	13.34
2.61	−103.0	−104.7	−101.2	−102.6	8.0	27.1 · 199	5.39
3.92	−109.1	−107.8	−105.3	−104.3	5.75	25.1 · 150	3.77
5.16	−95.0	−97.4	−94.5	−95.7	17.58	15.9 · 610	9.70
6.30	−102.1	−104.9	−101.7	−105.0	6.80	7.5 · 437	3.28
7.50	−127.1	−129.0	−128.9	−129.6	0.34	1.7 · 108	0.18
(new driver gain)	−122.4	−123.3	−123.3	−121.7	0.75	4.3 · 108	0.46

90 kHz (R mix, C mix) — 10 kHz (R mix, C mix)

dBV/√ (250 kHz range) (25 kHz range)

OK agreement...

Increased Driver board 7.50 MHz mixer gain by replacing 56 μH L's by 27 μH ones and adding 10 pf across series caps.

Next step: Measure capacities to determine needed Bridge capacitors and Ringing Inductors

Predict capacities for fm:

Plate	Area cm²	Capacity @ 1mm	Measured cable cap. pf	Predicted	Cdet @ 1mm
X+Z S	39.1	34.6	130.5	165.1	107.1
X−Z S	43.8	38.8	116.0	154.8	96.8
Y+X S	41.8	37.0	123.5	160.5	102.5
Y−X S	41.8	37.0	136.3	173.3	115.3
Z+Y S	54.0	47.8	121.5	169.3	111.3
Z−Y S	54.0	47.8	124.5	172.3	114.3

Measured cable cap.: with standard cable / without. Predicted: with S.C.; Cdet: without S.C.

using $C_{pf} = \frac{A_{cm^2}}{4\pi\, d_{cm}\, 0.9}$ (1.13 @ 1mm)

Measured values are for *±*D no *±*S

See next page

Use Bridge Capacitors ≈ 100 pf – 120 pf → 110 pf

L Ring's needed for a 110 pf bridge:

f	L_{Ring} mH = $6.397/f^2_{MHz}$
1.01	6.271
2.61	0.939
3.92	0.416
5.16	0.240
6.30	0.161
7.50	0.114

1/27/83 Expect ≈ 125 pf

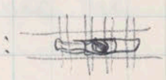
L_{Ring} mH = $\frac{5.63\text{ mH}}{f^2_{MHz}}$	L used
5.52	#22
0.83	#11
0.37	#6
0.21	
0.14	#1 stretched out
0.10	2T on #1

1/19/83

David soldened up the plates -- now:

Capacities (Distance, mm)
(including standard cable)

PLATE	C(∞)	C(3.3)	C(0.89)	C(1.75)	C(d)
X+ZS	160.3	168.2 (0.4)	193.2 (0.2)	177.3 (0.6)	159.44 + 30.22/d
X+ZD	174.5	184.5	217.5	196.0	172.68 + 40.03/d
X-ZD	160.5	170.2	209.0	182.4	155.62 + 47.42/d
X-ZS	147.6	156.2	190.0	167.0	143.59 + 41.26/d
Y+XS	151.5	159.8	188.0	170.5	150.14 + 33.97/d
Y+XD	168.0	176.3	209.0	187.7	164.59 + 39.66/d
Y-XD	171.0	181.2	214.5	192.3	169.01 + 40.53/d
Y-XS	163.4	172.5	205.5	185.0	161.19 + 39.76/d
Z+YS	161.2	172.5	213.0	186.3	157.83 + 49.21/d
Z+YD	173.7	186.0	232.0	201.5	169.25 + 55.94/d
Z-YD	170.0	182.0	230.0	198.2	164.53 + 58.36/d
Z-YS	166.3	178.0	219.0	192.2	163.26 + 49.75/d
	No mass in place	1/8"	1/32"	1/16"	

Teflon spacers Magic Taped to mass
mass grounded by clip lead to coax tie down: 

Before measuring these ↑ found Driver and Sensor plates had been reversed: switched them to be correct then measured above.

Sensor Capacitors:

PLATE	C(1mm+S.C.)	C_{det} C(1mm)	dC_{pf}/dx_{mm} @1mm
X+ZS	189.66	131.66	30.22
X-ZS	184.85	126.85	41.26
Y+XS	184.11	126.11	33.97
Y-XS	200.95	142.95	39.76
Z+YS	207.04	149.04	49.21
Z-YS	213.01	155.01	49.75
		average = 138.6 pf	

1/32" + 3 layers of Tape = 1mm

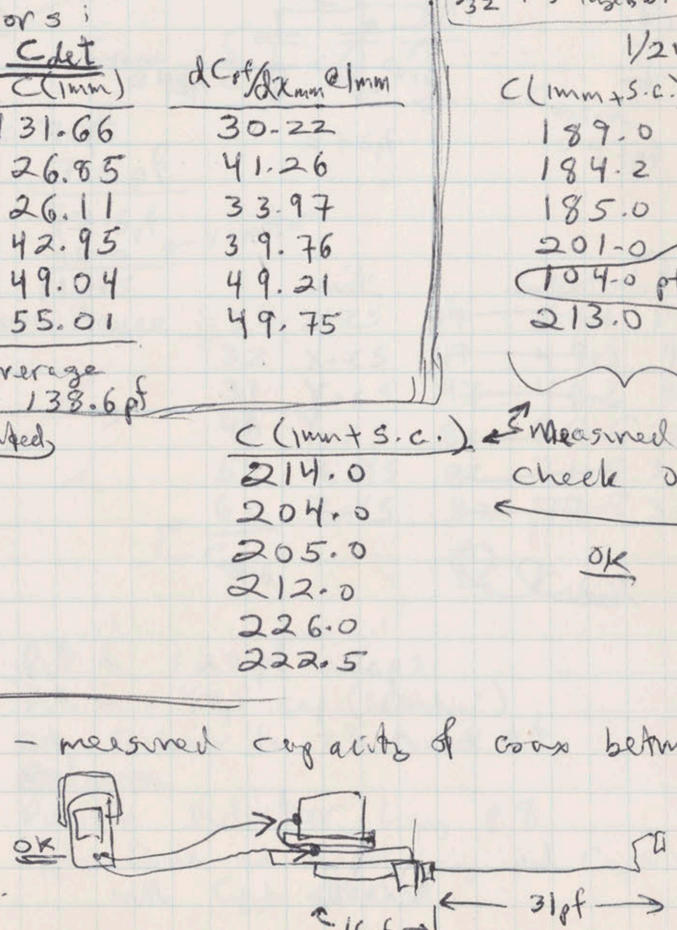
1/24/83

C(1mm+S.C.)	C(1mm)
189.0	
184.2	
185.0	
201.0	
104.0 pf ??	
213.0	

	C(1mm+S.C.) computed	C(1mm+S.C.)
X+ZD	212.71	214.0
X-ZD	203.04	204.0
Y+XD	204.25	205.0
Y-XD	209.54	212.0
Z+YD	225.19	226.0
Z-YD	222.89	222.5

← Measured values check others: OK

Problem with Z+YS - measured capacity of coax between mount and boards:



The open ckt is probably at the feed through... (yech)

16+31+58 = 105 pf

The mighty Richard fixes feedthrough! 1/25/83

Measured Capacities @ 1mm → ← From Interpolation

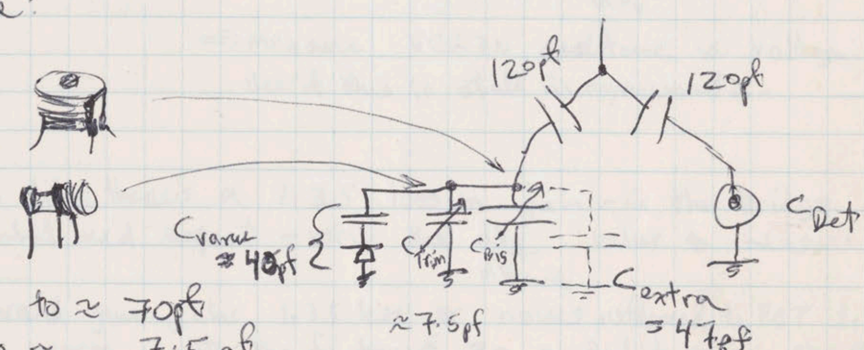
Unit	C(1mm)+S.C.	C(1mm)+S.C.
X+Z S	187.5	189.6
X+Z D	211.5	212.7
X−Z D	201.0	203.0
X−Z S	181.0	184.8
Y+X S	186.0	184.1
Y+X D	206.0	204.2
Y−X D	211.5	209.5
Y−X S	201.0	201.0
Z+Y S	207.0	207.0
Z+Y D	225.5	225.2
Z−Y D	222.5	222.9
Z−Y S	213.0	213.0

Bridge Balancing

The Bridges have two capacitors in them now to balance the Detector capacitance:

Big variable: 6–100pf

Trimmer 0–15pf



Set Big variable to ≈ 70pf
← Set Trimmer to ≈ 7.5pf by screwing in all the way then coming out 3½ Turns.

77.5pf
40.0 ← varactor
117.5

will need more capacitance:

If we set C_{extra} = 47pf then C_{Big} must be →

ΣC_{Big}	Unit	C_{extra}		C_{Det} @ 1mm
37	~~X+Z S~~	~~47 54.1~~	14	131.60
32	X−Z S	~~47 49.3~~	9.3	126.8
31	Y+X S	~~47 48.6~~	8.6	126.1
48	Y−X S	~~82 65.5~~	25.5	143.0
54	Z+Y S	~~82 71.5~~	31.5	149.0
60	Z−Y S	~~82 77.5~~	37.5	155.0

R. Used

Do to Bridge Boards: Put in 120pf Caps.
Put in 47pf cap ("Cextra")
Set Trimmer to 3½ turns out
~~Balance~~
Put in Inductor, Lring 88
Apply Drive and adjust Lring and Caps to balance with C_{Det} attached

1/28/83

Measure C and Ω Feedback gains.

Find $\frac{dV^{pp}_{\text{Bridge Board out}}}{dV^{DC}_{\Omega \text{ and } C \text{ MON}}}$ and Compare to Theory.

Vmt		V_B^{pp}	Cdet	RF Gain	$\frac{dV^{pp}}{dV_{CMON}}$		$\frac{dV^{pp}}{dV_{CMON}}$	$\frac{dV_{pp}}{dV_{\Omega MON}}$	$\rightarrow \times \frac{2\pi f}{V_B^{pp} \cdot \text{RF Gain}}$
X+Z	1.01	60	131.6	486	21.5	2.47	8.7	2.7	587 $\times \frac{2.47}{1.35} = 1080$
X−Z	2.61	58	126.8	314	13.9	1.32	10.5	1.46	1314
Y+X	3.92	42	126.1	212	6.8	1.42	4.8	0.40	1106
Y−X	5.16	43	143.0	1093	31.7	2.0	15.4	0.94	648 $\times \frac{2.0}{1.35} = 960$
Z+Y	6.30	(30) 15.5	149.0	529	(10.3) 5.3	1.39	3.8	0.23	1110
Z−Y	7.50	17.0	155.0	126	1.3	1.30	1.0	0.15	3298

Theory / Exp

Theory | Exp. | Exp.

← known that R is not 100K here...

Theory:

$$\frac{dV_{pp}}{dV_{CMON}} = \frac{V_B^{pp} \cdot \text{Gain} \; \frac{dC_V}{dV_V}}{\left(1+\frac{C_{det}}{C_B}\right)(C_B + C_{det})\left(\frac{C_V}{C_S}+1\right)^2}$$

where $C_B = 120\,pf$

$C_V = 321\,pf$

$C_S = 47\,pf$

$\frac{dC_V}{dV_V} = 23.8\,pf/V$

In theory this should be:

$$\frac{1}{4RC_B} \frac{1}{R} \frac{dR}{dV_V}$$

for $R \approx 10^5 \implies \frac{dR}{dV_V} \approx 5.2\,K\Omega/V$

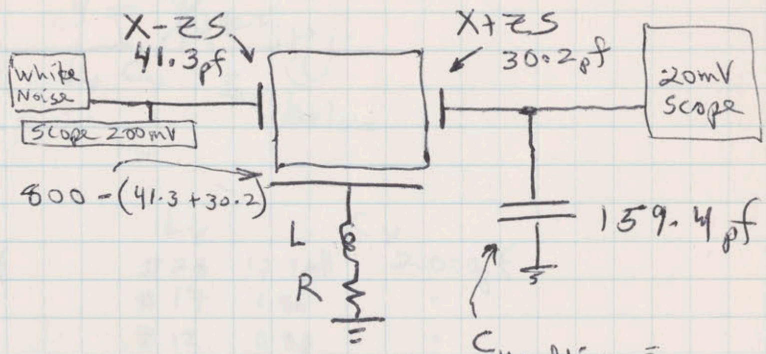
⇒ Measure VCR7N resistance vs. voltage to see if this is at all in agreement...

Comments:
- Looks like there's a 1.35 loss in gain in the bridge over what we'd expect — using the $\frac{dV_{pp}}{dV_{CMON}}$ value to measure gain would give gains 1.35 less or noises referred to FET 1.35 times worse — not the factor of 20 needed to explain EM noise.
- The X+Z, Y−X systems show an additional loss (≈ 1.66) — this must be in the bridge or RF Amp or change in Bridge drive... as it shows up in both C and Ω data and scales well.

1/31/83

Minimizing Inductance and Resistance of CM supporting Rod:

Measure capacitance of CM mass to ground with all boards attached:



$C_{cm\ total} = 800pf$

we expect $L \approx 1\mu H$
$R \approx 60\Omega$

$C_{Hardline} =$
$+ C_{cable} = 58pf$
$+ C_{scope\ input} = 20pf$

Expected attenuation from X-ZS to scope output:

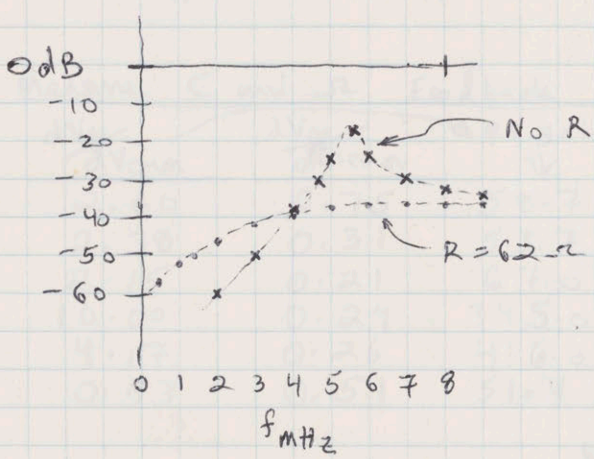
$$\approx \frac{41.3}{(800-41.3)} \cdot \frac{30.2}{(159.4+58+20)} \approx 0.00692 = \underline{-43dB}$$

Measure ≈ 40dB - OK.

Now put in an L to ground - should resonate at $\frac{1}{2\pi\sqrt{1\mu H\ 800pf}} = \underline{5.6MHz}$ OK

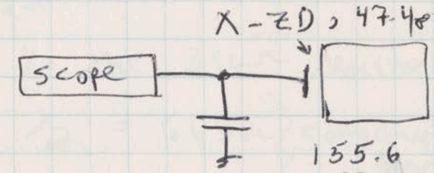
Add $R = 62\Omega$ to get final transfer function:

X-ZS to X+ZS transfer funct. with L and R in place (•) L only (x)



Measure RF voltages on CM:

Drive Unit	Vscope	Vcm, Vpp
1.01	75 mVpp	0.44
2.61	240 mVpp	1.41
3.92	245 mVpp	1.44
5.16	335 mVpp	1.97
6.30	295 mVpp	1.74
7.50	255 mVpp	1.50

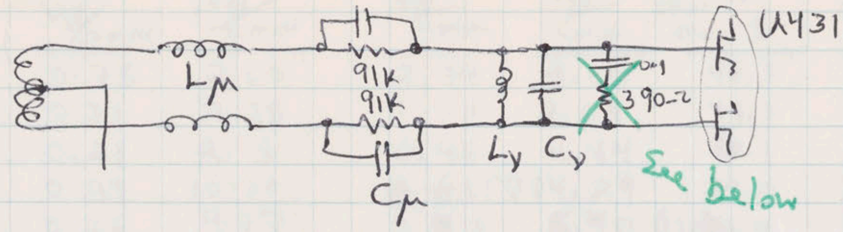


155.6
58
20
233.6

attenuation from Vcm to Vscope

≈ 0.17

Install Bridge Board Filters 2/1/83



Freq	Lμ		Cμ	Ly		Cy
1.01	#42	49.7 μH	510pf	#28	12.4μH	2000pf
2.61	#42	45.4	82	#17	1.86	"
3.92	#42	45.8	36	#12	0.83	"
5.16	#42	52.9	18	#9	0.48	"
6.30	#38	35.5	18	#7	0.32	"
7.50	#39	45.1	10	#5	0.23	"
				H		

Measure gains and equivalent noise of boards now:

Board	Input @ XFormer	Output into Scope	Gain, dB	U431 Level (50Ω input) (RF OUT into 50Ω)	nV/√Hz	Transformer Input Noise eq.
~~1.01~~						
2.61	4.5mVpp	1.75Vpp	377, 51.4	−70dBm	224	0.20
3.92	14.3 mVpp	2.2Vpp	154, 43.8	−72dBm	178	2.31
5.16	6 mVpp	3.15 Vpp	525, 54.4	−60dBm	708	2.70
6.30	4.5mVpp	1.80 Vpp	400, 52	−63dBm	501	2.51
7.50	16.5mVpp	1.08 Vpp	65.4, 36.3	−74dBm	141	4.32
1.01	5.6mVpp	3.65Vpp	663, 56.4	−61dBm	631	1.90

Measure C and Ω Feedback gains again

Unit	dVpp / dVcmon	dVpp / dΩcmon	RF gain
1.01	2.60	0.75	58.7
2.61	2.38	0.31	53.7
3.92	2.15	0.21	67.0
5.16	10.00	0.29	345.0
6.30	4.17	0.26	416.0
7.50	0.53	0.51	51.4

} ?? :(

measured here

Low gain of 1.01 and 2.61 units is due to the 390Ω resistor loading the bridge

$X_{120pf @ 1MHz} = 1327 \Omega / 2 = 663 \Omega$ } compared to 200Ω

$@ 7.5 MHz = 177 \Omega / 2 = 88 \Omega$

Remove 390Ω resistors and measure everything again.

2/2/83

Freqv	Vpp/Σ MON	Vpp/CMON	Vpp/Σ MON	Vpp/CMON	mVpp/CMON for Gain = 1	Theory Gain	nV/√ into Scope (no load)	Xformer input Noise
1.01	0.75	2.60	2.38	8.00	44.2	181	800	4.4
2.61	0.31	2.38	1.02	7.69	44.3	174	710	4.1
3.92	0.21	2.15	0.46	4.44	32.1	138	448	3.2
5.16	0.29	10.00	2.63 (?!)	14.29	29.0	493	1782	3.6
6.30	0.26	4.17	0.97	5.40	(19.4) 10.0	540	1416	2.6
7.50	0.51	0.53	~~0.74~~	~~0.85~~	~~10.3~~	~~83~~	~~356~~	~~4.3~~
7.50 modified			1.30	1.47	(11.5) 10.3	143	448	3.13

└ OLD VALUES ┘ (30Vpp) (19Vpp)

Modify 7.5 Bridge Bd to get some more gain: ↑
56μH → 27μH
put 2.2K's in parallel with 4.5 K's on followers.

2/3/83

Attach Bridge Boards to Mass, Balance, put output into Driver RF in.
Remove Bridge Drive and look at noise of RF TP:

Noise out of Bridge Board only: (into 47 Ω)

Freqv.	Noise at RF TP dBm into 10 kHz	RF TP Noise No load equiv. nV/√	÷ RF IN to RF TP Gain		dBm 10KHz	nV/√	(X2 =)
1.01	−33.0 +6	100.0	1000 nV/√	1.42	−70dBm	708	1416 ⇐?
2.61	−42.0 +6	35.5	473	1.50	−76dBm	355	710
3.92	−41.5 +6	37.6	376	1.34	−79dBm	251	502
5.16	−30.5 +6	133.4	1906	1.05	−67dBm	1000	2000
6.30	−38 +6	56.3	1126	1.12	−71dBm	631	1262
7.50	−46 +6	22.4	521	0.86	−80dBm	224	448

X2 because of spec. Anal Load

attenuation ↑ = Noise out of Bridge Board into ∞ / Noise into RF IN

aeqv of total chain = adriver · "Theory Gain" of B.B. / attenuation

Freqv	aeqv	μV/√ / aeqv.	X mixer loss	Gain Reduction for a = 800	
1.01	5200	19 nV/√	7.7 nV/√	6.5	↙
2.61	3143	11 nV/√	5.2 nV/√	3.9	↙
3.92	2585	15 nV/√	3.8 nV/√	3.2	↙
5.16	7465	18 nV/√	4.1 nV/√	9.3	↙
6.30	3616	16 nV/√	2.4 nV/√	4.5	↙
7.50	715	31 nV/√	3.1 nV/√	OK as is	—

Changed U431 Biases to reduce gain ↓ :

Freqv	U431 Bias (@ output) 1st	Second	Gain reductions 1st	2nd	dVpp/dVamn	"Theory" Gain	RF OUT Noise into 47 Ω	
1.01	−7.0	−8.0	÷2	÷3.3	1.27	28.7	112 nV/√	5.5
2.61	−7.0	−7.5	÷2	÷2	2.08	47.0	94.5	3.0
3.92	−7	−7.7	÷1.5	÷2	1.43	44.7	79.5	2.4
5.16	−7	−7.5	÷2	÷4.5	1.46	50.3	112.3	2.3
6.30	−7	−7.5	÷1.5	÷3	1.74	174.0	158.6	1.0
7.50	−3.5	−3.5	—	—	1.47	142.7	224.0	1.3

2/4/83

Setting b values:

$$b = \frac{1}{\pi} \frac{V_B^{gg} \cdot A_{CFB}}{\left(1+\frac{C_{det}}{C_B}\right)(C_{det}+C_B)} \frac{\frac{dC_v}{dV_v}}{\left(1+\frac{C_v}{C_s}\right)^2} \leftarrow 1/2.64 \text{ pf/v}$$

Thus

$$A_{CFB} = \frac{\pi b}{V_B^{gg}} \left(1+\frac{C_{det}}{C_B}\right)(C_{det}+C_B) \cdot 2.64 \text{ V/pf}$$

we want b = 0.05
and have C_B = 120pf so:

Freq	V_B^{gg}	A_{CFB} calc	Resistor used in feedback	Measured A_{CFB}	"Real b"
1.01	60	3.65	8.2k	3.90	0.053
2.61	58	3.63	8.2k	3.76	0.052
3.92	42	4.99	11k	4.97	0.050
5.16	42	5.70	12k	5.59	0.049
6.30	30	8.34	18k	7.87	0.047
7.50	19	13.77	30k	13.4	0.049

Also set $\omega_{RC} \approx 1$ (0.15 Hz) by shunting 4MΩ by 360K

Closing Loops: Drive CFB with noise source and adjust ϕ_1 and ϕ_2 so that Ω mixer out shows little correlation. Then drive ΩFB and adjust ϕ_3 so that CMO shows little correlation. Measure phase ∡ CFB→CMO and ΩFB→ΩMO should be 0° - change bridge board jumper if necessary.

Measure ab gain --- + Noise 2/7/83

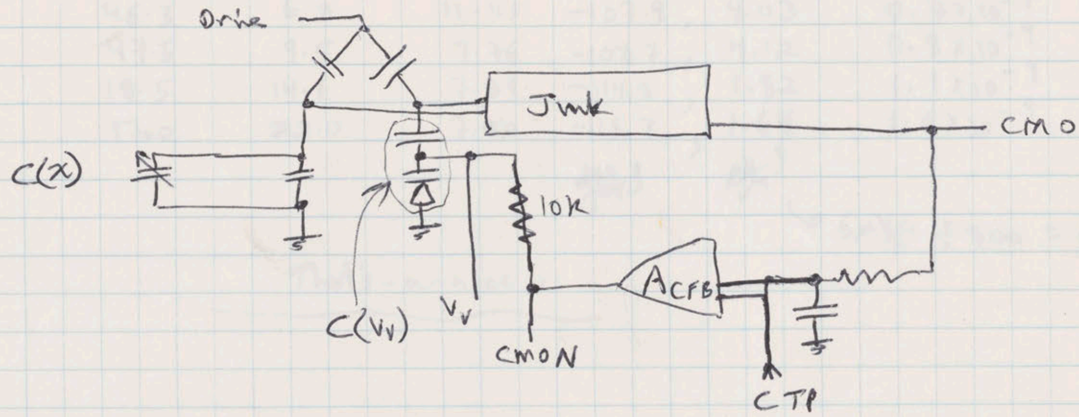
Freqv.	ab ∡ C Loop	a	Noise ÷ a at CMO (12.6 kHz) Normal CMO	No drive CMO	FET short
1.01	29.5	556	11.3	9.0	4.8
2.61	34.0	654	9.6	4.8	2.7
3.92	36.3	726	12.3	16.0	2.3
5.16	27.2	555	10.6	4.8	3.0
6.30	21.5	457	10.9	9.2	2.3
7.50	18.1	369	7.9	7.9	3.0

Adjust Bias of first V431 stage to get 1.01, 2.61, 3.92 and 5.16 ab gains ≈ 40. CMO noise of these is ≈ -103 dBV/√ which for b = 1/20 gives FET noise ≈ 8.9 nV/√ — OK!

System essentially finished.

2/8/83

Relation between output noise (at CMO) and Displacement noise referred to mass.



$$\text{Displacement noise (mm)} = \text{CMO noise voltage} \cdot \frac{A_{CFB}}{\text{ab gain}} \cdot \boxed{\frac{dC_V}{dV_V} \frac{1}{\left(1+\frac{C_V}{C_S}\right)^2} \frac{1}{C_{pf/mm}}}$$

mm/varactor volt

For all units $\frac{dC_V}{dV_V} = 23.8$ pf/V and $\frac{1}{\left(1+\frac{C_V}{C_S}\right)^2} = \frac{1}{61.31}$

	Unit	ab gain	ACFB	$C_{pf/mm}$	mm/varac volt	CMO noise μV/√	x equiv motion
x-z	1.01	40	3.9	30.22	12.85	8.52	1.1 × 10⁻⁹ cm/√
x+z	2.61	40	3.76	41.26	9.41	7.4	0.6 × 10⁻⁹ cm/√
y-x	3.92	40	4.97	~~33~~.97	11.43	9.87 μV/√	1.4 × 10⁻⁹ cm/√
y+x	5.16	40	5.59	39.76	9.76	8.65	1.1 × 10⁻⁹ cm/√
z-y	6.30	21.5	7.87	49.21	7.89	4.98	1.4 × 10⁻⁹ cm/√
z+y	7.50	18.1	13.4	49.75	7.80	2.92	1.6 × 10⁻⁹ cm/√

Modifications to Driver boards made. See EM #2 p8, 9.

Measure V_B^{PP} again and set b values according to:

	Unit	Old V_B^{PP}	New V_B^{PP}	Ratio	New ACFB	New ~~	measured ACFB	"Real b"
x-z	1.01	60	43	1.40	5.11	11K 1500pf	5.33	0.052
x+z	2.61	58	47	1.23	4.46	10K 1500pf	4.65	0.052
y-x	3.92	42	32	1.31	6.54	15K 1200pf	6.81	0.052
y+x	5.16	42	26	1.62	9.23	20K 1200pf	9.45	0.051
z-y	6.30	30	17.5	1.71	14.26	30K 750pf	14.1	0.049
z+y	7.50	19	12.0	1.58	21.76	47K 750pf	21.9	0.050

↑ capacitor to get rid of RF

Vint	ab gain	A_{CFB}	mV/varac V.	@ 12.6 kHz CMO noise		X equiv. motion
1.01	39.9	5.3	12.65	-103.7	, 6.53	1.1 x 10^{-9} cm/√
2.61	35	4.7	9.41	-106.4	, 4.79	0.6 x 10^{-9}
3.92	45.3	6.8	11.43	-107.9	, 4.03	0.7 x 10^{-9}
5.16	47.5	9.5	9.76	-107.7	, 4.12	0.8 x 10^{-9}
6.30	18.5	14.1	7.89	-114.8	, 1.82	1.1 x 10^{-9}
7.50	17.0	22.0	7.80	-115.7	, 1.64	1.6 x 10^{-9}
				dBV/√	μV/√	

→ 5 μV/√ ÷ 800 = 6.25 nV/√

That's - a - nice.

3/1/83

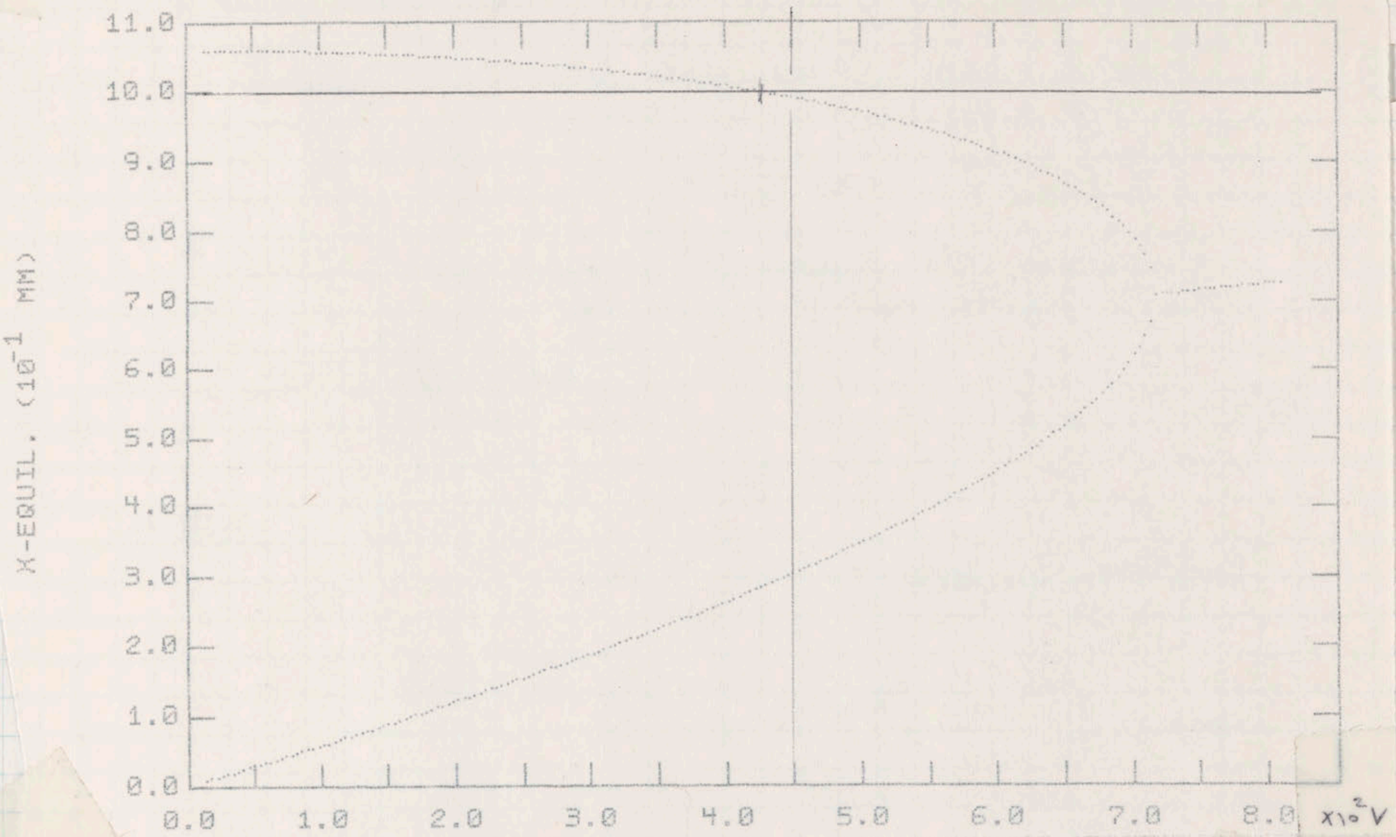
V_{HV}	$C_{pf\,drive}$	α	V_B^{pp}	$\frac{dC}{dx}$ $\frac{pf}{cm}$	C_{det}	$\frac{dV}{dx}$ $\frac{v}{cm}$	G_{HV}	M_g	G_F^P	$1+\left(\frac{\omega}{h}\right)^2$	G_F^R	G_P ($Q=1$)	G_R ($Q=5$, 0.5 Hz)	SYSTEM	
450	43.7	1.97	45	360	129	9.98	26.7	15000	112	2	42	1.2	10.5	CM	X
450	40.1	1.80	29	369	135	6.29	26.7	15000	64.5	2	24.2	2.1	18.1		Y
450	57.1	2.57	14.7	495	152	3.76	26.7	15000	55.0	2	20.6	— (2.5)	21.4		Z
400	59.3	2.37	45.5	438	143	11.0	23.5	8000	245	1.12	164	0.55	2.7	EM1	X
450	29.1	1.31	29.5	178	101	4.1	22.8	8000	49	3.72	9.9	2.8	44		Y
500	25.0	1.25	22.0	148	86.5	2.92	25	8000	36.5	3.92	6.98	— (3.7)	63		Z
400	51.4	2.05	46.7	430	167	9.31	29	8000	221	1.12	148	0.61	3.0	EM2	X
450	23.3	1.05	32.8	181	111	4.3	27	8000	48.8	3.72	9.8	2.8	45		Y
500	17.2	0.86	21.5	124	93	2.24	28.6	8000	22.0	3.92	4.22	— (6.2)	104		Z

assumed: $C_B = 120\,pf$
$a = 800$
$b = 0.05$
$RC = 1$ sec

all parameters are averaged over both systems for a given axis.

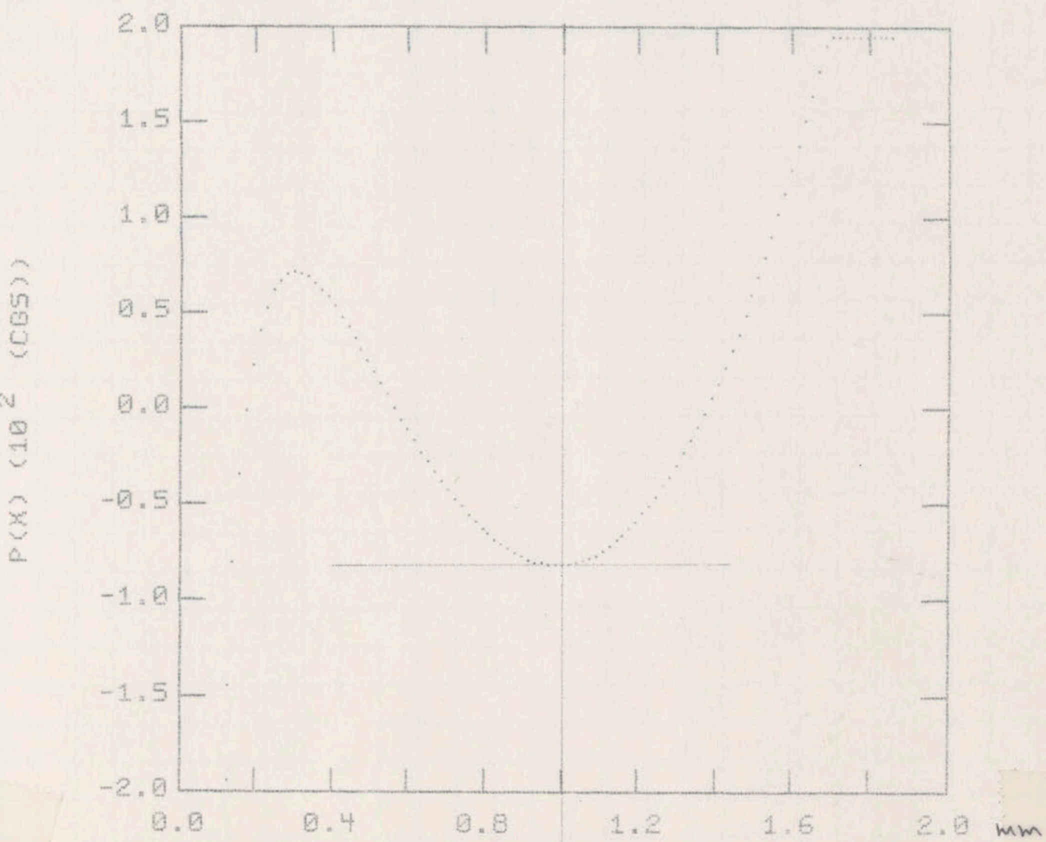
A = 95.00 cm² X-S = 1.06 mm

CENTRAL MASS (13,000g)



VHV = 450.00 V A = 95.00 cm² X-S = 1.06 mm

CENTRAL MASS



Damping the C.M.

High voltage bias to use: $M \approx 15{,}000$ g
$A \approx$ ~~[illegible]~~ $\approx 95\ cm^2$ (x and y plates)

pick a high voltage plate bias of $\approx$ **450 V** (see over).

Computed the approximate damping gains needed for the various systems ←

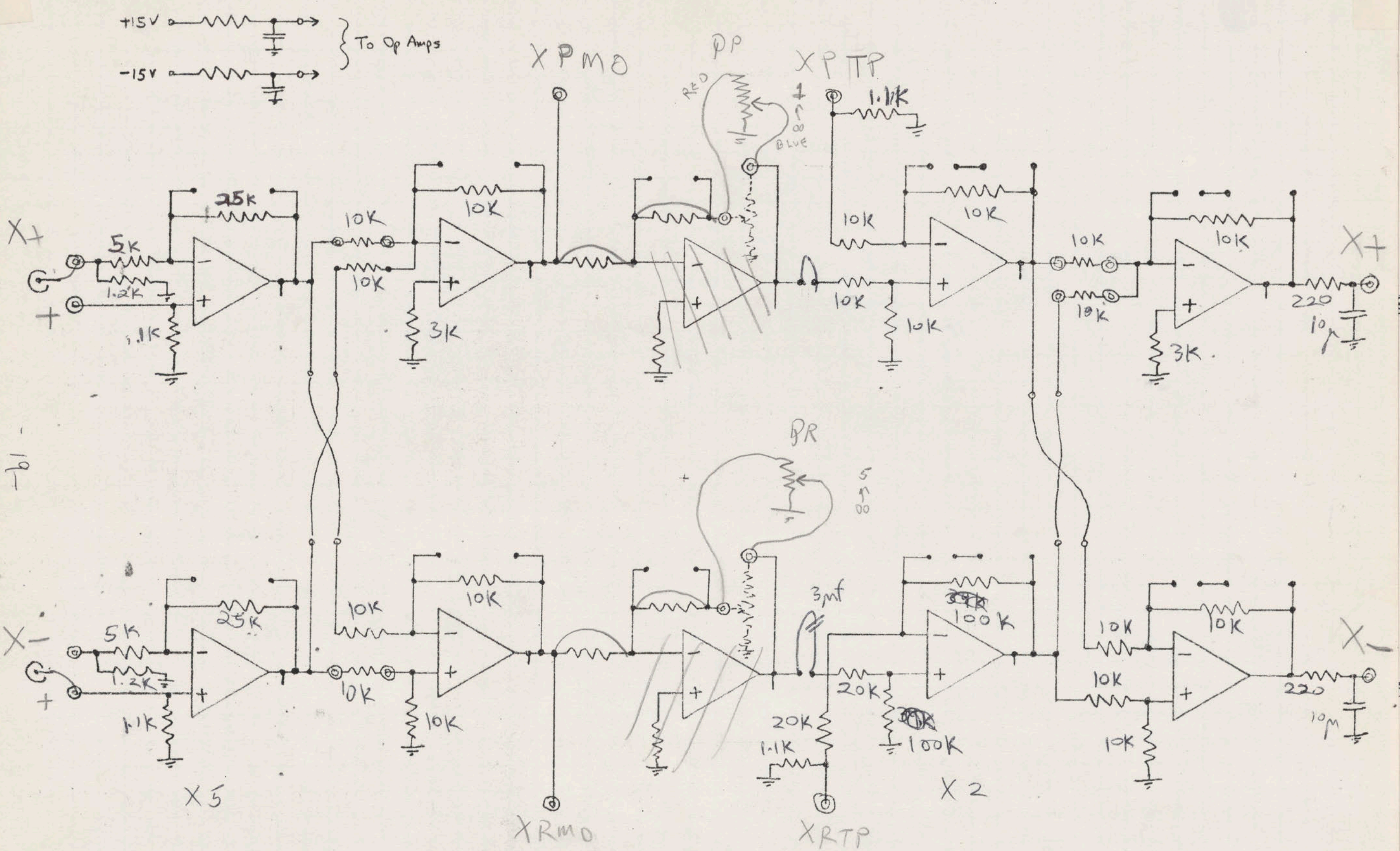
See [D. Dewey #2] p 44-45

4/7/83

Modified HV Amps for lower noise

Amp	Gain @512Hz	$\phi = 45°$ Frequency	Noise out 512Hz	Noise out 25kHz	
X + Z	25.0	25 kHz	−98.9 (11.3)	−112 (2.5)	dBV/√Hz μV/√Hz
X − Z	26.2	25 kHz	−101.4 (8.5)	−112.5 (2.4)	dBV/√Hz
Y + X	24.2	≈ 28 kHz	−104.0 (6.3)	−115 (1.8)	dBV/√Hz
Y − X	26.5	≈ 28 kHz	−110.7 (2.9)	−116.7 (1.5)	dBV/√Hz
Z + Y	26.8	25 kHz	−103.9 (6.4)	−115.4 (1.7)	dBV/√Hz
Z − Y	26.5	30 kHz	−105.9 (5.1)	−114.3 (1.9)	dBV/√Hz

+15V

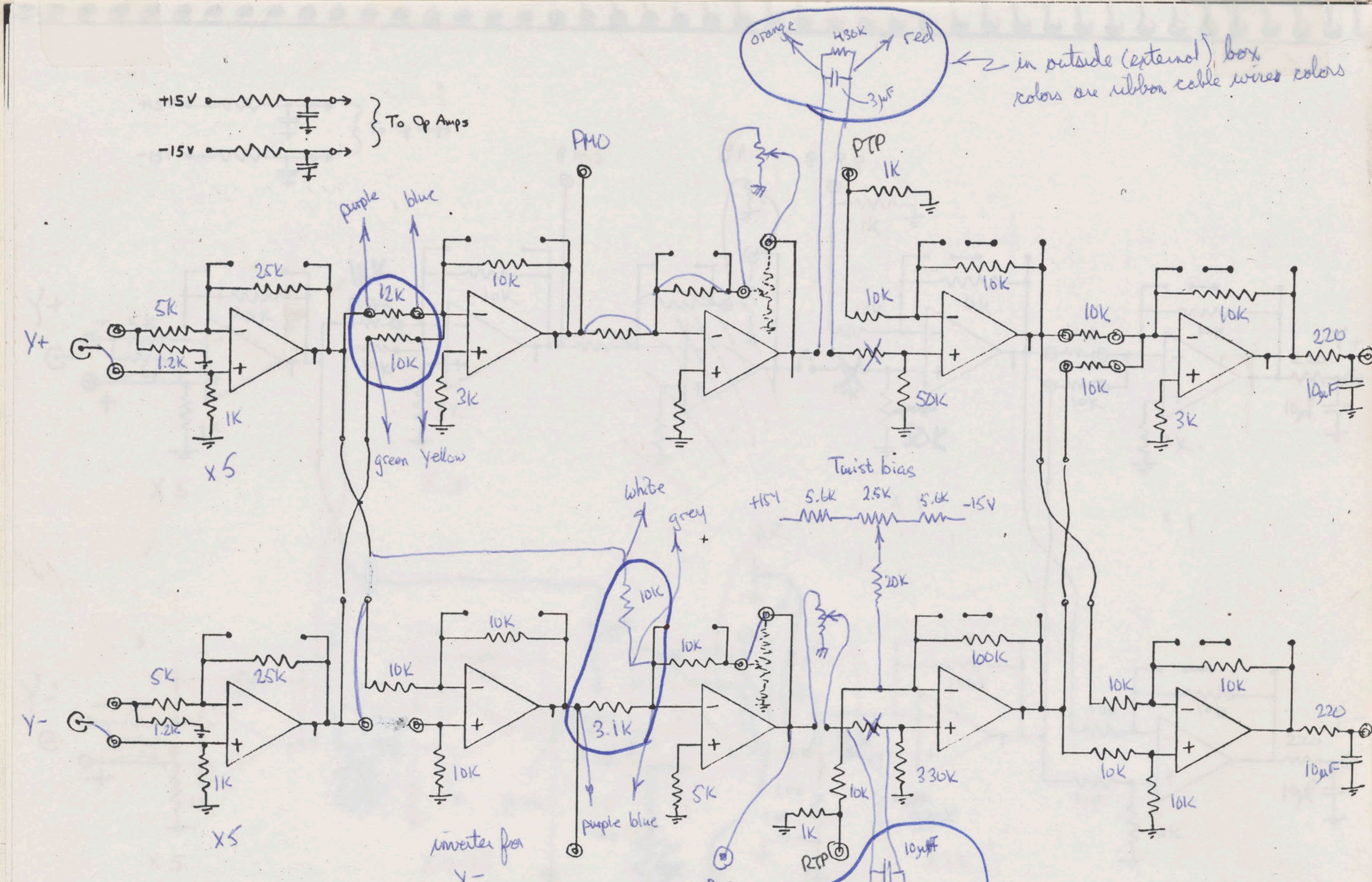


All Op Amps are LF356

CM Matrix Box : X Pair-a-degrees

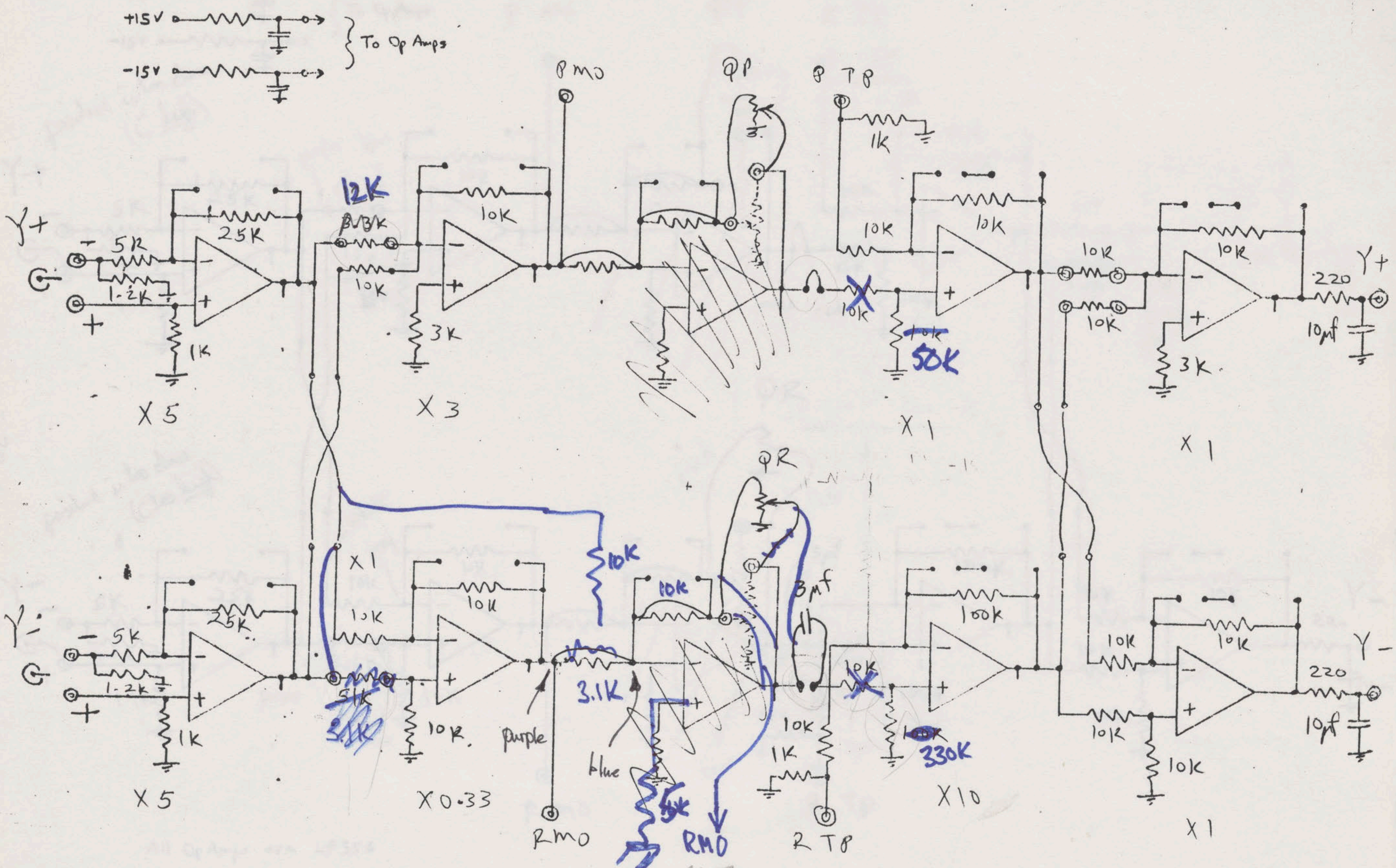
Nominal $G_P = 1.2$

$G_R = 10.5$



All Op Amps are LF356

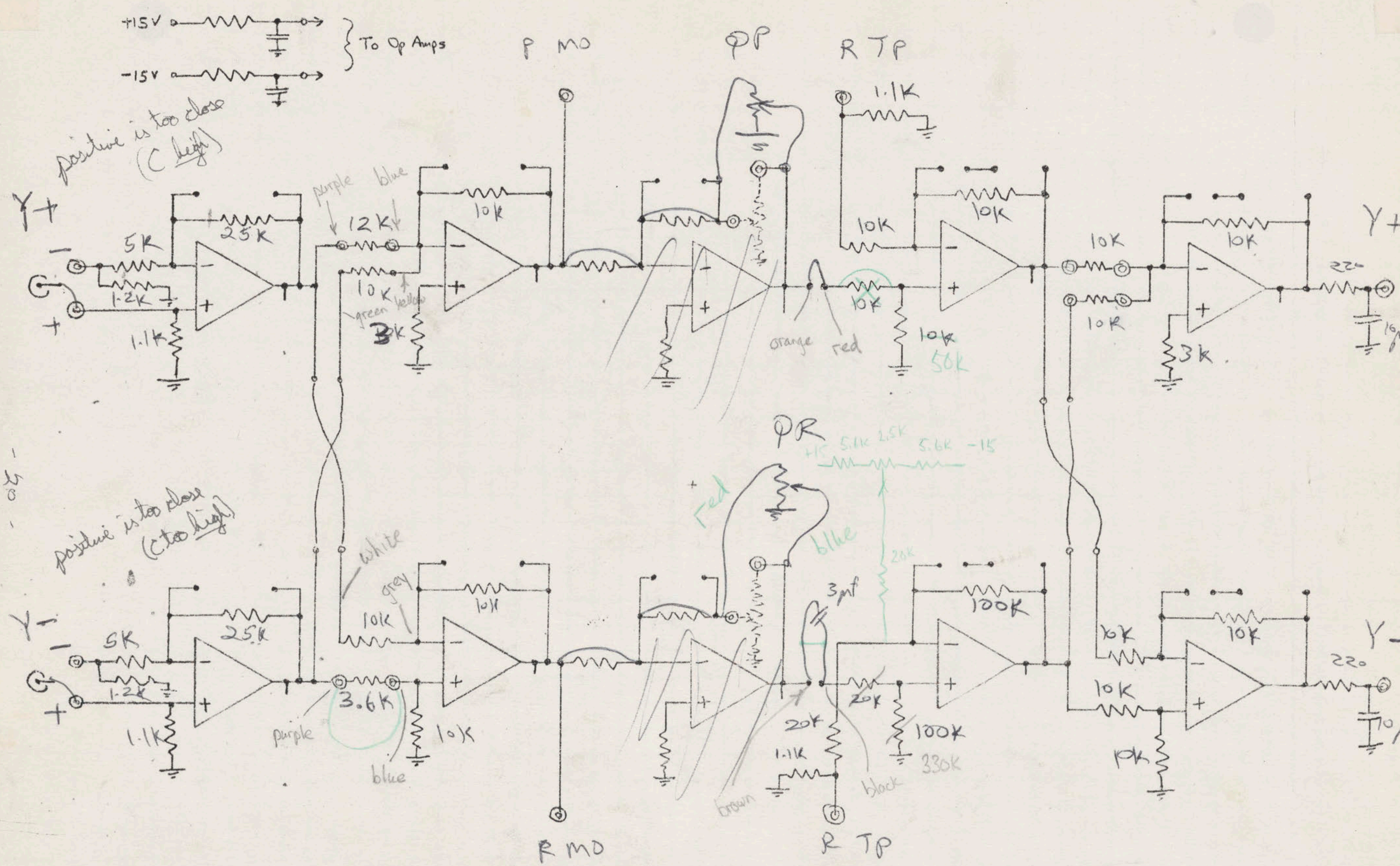
CM Matrix Box : Y Pair-a-degrees



All Op Amps are LF356

~~EMT~~ CM Matrix Box : Y Pair-a-degrees

Nominal Gp = 2.8

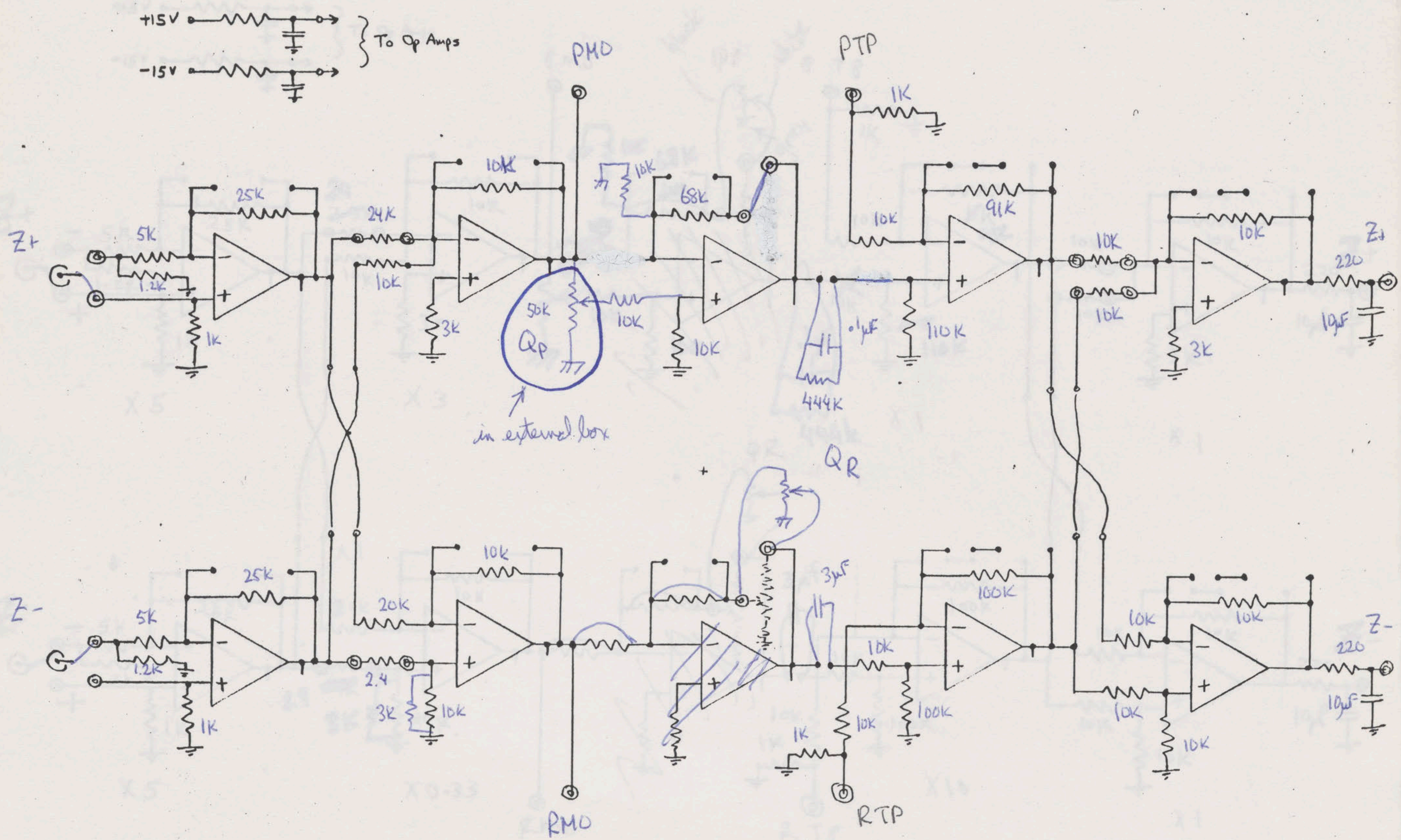


All Op Amps are LF356

CM Matrix Box : Y Pair-a-degrees

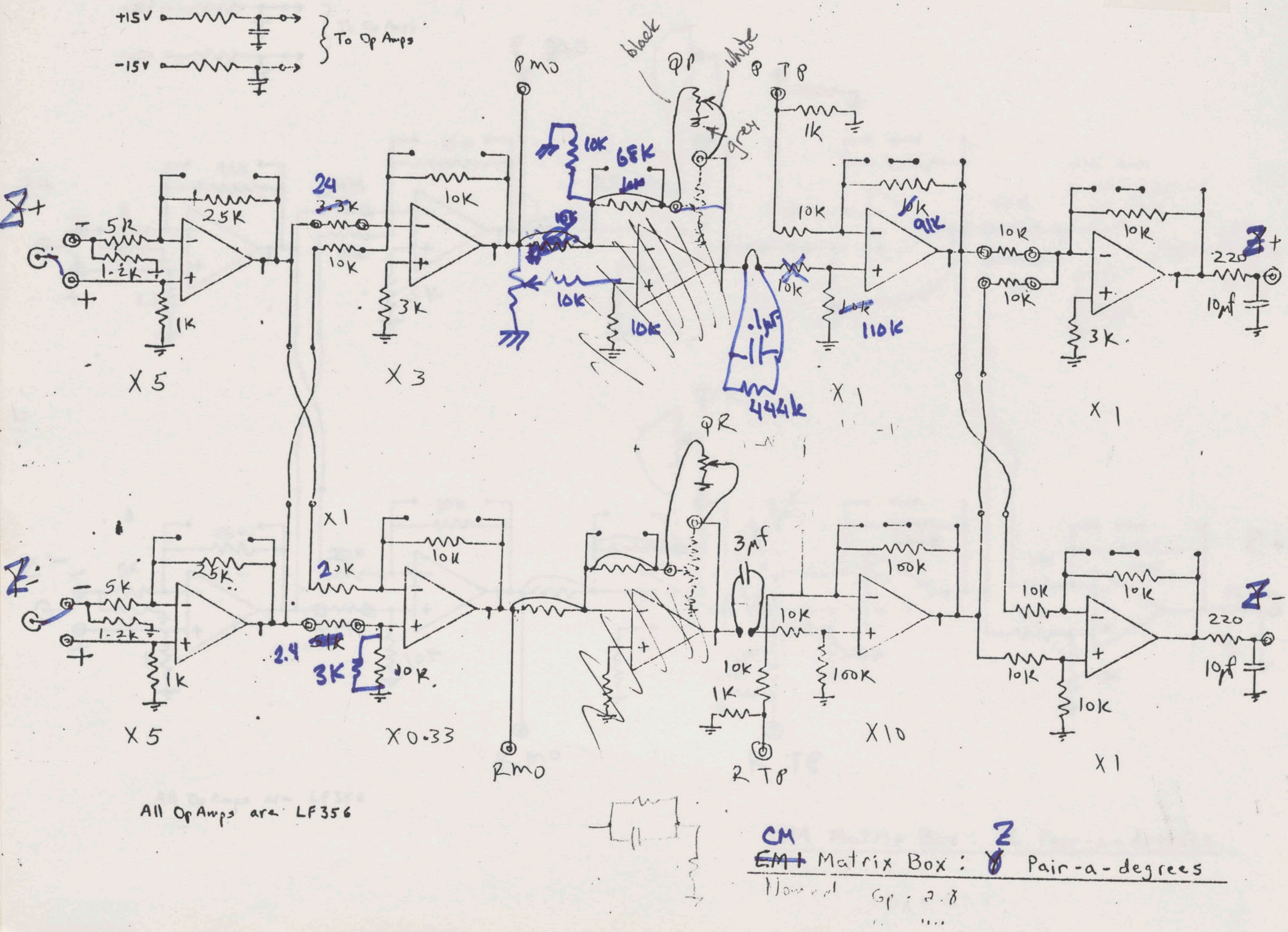
Nominal $G_P = 2.1$

$G_R = 19.1$



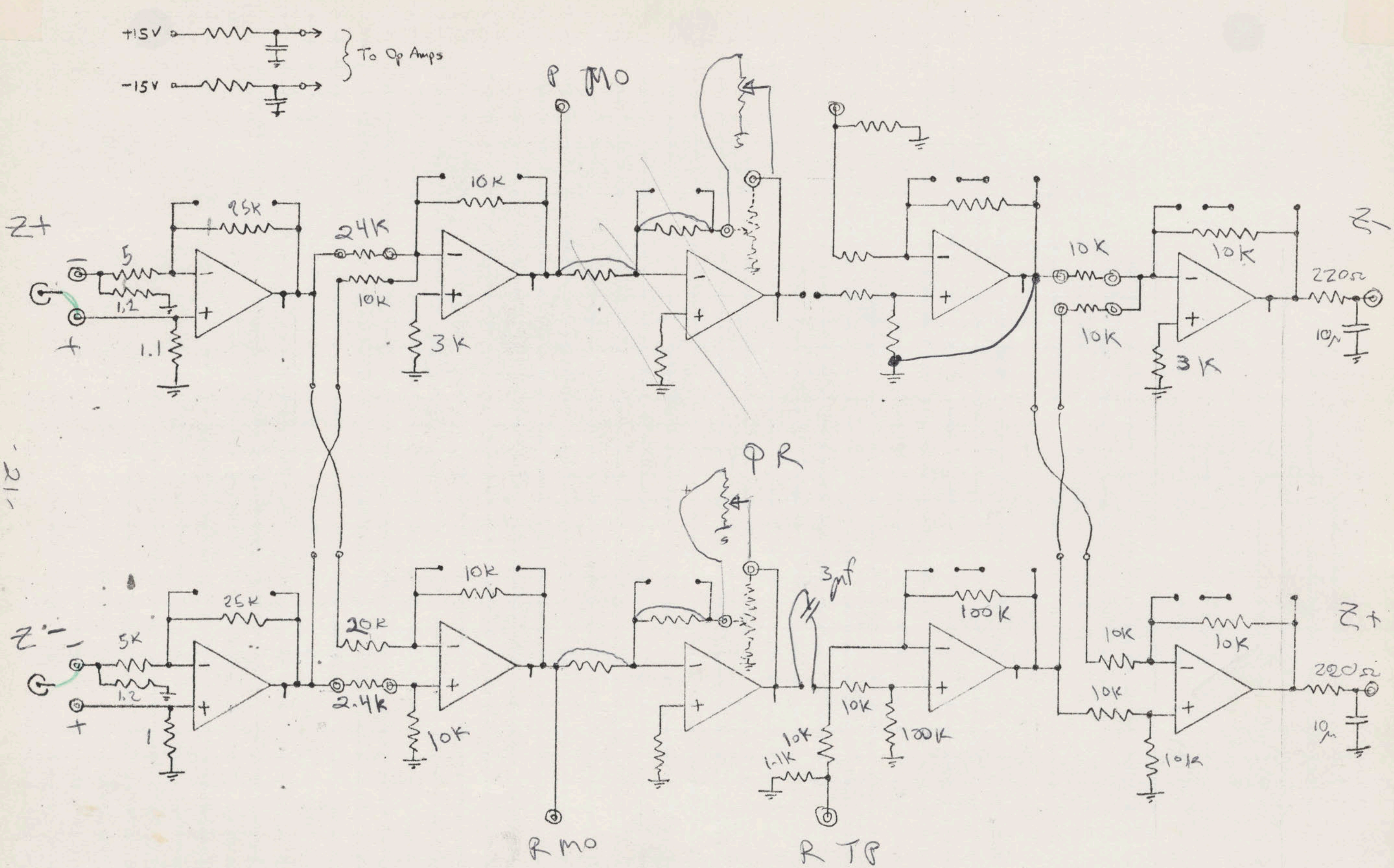
All Op Amps are LF356

CM Matrix Box : Z Pair-a-degrees



All Op Amps are LF356

~~EM1~~ CM Matrix Box : ~~Y~~ Z Pair-a-degrees



All Op Amps are LF356

CM Matrix Box : Z Pair-a-degrees

Nominal G_P = —

G_R = 21.4

6/1/83

Central Mass in it's cage - 1mm x, y. Bumper Z.

↓ Not Grounded* Readings with S.C. at SMA panel.

PLATE		Capacity & Rest of Hard line ↗				Spacing
X+ZS	174.5	178.5	+ 30.3	=	208.8	0.61 mm
X+ZD	198.5	205.0	+ 30.3	=	235.3	0.64
X-ZD	196.0	204.5	+ 25.0	=	229.5	0.64
X-ZS	174.5	179.5	+ 24.5	=	204.0	0.68
Y+XS	157.5	159.5	+ 24.5	=	184.0	1.00
Y+XD	168.5	171.0	+ 29.5	=	200.5	1.10
Y-XD	182.5	185.9	+ 24.6	=	210.5	0.98
Y-XS	171.5	174.2	+ 30.0	=	204.2	0.92
Z+YS	213	226	+ 30.1	=	256.1	0.50
Z+YD	770*	(245) 10 Ω !	33.7		(278.9) ←	(0.51)
Z-YD	231	250	+ 28.9	=	278.9	0.51
Z-YS	216	229	+ 32.0	=	261.0	0.51

↑ Grounded with clip lead

* This is huge!? Is mass shorted to Z+YD plate?? YES ↵
Small bumper spacing.
Shorting Bumper Screw?

Plate	David's Readings	above ↑ - David	Distance	Again	Distance
X+ZS	186.2		0.53	186.5	0.53
X+ZD	~~30~~ → ∞ Ω *				
X-ZD	207			207.5	0.62
X-ZS	181.7			181.8	0.66
Y+XS	160.5		0.98		
Y+XD	172.3		1.07		
Y-XD	186.7		0.96		
Y-XS	175.3		0.90		
Z+YS	226.5		0.50		
Z+YD	43 Ω				
Z-YD	249.0		0.51		
Z-YS	229.0		0.51		

Tube down. Mass grounded.

* ~~looks like~~

Nov. 7 '83

Before Lifting

Plate #		C	x_{mm}		C(1mm)
(1)	X+Z S	216	0.55		191
(2)	X+Z D	Reads 90‡			214
(3)	X−Z D	232	0.63		204
(4)	X−Z S	207	0.67		186
(5)	Y+X S	186.5	0.97		186
(6)	Y+X D	202	1.10		206
(7)	Y−X D	212	0.97		211
(8)	Y−X S	206	0.92		202
				~~C(1mm)~~	
(9)	Z+Y S	257	0.50	~~191~~	208
(10)	Z+Y D	~770*		~~214~~	227
(11)	Z−Y D	279	0.52	~~204~~	224
(12)	Z−Y S	262	0.51	~~186~~	214

‡ X+Z D plate:
* Z+Y D plate:

Z = 7.22mm on vernier scale ← pick it up!
Z = 6.31mm $C_{Z-YD} \to 224pf$

	C	C	C	x	C	x
X +	171	180	209	0.63	206	0.67
+	(89)	(90)	(90)	—	(90)	
−	174	180	195	1.25	204	1.01
−	159	164	176	1.33	183	1.09
Y +	157	157	173	1.58	184	1.05
+	173	173	189	1.72	201	1.13
−	178	176	194	1.72	213	0.95
−	171	169	186	1.70	205	0.94
Z +	212	194	212	0.93	215	0.88
+	230	212	238	0.83	234	0.88
−	224	210	219	1.10	215	1.19
−	215	201	205	1.23	204	1.26

Adjust x plate: x(plate 1) = 0.85mm for C_1 = 196pf.

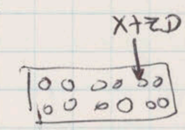
Z 4.5 + .03
Y (Em1) 3.5 + .31
X (Em2) 7.0 + .45

measure capacitances : Nov. 8 '83

		c	x	c		c
X	+	199	0.79 mm	198	0.81	200
	+	90	← Not a short.	219	0.89	220
	−	197	1.19 mm	197	1.19	198
	−	178	1.25 mm	178	1.25	178
Y	+	184	1.05	184	1.05	184
	+	201	1.13	202	1.10	202
	−	213	0.95	213	0.95	213
	−	205	0.94	205	0.94	205
Z	+	214	0.90	214		215
	+	233	0.90	233		234
	−	214	1.21	214		215
	−	204	1.26	204		204

The X+ZD plate reads a real 90pf (with s.c.)
Removing SC capacitance of ≈ 59.4pf gives
X+ZD cap ≈ 30.6 pf compared with the hardline extension capacity of 30.3 pf (p 22)

⟹ The problem is at the CM connector block
Can see female center protruding from teflon.



Check RF-RF feedthrough (à la p 12)
Pockel short still exists (see GRAVITY ANTENNA #12 p 135)
but grounding DC2 does not produce a 5.5MHz resonance?!
Look OK.

Nov. 9 '83

See how much Pockel RF (5.38 MHz)
shows up in 5.16 unit!

See over for RF on CM now.

This RF saturates 5.16 system at RF TP.
At RF OUT of Bridge board we see ≈ 3 V_{pp} @ 5.38
when attached to Drive board RF IN.
Saturation of RF TP at 4 V_{pp}
happens for RF OUT ≈ 60 mV_{pp}

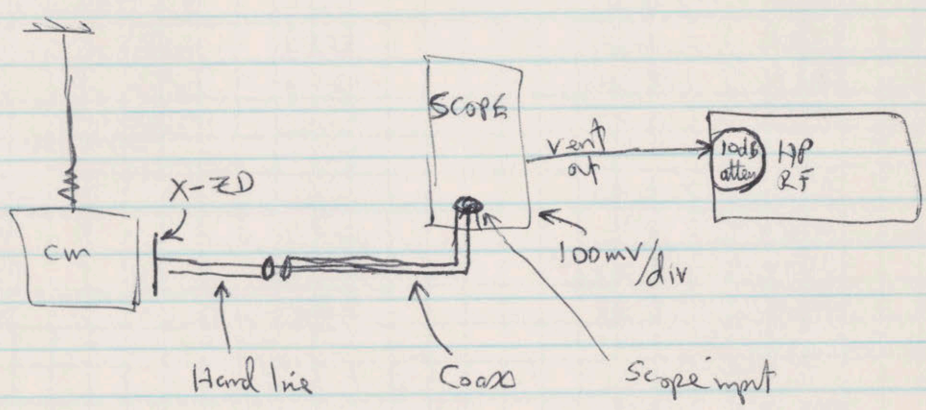
Have to get 3 V_{pp} feedthrough at Bridge Board Out to < 60 mV_{pp}.

this is 34dB

11/9/83

RF on cm

Look with X-ZD plate :



(5.38) Pockel feed through : 370 mVpp 3.7div −17.5 dBm

5.16 Drive : 165 mVpp 1.65div −25 dBm

+9dB = dBVpp → Scope → X6.8 → Vpp on MASS

f	dBm	Vpp	Vpp on MASS
1.01	−44	18 mVpp	0.122
2.61	−34	56 mVpp	0.381
3.92	−30.5	84 mVpp	0.571
5.16	−25.0	158 mVpp	1.074
6.30	−25.5	150 mVpp	1.020
7.50	−28.0	110 mVpp	0.750
Pockel 5.38	−17.5	370	2.52

$C_{X\text{-}ZD} + C_{Hardline} + C_{Coax} = 298\,pf$

$C_{scope} = 20\,pf$

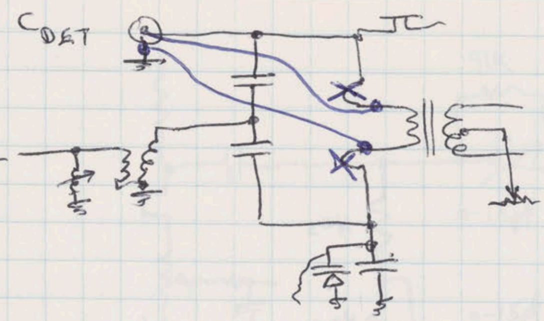
$C_{X\text{-}ZD\ @1mm} = 47.4\,pf$

The measured voltages are attenuated by $\approx$ ~~$\frac{47\,pf}{(298-47)+20\,pf}$~~

$$\frac{\dfrac{1}{(298-47)+20}}{\dfrac{1}{(\ )+20}+\dfrac{1}{47}} \approx 0.15 = 1/6.8$$

Nov. 10 '83

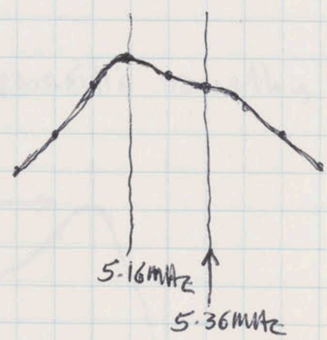
Modify C_{DET} input connector and bridge so that signals go right into 1:1 transformer:



Frequency Response (20MHz Noise source as input on -40dB 10mV range max output meter ≈ 0.3)

-46dBm (10kHz BW) →

10dB ↕



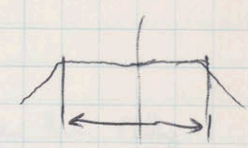
Gain at 5.16 MHz 5mVpp → 300mVpp into 50Ω (-7.8dBm → 0.26Vpp)

5.36MHz 5mVpp → -15.6dBm

> 7.8dB

Look at just the input bridge filter

Signal out of RF1 amp looks like : ⟶



Can narrow this by a factor of 4 ish and still have OK ρ's. (≈40)

Input Z of 1st fet pair is ≈ 960Ω

Retuned filter components to get response:

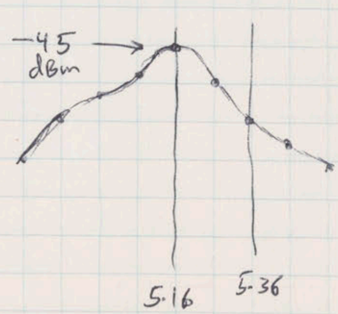
5.16 5mVpp → 330mVpp (-6.5dBm)

5.38 " → 33mVpp (-27dBm)

> 20.5dB

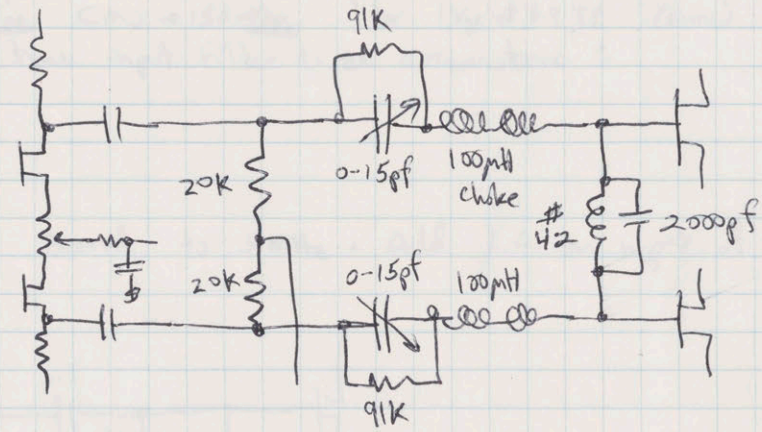
-45 dBm →

10dB ↕

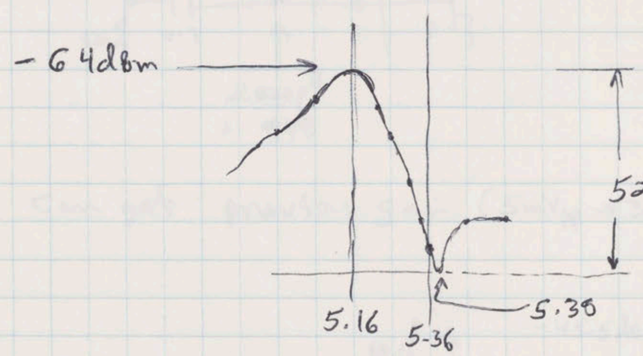


Nov. 10 '83

Add another filter between FET 1 and 2:



A mysterious parasitic something gives the following:



This is garbage - changes with gain adjust of FET's ...

11/11/83

Put in a copy of the Cp loop input filter where the silly 100μH one is.

11/11/83

Modify 5.16 Drive board for 5.00 MHz :

No load:

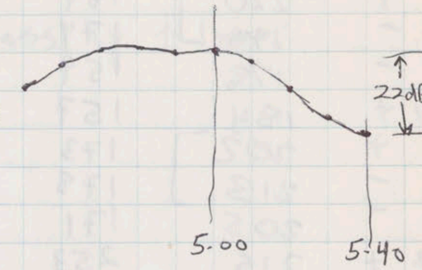
5mVpp in gives 250mVpp at @ 5.00 MHz

~~5mVpp~~

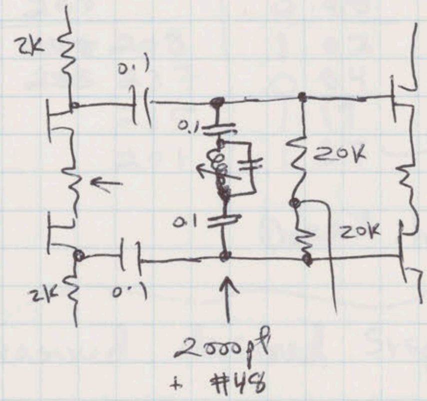
5mVpp in gives 30mVpp at @ 5.38

-2mo → 140mVpp   Cmo → 150mVpp   for 1Vpp at RF TP   (same)

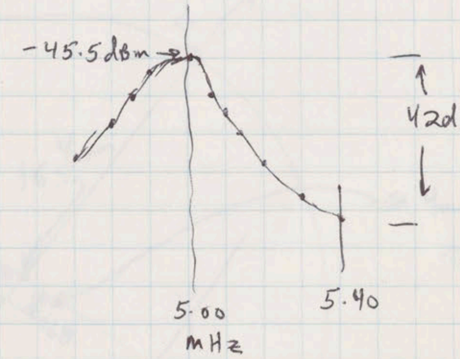
Retune input filter to be assymetric :



Bridge Board to 5MHz. Add LC on input of 2nd FET :



Can get previous gain (5mVpp → 330mVpp) with f response:



The system works with Pockel drive on - lots of 5.38 stuff at RF TP (3Vpp ?) but doesn't come out of mixers...

11/16/83

Look more carefully at motion of CM; find that the suspension is bistable in X, with free oscillation at one position and much other. Open up top, find that rod is too short by 1⅛". Put spacers in 5/8 rods, close up, tighten up screws in XYZΘ mover. Ready to try again.

C mom

x	+	200	171	171	204
	+	220	187	188	224
	−	198	174	174	200
	−	178	159	159	180
y	+	184	157	157	186
	+	202	173	173	204
	−	213	178	178	214
	−	205	171	171	204
z	+	215	253	203	217
	+	234	278	220	236
	−	215	277	214	213
	−	204	261	206	203

Yuck ∅ behavior.

~~Mover is off center~~

Nov. 17 '83

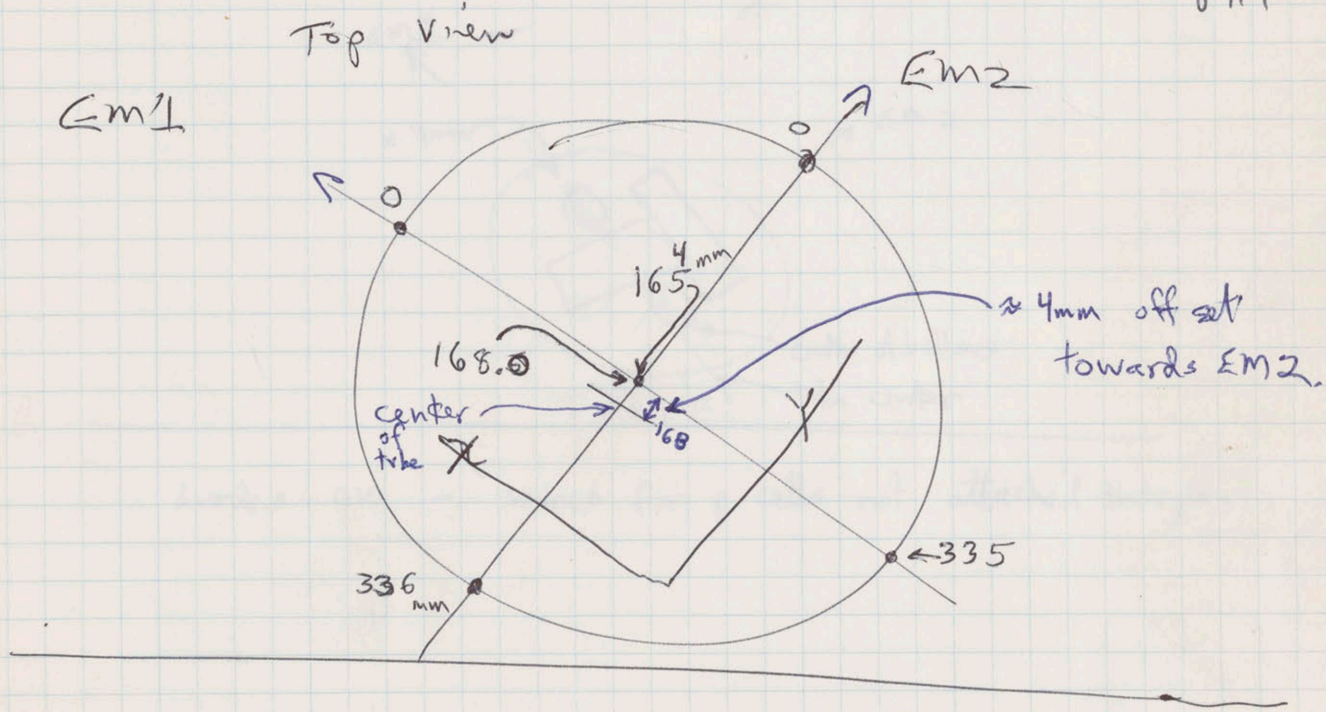
Rotated top mover by 180°.

with micrometers centered and mass up to 1mm:

	C	X
X +	206	0.67
+	225	0.77
−	190	1.44
−	172	1.53
Y +	192	0.84
+	209	0.99
−	217	0.87
Z −	208	0.88
+	~~256~~ 208	1.02
+	~~255~~ 237	0.84
−	215	1.19
−	201	1.37

Doesn't help – shimming into bellows...

Measured desired suspension point: (using cube arrangement described in "GRAVITY" p119)



Remade "Banjo" for correct location
& suspension point. (4mm towards EM2
from center)

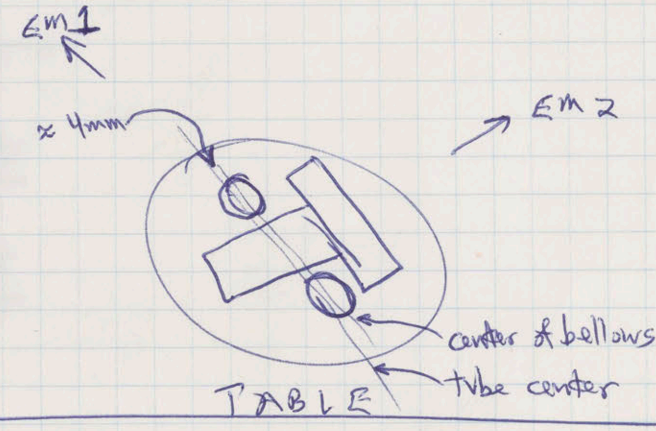
up with no shims!

	C	X
X +	190	1.04
+	209	1.15
−	191	1.40
−	173	1.47
Y +	191	0.86
+	207	0.97
−	213	0.95
−	206	0.92
Z +	207	1.03
+	226	1.01
−	219	1.10
−	209	1.12

} new nominal

Moner mounts in orientation:

Top View



Looks OK - wires for p-cells not attached though.

P = 1/10 atm Driver Cap 3 12/1/83
↑ 159.4 pf S.C

			X_{mm}
(3)	X −	290	1.44
(2)	X +	309.5	1.13
(7)	Y −	304	1.21
(6)	Y +	300	1.17
(11)	Z −	317	1.14
(10)	Z +	328	0.98

Micrometer readings
(correctly)

X (Em2) = 6.05
Y (Em1) = 7.77
Z = 6.55

Damping Signs:

X −	+
X +	−
Y −	+
Y +	+
Z −	
Z +	

Mixer at Ratios:

X−/X+ = 0.9 dB at 0.50 Hz and 3.04 Hz

Y−/Y+ = 0.86 @ 0.48 Hz
0.68 @ 1.02 Hz

Z−/Z+ = 0.412 @ 4.62 Hz

12/28/83

2 or 3 VPTB550's in the CM X+Z HV amp blew out — sympome was constant HV out ≈ −375V with no sensitivity to input or offset control.

~~Yes, "Lowest" VPTB550 was gone.~~

Y+ and Z+ HV AMPS show above problem... 5/7/84

IL-15 + VPTB 550 in one, VPTB 550 only in other.

X+ZS SMA connector soldered. 5/8/84

129

Gravity II

5/8/84

				χ_{min}
CM:	(1)	X+Z S	297	0.99
	(2)	X+Z D	315	1.13
	(3)	X−Z D	296	1.42
	(4)	X−Z S	278.5	1.48
	(5)	Y+X S	290	1.03
	(6)	Y+X D	306	1.15
	(7)	Y−X D	311	1.16
	(8)	Y−X S	303	1.14
	(9)	Z+Y S	~~303~~ 314.5	0.99
	(10)	Z+Y D	~~314.5~~ 334	0.97
	(11)	Z−Y D	323	1.13
	(12)	Z−Y S	313	1.16

from Gravity III p. 120

4-Nov-84

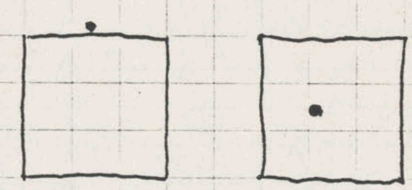
Final capacities: Central Mass

#		C (pF)	d (mm)	
4	X-ZS	~~307~~ 290	~~1.94~~	?. 1.31
3	X-ZD	307	1.30	
2	X+ZD	328	.99	
1	X+ZS	~~290~~ 309	.82	.87
8	Y-XS	317 → 313	~~.66~~	.97
7	Y-XD	326	.97	
6	Y+XD	320	.98	
5	Y+XS	304 → 300 (see p130)	~~1.43~~	?. .87
12	Z-YS	337	~~.77~~	.85
11	Z-YD	350	.83	
10	Z+YD	366	.68	
9	Z+YD	345	~~.75~~	.68

standard cable 173 pF

Loops

+	−
9.6	−12.6
2.8	3.1
9.0	8.8



Also - soldered X+ZS sma connector back on.

12/10/84

Replaced UTB 550's on Z+Y HV Board.

2/19/85

Replaced UTB550's and the IL-15 on the y-x HV board.

5/5/85

The y+x drive plate connection broke off of its contact plate. Soldered back on and arc-checked the y and x plates. Also resoldered the shield of the X+Z hardline.

5/30/85

Replaced UTB550's on X-Z HV amp.

```
        PROGRAM CMXC:
C
C       THIS PROGRAM COMPUTES THE DISTANCE OF PLATE MASS SEPERATION
C       OF THE END MASS GIVEN CAPACITANCE WITH S.C.
C
        DIMENSION OFF(12)
        DIMENSION DCDX(12)
        OFF(1)=159.44               !X+ZS
        OFF(2)=172.68               !X+ZD
        OFF(3)=155.62               !X-ZD
        OFF(4)=143.59               !X-ZS
        OFF(5)=150.14               !Y+XS
        OFF(6)=164.59               !Y+XD
        OFF(7)=169.01               !Y-XD
        OFF(8)=161.19               !Y-XS
        OFF(9)=157.83               !Z+YS
        OFF(10)=169.25              !Z+YD
        OFF(11)=164.53              !Z-YD
        OFF(12)=163.26              !Z-YS
        DCDX(1)=30.22
        DCDX(2)=40.03
        DCDX(3)=47.42
        DCDX(4)=41.26
        DCDX(5)=33.97
        DCDX(6)=39.66
        DCDX(7)=40.53
        DCDX(8)=39.76
        DCDX(9)=49.21
        DCDX(10)=55.94
        DCDX(11)=58.36
        DCDX(12)=49.75
C
        TYPE*,'ENTER STANDARD CABLE CAPACITANCE (PF):'
        ACCEPT*,CSTD
        DO 5 N=1,12
        OFF(N)=OFF(N)+CSTD-58.0            !COMPENSATE FOR NEW STD CABLE
5       CONTINUE
10      CONTINUE
        TYPE *,'ENTER PLATE NUMBER, CAPACTANCE (pF) :'
        ACCEPT *,NPLATE,C
        IF(NPLATE.LE.0) STOP
        X=DCDX(NPLATE)/(C-OFF(NPLATE))
        TYPE 50,C,X
50      FORMAT(3X,'X(',F4.0,'pF) = ',F5.2,' mm')
        GOTO 10
        END
        PROGRAM EM2XOC
C
C       THIS PROGRAM COMPUTES THE DISTANCE OF PLATE MASS SEPERATION
C       OF THE END MASS GIVEN CAPACITANCE WITH S.C.
C
        DIMENSION OFF(12)
        DIMENSION DCDX(12)
        OFF(1)=174.51               !X-ZS
        OFF(2)=208.44               !X+ZD
        OFF(3)=189.86               !X-ZD
        OFF(4)=190.26               !X+ZS
        OFF(5)=152.77               !Y+XS
        OFF(6)=168.19               !Y+XD
        OFF(7)=162.64               !Y-XD
        OFF(8)=150.34               !Y-XS
        OFF(9)=140.26               !Z-YS
        OFF(10)=142.19              !Z+YD
        OFF(11)=141.01              !Z-YD
        OFF(12)=136.81              !Z+YS
C
        TYPE*,'ENTER STANDARD CABLE CAPACITANCE IN PF:'
        ACCEPT*,CSTD
        DO 5 I=1,12
        OFF(I)=OFF(I)+CSTD-58.0            !EXTRA pF OF NEW STANDARD CABLE
5       CONTINUE
        DCDX(1)=43.32
        DCDX(2)=49.23
        DCDX(3)=53.50
        DCDX(4)=42.88
        DCDX(5)=16.14
        DCDX(6)=22.17
        DCDX(7)=24.34
        DCDX(8)=20.09
```

```
        DCDX(9)=12.35
        DCDX(10)=17.89
        DCDX(11)=16.48
        DCDX(12)=12.44
10      CONTINUE
        TYPE *,'ENTER PLATE NUMBER, CAPACTANCE (pF) :'
        ACCEPT *,NPLATE,C
        IF(NPLATE.LE.0) STOP
        X=DCDX(NPLATE)/(C-OFF(NPLATE))
        TYPE 50,C,X
50      FORMAT(3X,'X(',F4.0,'pF) = ',F5.2,' mm')
        GOTO 10
        END

        PROGRAM EM1XOC
C
C       THIS PROGRAM COMPUTES THE DISTANCE OF PLATE MASS SEPERATION
C       OF THE END MASS GIVEN CAPACITANCE WITH S.C.
C
        DIMENSION OFF(12)
        DIMENSION DCDX(12)
        OFF(1)=156.81              !X-ZS
        OFF(2)=180.14              !X+ZD
        OFF(3)=174.90              !X-ZD
        OFF(4)=159.69              !X+ZS
        OFF(5)=141.74              !Y-XS
        OFF(6)=159.13              !Y+XD
        OFF(7)=154.49              !Y-XD
        OFF(8)=144.12              !Y+XS
        OFF(9)=130.20              !Z-YS
        OFF(10)=134.36             !Z+YD
        OFF(11)=133.49             !Z-YD
        OFF(12)=132.25             !Z+YS
C
        TYPE*,'ENTER STANDARD CABLE CAPACITANCE IN PF:'
        ACCEPT*,CSTD
        DO 5 I=1,12
        OFF(I)=OFF(I)+CSTD-58.0            !EXTRA pF OF NEW STANDARD CABLE
5       CONTINUE
        DCDX(1)=41.44
        DCDX(2)=60.29
        DCDX(3)=58.22
        DCDX(4)=46.20
        DCDX(5)=18.11
        DCDX(6)=27.44
        DCDX(7)=30.80
        DCDX(8)=17.46
        DCDX(9)=15.03
        DCDX(10)=27.35
        DCDX(11)=22.58
        DCDX(12)=14.46
10      CONTINUE
        TYPE *,'ENTER PLATE NUMBER, CAPACTANCE (pF) :'
        ACCEPT *,NPLATE,C
        IF(NPLATE.LE.0) STOP
        X=DCDX(NPLATE)/(C-OFF(NPLATE))
        TYPE 50,C,X
50      FORMAT(3X,'X(',F4.0,'pF) = ',F5.2,' mm')
        GOTO 10
        END
```

[illegible]

```
 r cmcox
Enter the distance in mm, please:   1.4
  For plate  1 : C(1.40mm) = 182. pf
  For plate  2 : C(1.40mm) = 203. pf
  For plate  3 : C(1.40mm) = 191. pf
  For plate  4 : C(1.40mm) = 174. pf
  For plate  5 : C(1.40mm) = 176. pf
  For plate  6 : C(1.40mm) = 194. pf
  For plate  7 : C(1.40mm) = 199. pf
  For plate  8 : C(1.40mm) = 191. pf
  For plate  9 : C(1.40mm) = 194. pf
  For plate 10 : C(1.40mm) = 211. pf
  For plate 11 : C(1.40mm) = 208. pf
  For plate 12 : C(1.40mm) = 200. pf
$ r cmcox
Enter the distance in mm, please:   1.5
  For plate  1 : C(1.50mm) = 181. pf
  For plate  2 : C(1.50mm) = 201. pf
  For plate  3 : C(1.50mm) = 189. pf
  For plate  4 : C(1.50mm) = 172. pf
  For plate  5 : C(1.50mm) = 174. pf
  For plate  6 : C(1.50mm) = 192. pf
  For plate  7 : C(1.50mm) = 197. pf
  For plate  8 : C(1.50mm) = 189. pf
  For plate  9 : C(1.50mm) = 192. pf
  For plate 10 : C(1.50mm) = 208. pf
  For plate 11 : C(1.50mm) = 205. pf
  For plate 12 : C(1.50mm) = 198. pf
$ r cmcox
Enter the distance in mm, please:   1.6
  For plate  1 : C(1.60mm) = 180. pf
  For plate  2 : C(1.60mm) = 199. pf
  For plate  3 : C(1.60mm) = 187. pf
  For plate  4 : C(1.60mm) = 171. pf
  For plate  5 : C(1.60mm) = 173. pf
  For plate  6 : C(1.60mm) = 191. pf
  For plate  7 : C(1.60mm) = 196. pf
  For plate  8 : C(1.60mm) = 187. pf
  For plate  9 : C(1.60mm) = 190. pf
  For plate 10 : C(1.60mm) = 206. pf
  For plate 11 : C(1.60mm) = 202. pf
  For plate 12 : C(1.60mm) = 196. pf
$ r cmcox
Enter the distance in mm, please:   1.7
  For plate  1 : C(1.70mm) = 179. pf
  For plate  2 : C(1.70mm) = 198. pf
  For plate  3 : C(1.70mm) = 185. pf
  For plate  4 : C(1.70mm) = 169. pf
  For plate  5 : C(1.70mm) = 172. pf
  For plate  6 : C(1.70mm) = 189. pf
  For plate  7 : C(1.70mm) = 194. pf
  For plate  8 : C(1.70mm) = 186. pf
  For plate  9 : C(1.70mm) = 188. pf
  For plate 10 : C(1.70mm) = 204. pf
  For plate 11 : C(1.70mm) = 200. pf
  For plate 12 : C(1.70mm) = 194. pf
$
```

OK

OK

(1)

```
  r cmcox
Enter the distance in mm, please:    1.0
   For plate  1 : C(1.00mm) = 191. pf
   For plate  2 : C(1.00mm) = 214. pf
   For plate  3 : C(1.00mm) = 204. pf
   For plate  4 : C(1.00mm) = 186. pf
   For plate  5 : C(1.00mm) = 186. pf
   For plate  6 : C(1.00mm) = 206. pf
   For plate  7 : C(1.00mm) = 211. pf
   For plate  8 : C(1.00mm) = 202. pf
   For plate  9 : C(1.00mm) = 208. pf
   For plate 10 : C(1.00mm) = 227. pf
   For plate 11 : C(1.00mm) = 224. pf
   For plate 12 : C(1.00mm) = 214. pf
$ r cmcox
Enter the distance in mm, please:    1.1
   For plate  1 : C(1.10mm) = 188. pf
   For plate  2 : C(1.10mm) = 210. pf
   For plate  3 : C(1.10mm) = 200. pf
   For plate  4 : C(1.10mm) = 182. pf
   For plate  5 : C(1.10mm) = 182. pf
   For plate  6 : C(1.10mm) = 202. pf
   For plate  7 : C(1.10mm) = 207. pf
   For plate  8 : C(1.10mm) = 199. pf
   For plate  9 : C(1.10mm) = 204. pf
   For plate 10 : C(1.10mm) = 222. pf
   For plate 11 : C(1.10mm) = 219. pf
   For plate 12 : C(1.10mm) = 210. pf
$ r cmcox
Enter the distance in mm, please:    1.2
   For plate  1 : C(1.20mm) = 186. pf
   For plate  2 : C(1.20mm) = 207. pf
   For plate  3 : C(1.20mm) = 197. pf
   For plate  4 : C(1.20mm) = 179. pf
   For plate  5 : C(1.20mm) = 180. pf
   For plate  6 : C(1.20mm) = 199. pf
   For plate  7 : C(1.20mm) = 204. pf
   For plate  8 : C(1.20mm) = 196. pf
   For plate  9 : C(1.20mm) = 200. pf
   For plate 10 : C(1.20mm) = 217. pf
   For plate 11 : C(1.20mm) = 215. pf
   For plate 12 : C(1.20mm) = 206. pf
$ r cmcox
Enter the distance in mm, please:    1.3
   For plate  1 : C(1.30mm) = 184. pf
   For plate  2 : C(1.30mm) = 205. pf
   For plate  3 : C(1.30mm) = 193. pf
   For plate  4 : C(1.30mm) = 177. pf
   For plate  5 : C(1.30mm) = 178. pf
   For plate  6 : C(1.30mm) = 196. pf
   For plate  7 : C(1.30mm) = 202. pf
   For plate  8 : C(1.30mm) = 193. pf
   For plate  9 : C(1.30mm) = 197. pf
   For plate 10 : C(1.30mm) = 214. pf
   For plate 11 : C(1.30mm) = 211. pf
   For plate 12 : C(1.30mm) = 203. pf
$
```

looks funny - sort of some bang in successive plates

← use plate 3

looks a little funny.

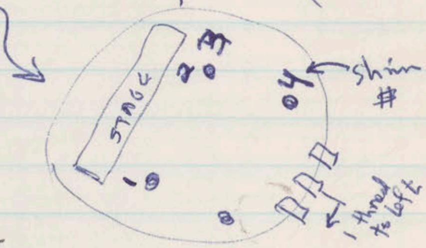
OK

```
  Job 9 entered on queue TXA7
$

  run shoemaker\rek\
%DCL-W-ACTIMAGE, error activating image SHOEMA
-CLI-E-IMAGEFNF, image file not found _DQA0:[SAULSON]SHOEMA.EXE;
$ run [shoemaker]cmcox
Enter the distance in mm, please:   0.9
  For plate  1 : C(0.90mm) = 194. pf
  For plate  2 : C(0.90mm) = 219. pf
  For plate  3 : C(0.90mm) = 210. pf
  For plate  4 : C(0.90mm) = 191. pf
  For plate  5 : C(0.90mm) = 189. pf
  For plate  6 : C(0.90mm) = 210. pf
  For plate  7 : C(0.90mm) = 215. pf
  For plate  8 : C(0.90mm) = 207. pf
  For plate  9 : C(0.90mm) = 214. pf
  For plate 10 : C(0.90mm) = 233. pf
  For plate 11 : C(0.90mm) = 231. pf
  For plate 12 : C(0.90mm) = 220. pf
$ run s\s\[shoemaker]cmcox
Enter the distance in mm, please:   0.8
  For plate  1 : C(0.80mm) = 199. pf
  For plate  2 : C(0.80mm) = 224. pf
  For plate  3 : C(0.80mm) = 216. pf
  For plate  4 : C(0.80mm) = 197. pf
  For plate  5 : C(0.80mm) = 194. pf
  For plate  6 : C(0.80mm) = 216. pf
  For plate  7 : C(0.80mm) = 221. pf
  For plate  8 : C(0.80mm) = 212. pf
  For plate  9 : C(0.80mm) = 221. pf
  For plate 10 : C(0.80mm) = 241. pf
  For plate 11 : C(0.80mm) = 239. pf
  For plate 12 : C(0.80mm) = 227. pf
$ run [shoemaker]cmcox
Enter the distance in mm, please:   0.7
  For plate  1 : C(0.70mm) = 204. pf
  For plate  2 : C(0.70mm) = 231. pf
  For plate  3 : C(0.70mm) = 225. pf
  For plate  4 : C(0.70mm) = 204. pf
  For plate  5 : C(0.70mm) = 200. pf
  For plate  6 : C(0.70mm) = 223. pf
  For plate  7 : C(0.70mm) = 228. pf
  For plate  8 : C(0.70mm) = 219. pf
  For plate  9 : C(0.70mm) = 230. pf
  For plate 10 : C(0.70mm) = 251. pf
  For plate 11 : C(0.70mm) = 249. pf
  For plate 12 : C(0.70mm) = 236. pf
$ run [shoemaker]cmcov\v\x
Enter the distance in mm, please:   0.6
  For plate  1 : C(0.60mm) = 211. pf
  For plate  2 : C(0.60mm) = 241. pf
  For plate  3 : C(0.60mm) = 236. pf
  For plate  4 : C(0.60mm) = 214. pf
  For plate  5 : C(0.60mm) = 208. pf
  For plate  6 : C(0.60mm) = 232. pf
  For plate  7 : C(0.60mm) = 238. pf
  For plate  8 : C(0.60mm) = 229. pf
  For plate  9 : C(0.60mm) = 241. pf
  For plate 10 : C(0.60mm) = 264. pf
  For plate 11 : C(0.60mm) = 263. pf
  For plate 12 : C(0.60mm) = 248. pf
$
```

- Shim + Swing
  Y axis small Δ ~~Ay~~ mvmts swing?

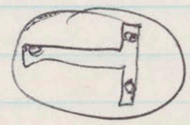
- micro screw positions → X 6.18, Y 6.06, Z 6.44 (on zero of verniers)
  Shim arrangement sketched



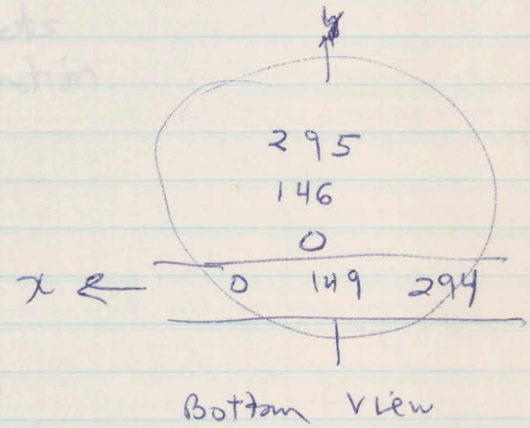
- Drop F
- Remove top ...

- Reassemble top — look --
  measure position of cone ...

- Cute support ...
  Verify ~~Ball~~ behavior
  Lights ... Action!



Location of cone when shimmed and positioned as above



Bottom view

- Mounting screws and tube
- Packed wires ??
- Measure CS ....
- LIGHT
- Drop in norm pos.
- LIGHT

- Raise Tube

- LIGHT

Look for
Pocket Short
Tab positions wrt spot pattern
Inspect Rod clamp.
Big Bolts

- What is level of mass?

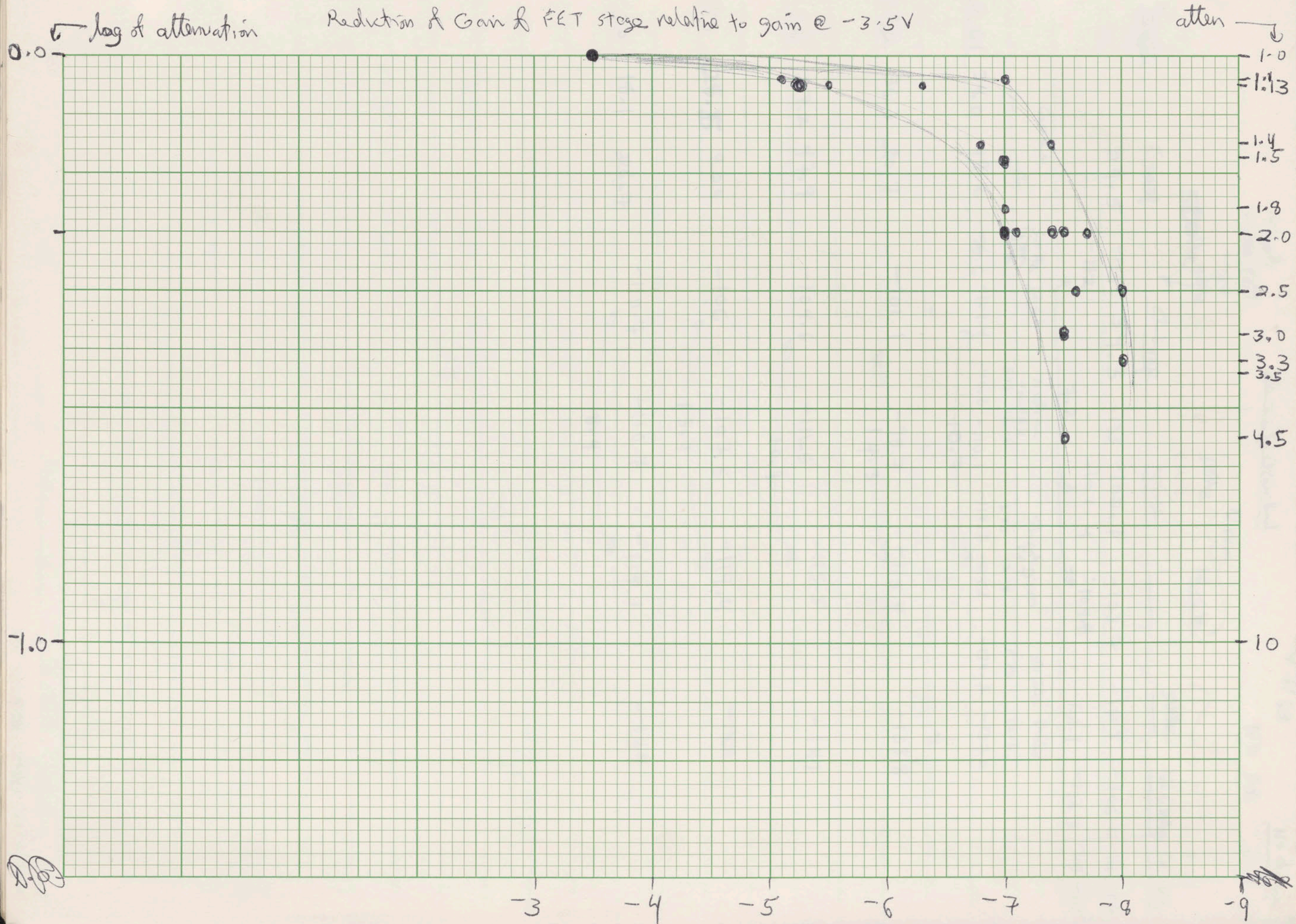
- Mass out of cage
  - Remove Foreign Objects
  - Check Cage Plate motion
  □ + Level ...

- ~~Tram~~ Shim CM Level
  Check optics

2/28/83

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 0780

Reduction of Gain of FET stage relative to gain @ −3.5V



2/7/83

CTP to CMON

	Preamp	C loop		Ω loop		Norm 500Hz Circ. Noise	Norm 12.6K	NO FB 500Hz	NO FB 12.6kHz	No drive 500	No drive 12.6
(3.90)	1.01	29.5	-113	34.3	-135	-102.7	-103.7	-100.9	-106.0	-106	-105
			-112			-101.4	-104.8	-101.1	-106.3	-105	-105

Short across FET input 500Hz → Ω loop

50Ω into Driver Bad ↓

7.2

	Preamp	Gains C	Gains Ω	500Hz Norm Noise	12.6K	No drive + No FBK 500	No drive + No FBK 12.6	Short across FET 500	Short across FET 12.6	50 into Driver 500	50 into Driver 12.6	Difference
(3.76)	2.61	34.0	49.2	~~-88.6~~	-104.4	-110.8	-110.1	-114.7	-115.1	-134.2	-137.0	10.7
(4.97)	3.92	36.3	20.7		-101.1		-98.7		-115.4		-138.8	14.3
(5.59)	5.16	27.2	47.9		-104.6		-111.5		-115.5		-141	10.9
7.87	6.30	21.5	9.24		-106		-107.5		-119.4		-143	13.4
13.4	7.50	18.1	26.7		-110.7		-110.7		-119.1		-139	8.4

= 0.15 Hz

2/4/83

Setting b

$$b = \frac{1}{\pi}\,\frac{V_{Bpp}}{\left(1+\frac{C_{det}}{C_B}\right)\left(C_{det}+C_B\right)\left(1+\frac{C_V}{C_S}\right)^2}\,\frac{dC_V}{dV_V}\,A_{CFB}$$

$$A_{CFB} = \frac{\pi b}{V_{Bpp}}\,\frac{\left(1+\frac{C_{det}}{C_B}\right)\left(C_{det}+C_B\right)\left(1+\frac{C_V}{C_S}\right)^2}{\frac{dC_V}{dV_V}}$$

Want $b = 0.05$

have: $C_B = 120$

$$\frac{\left(1+\frac{C_V}{C_S}\right)^2}{\frac{dC_V}{dV_V}} = \frac{61.31}{23.2} = 2.64$$

$$\pi b\,[\;] = 0.415$$

$A_{CFB} = \frac{0.415}{V_{Bpp}}\left(1+\frac{C_{det}}{C_B}\right)(C_{det}+C_B)$ (A_{CFB} X 2.2K)

V_B^{AD}	Freq	A_{CFB}	
60	1.01	3.65	8 K (8.2K)
58	2.61	3.63	8K (8.2K)
42	3.92	4.99	11K
42	5.16	5.70	12.5 K (12K)
30	6.30	8.34	18 K
19	7.30	13.77	30 K

for ab = 40

$\omega_{max} = 40(0.15\,Hz) = 5.9\,Hz$

for $\omega_{RC} \approx 1$ use R = 360K || 4MΩ

C = 3 μf

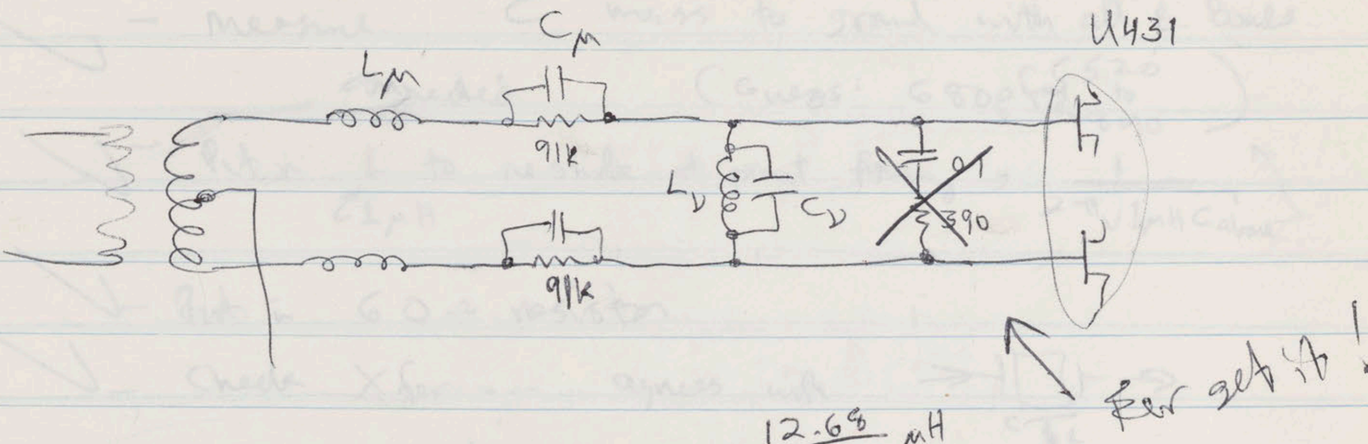
$\omega_{RC} = \frac{1}{RC} = 0.01$ rad/sec

= 0.15 Hz

Leave R_Ω = 4M
C_Ω = 3μf
A_{CFB} = 56K/2.2K = 25.4

2/1/1963

<u>CM Input Filters</u>



$$= \frac{12.68}{f^2}\ \mu H$$

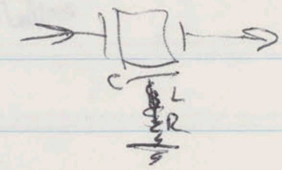
Frequ	Lµ	Cµ	Lν	Cν
1.01	#42 (49.7µH)	510pf	12.4 (#28)	2000pf
2.61	#42 (45.4)	82pf	1.86 (#17)	2000pf
3.92	(#42) (45.8)	36pf	0.83 (#12)	2000pf
5.16	(#42) (52.9µH)	18pf	0.48 (#9)	2000pf
6.30	(#38) (35.5µH)	18pf	0.32 (#7)	2000pf
7.50	(#39) (45.1)	10pf	0.23 (#5)	2000pf

✓ – Measure C mass to ground with all B-Boards connected (Guess: 680pf $\{$520 to 840$\}$)

✓ – Put in L to resonate at correct frequency = $\frac{1}{2\pi\sqrt{1\mu H\, C_{above}}}$
$\sim 1\mu H$

✓ – Put in 60 Ω resistor

✓ – Check Xfer – – agrees with



– VCR 7N

✓ – Drive all bridges – Cross coupling?

✓ – Change gains to a = 800 :

~~Bridge~~ a	~~Bridge~~ a $\frac{a}{18}$ ($\frac{MV}{V}$ out of mixers ÷ noise)	÷ 1.3 (Bridge loss)	÷ 0.8 (Extra loss; desired a gain 0.8)
1.01	11.5	8.9 ÷1.66	6.9
2.61	6.3	4.9	6.1
3.92	4.0	3.1	3.9
5.16	15.7	12.1 ÷1.66	9.1
6.30	4.1	3.15	3.94
7.50	0.44	0.34	0.43

Reduce RF gain by this

– Where is the loss of RF gain in Bridge Board?
⟹ Get another factor of 3 ish.

1/29/83

1/29/83

Gains Needed:

$$Q_{pend} = \frac{M\omega_p}{2c\,\alpha \frac{dV}{dx} \frac{RC}{b}} \approx 1$$

$$\frac{M\omega_p}{2\alpha \frac{dV}{dx}} = \frac{ac}{ab\,\omega_{RC}}$$

from EM (x plates) → CM (x_y plates)

$M \rightarrow \times 2$

$\alpha \rightarrow \times 1$

$\frac{dV}{dx} \rightarrow \times 1$

so need $\frac{ac}{ab\,\omega_{RC}} \approx 1000$

max freq ($ab\,\omega_{RC}$) $= 40$

∴ $ac = 40{,}000$

$2\,nV/\sqrt{}$ × 40,000 = 80 $\mu V/\sqrt{}$

$8 \times 10^{-16}\,cm/\sqrt{}$ @ 1kHz

$b = 0.05$

$a = 640$
$b = 0.05$
$c = 50$
$\omega_{RC} = 1$
$ac = 32{,}000$
$\omega_{max} = 32$
$\omega_{min} = 1$

a	800
b	= 0.05
c	= 50
ω_{RC}	= 1

$ab = 40$

$b = 0.05$

$\frac{ac}{ab\,\omega_{min}} = 1000$

$ac = 40{,}000$

$\omega_{max} = 40$
$\omega_{min} = 1$

$$\frac{1}{1+i\epsilon} \cdot (1-i\epsilon) = 1$$

|| to O(ϵ)

$$(1+i\epsilon)(1-i\epsilon) = 1+\epsilon^2$$

$$\frac{V_{out}}{V_B} = \frac{\dfrac{RSC_B}{1+RSC_B}}{1 + \dfrac{1}{1+\dfrac{1}{SC_BR}}}$$

$$= \frac{RSC_B \cdot \dfrac{1+\dfrac{1}{SC_BR}}{1+RSC_B}}{2 + \dfrac{1}{SC_BR}}$$

$$V_{out} = \frac{V_B}{2} \cdot \left\{ \frac{\dfrac{RSC_B+1}{1+RSC_B}}{\left(1+\dfrac{1}{2SC_BR}\right)} \right\}$$

$$= \frac{V_B}{2} \cdot \left(\frac{1}{1+\dfrac{1}{2SC_BR}} \right)$$

small

$$V_{out} = \frac{V_B}{2} \cdot \left(\frac{2SRC_B}{2SRC_B+1} \right)$$

$$\approx \frac{V_B}{2} \cdot \left(1 - \frac{1}{2SRC_B}\right)$$

$R = 10^5$
$C = 10^{-10}$
$S = 6\times10^6 \cdot f_m$

$2SRC = 12\times10^6 \times 10^5 \times 10^{-10}$
$= 120 \cdot f_m$

$$\frac{dV_{out}}{dR} = \frac{V_B}{2} \cdot \frac{1}{(2SRC_B)^2} \cdot 2SC_B$$

$$\frac{dV_{out}}{dV_R} = \frac{V_B}{2}\left(\frac{1}{2SC_B} \cdot \frac{1}{R^2}\right) = \frac{V_B}{4SRC_B} \cdot \frac{1}{R}\frac{dR}{dV_R}$$

3.92 data

$$4\times10^{-5} = \frac{1}{2SRC_B}\,\frac{1}{R}\,\frac{dR}{dV_R}$$

$$\frac{dR}{dV_R}(\text{ohms/volt}) = 4\times10^{-5} \times 2SRC_B\ 100K = 2.3K\Omega/\text{Volt}$$

1/29/83

1/29/83

Grounding the CMM in the lab to look like suspended mass

$$L_{Henries} = 2\times10^{-9}\, l_{cm} \ln\left(R_o/R_i\right)$$

l_{cm}: 130 cm; R_i: 0.32 cm; R_o: $10.1\,cm \cdot \frac{34.5}{25.5} = 13.66\,cm$

$= 0.98\,\mu H$

$$\Sigma A_{plates} = \frac{600\,cm^2}{1.13} = 520\,pf$$

$$3 \times (7 \times 2.54)^2 = \frac{950\,cm^2}{1.13} = 840\,pf$$

680 pf

$$\frac{1}{2\pi\sqrt{680\,pf\ 1\,\mu H}} = 6.11\,MHz$$

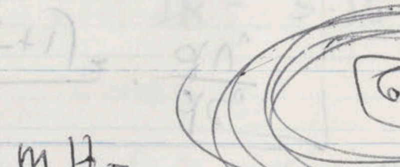
$$\sqrt{\frac{L}{C}} = 38\,\Omega$$

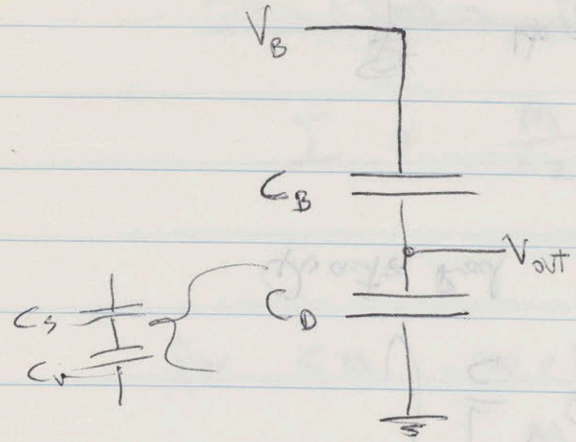
Quartz Rod has 15 Ω resistance × 3 = 45 Ω

three conductors ↑ spiral → × 1.4

63 Ω

Heavily damped resonance (just as well)





$$\frac{V_{out}}{V_B} = \frac{1/sC_D}{1/sC_D + \frac{1}{sC_B}} = \frac{1}{1 + \frac{C_D}{C_B}}$$

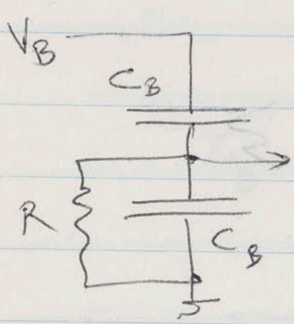
$$\frac{1}{V_B}\frac{dV_{out}}{dC_D} = \frac{-1}{\left(1 + \frac{C_D}{C_B}\right)^2} \cdot \frac{1}{C_B}$$

$$\frac{dV_{out}}{d\,[illegible]} = \frac{-V_B}{\left(1 + \frac{C_D}{C_B}\right)(C_B + C_D)} \quad \frac{dC_D}{d\,[illegible]}$$

$$C_D = \frac{1}{\frac{1}{C_s} + \frac{1}{C_v}} \qquad \frac{dC_D}{dV_v} = \frac{+1}{\left(\frac{C_v}{C_s} + 1\right)^2} \frac{dC_v}{dV_v}$$

$$\frac{dV_{out}^{pp}}{dV_v} = \frac{-V_B^{pp}}{\left(1 + \frac{C_D}{C_B}\right)(C_B + C_D)} \cdot \frac{1}{\left(\frac{C_v}{C_s} + 1\right)^2} \cdot \frac{dC_v}{dV_v}$$

$$\frac{dV_{out}^{pp}}{dx} = \frac{-V_B^{pp}}{\left(1 + \frac{C_D}{C_B}\right)(C_B + C_D)} \quad \frac{dC_D}{dx}$$



$$\frac{V_{out}}{V_B} = \frac{R \| 1/C_B s}{\frac{1}{C_B s} + R \| \frac{1}{sC_B}} = \frac{\frac{R/sC_B}{R + 1/sC_B}}{\frac{1}{sC_B} + \frac{R/sC_B}{R + \frac{1}{sC_B}}}$$

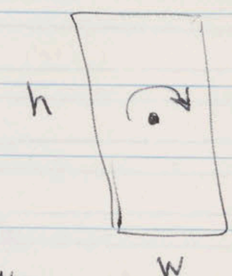
$$= \frac{\frac{R\,sC_B}{RsC_B + 1}}{1 + \frac{R}{R + 1/sC_B}}$$

$$= \frac{RsC_B}{R + \frac{1}{RsC_B} + R}$$

$$V_{out} = \frac{V_B\, sC_B}{2 + \frac{1}{sRC_B}}$$

Rocking + Torsion frequencies

$$I = \frac{M}{12}\left(w^2 + h^2\right)$$



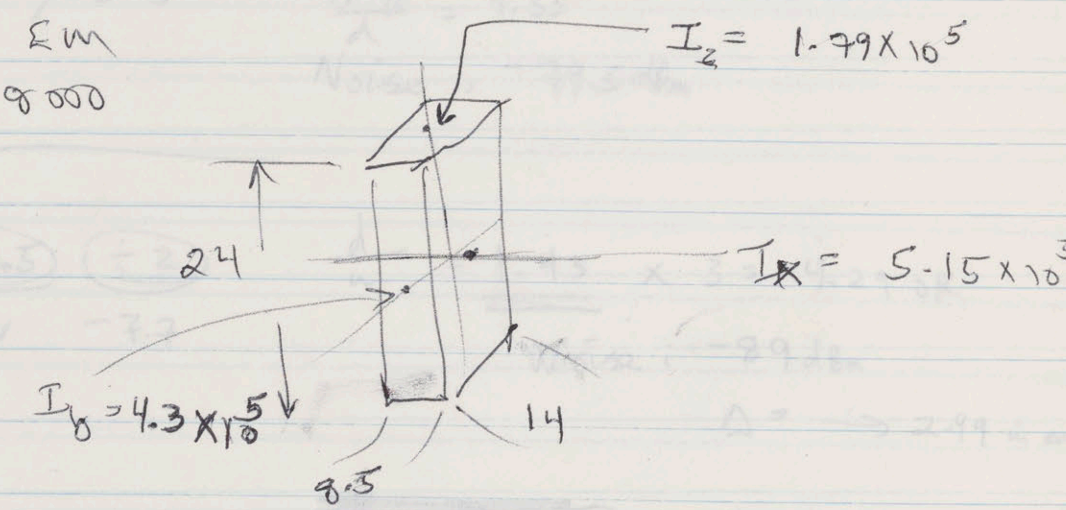
For CM $w = h$ for all axes $= 7 \times 2.54$ cm $= 17.8$ cm

$$I_{\text{all axes}} \approx \frac{15000\,g}{12}\left((17.8)^2 + (17.8)^2\right) \quad (M = 15000\,g)$$

$$= 7.9 \times 10^5\ g\,cm^2$$

For EM

$M = 8000$



The frequency of the torsion mode goes as $\sqrt{\frac{1}{I_z}}$

so $\sqrt{\frac{1.79}{7.9}} \approx \frac{1}{2} \rightarrow$ 1.1 Hz (Torsion)

other modes $\approx \sqrt{\frac{4.6}{7.9}} \approx 0.75 \times 5$ Hz $\approx$ 3.8 Hz (Rocking)

2/3/83

2.61 Gain Reduce by 4

-3.5, -3.5 7.69

$\frac{dv_{pp}}{dc}$

Noise = -76 dBm

(÷4)

-7.0 -7.5

(÷2) (÷2) $\frac{dv_{pp}}{dc}$ = 2.08 x 4 = 8.33 ok

-87.5 dBm 11.5dB OK

3.92 Gain Reduce by 3

-3.5 , -3.5 $\frac{dV_{pp}}{d}$ = 4.35

Noise = -79.5 dBm

(÷ 1.5) (÷ 2) $\frac{d}{m}$ = 1.43 x 3 = 4.29 ok

-7v -7.7

Noise = -89 dBm

Δ = → 2.99 in amplitude (ok)

5.16 Reduce by 9

-3.5, -3.5 15.4 -66 dBm

÷2 ÷4.5

1.46 x 9 = 13.1 ok

-7.0v -7.5v ok!

Noise = -86 dBm

2/3/83

6.30 Reduce gain by 4.5

-3.5, -3.5 $\frac{d_{pp}}{d}$ = 7.14

Noise = -71dB

÷2.5 ÷3 → 1.74 ×4.5 = 7.83 ok

-7V -7.5V Noise = -83 dBm

Δ = 12dB = ×4 ok

2/3/63

1.01 MHz to Nominal Gain

−3.5, −3.5

$\frac{dV_{pp}}{dG_{m}}$ = 8.00

Noise, 10 kHz into 47 Ω = −69. dBm = 790 nV/√

−3.5 , −3.5

Divide by 2:

−3.5 −7.5

$\frac{dV_{pp}}{dG_{m}}$ = 3.70

Noise, 10 kHz into 47 Ω = −76 dBm

= 355. nV/√ ok!

× 2 = 710

Divide by 3.3

−3.5 −8.0

$\frac{dV_{pp}}{d}$ = 2.47 × 3.3 = 8.15 ok!

Noise = −80 dBm = 224 nV/√ × 3.3 = 739

Divide by 2 and 3.3:

−7.0 −8.0

$\frac{dV_{pp}}{d}$ = 1.27 × 6.6 = 8.35 ok

Noise = −86 dBm = 112 nV/√ × 6.6 = 739.

2/2/83

1.01 MHz Band

C mon	5.15 – 4.90	2 V_{pp}
Ω mon	−7.00 – −7.84	2 V_{pp}

400 nV/m noise out (ignoring AM Radio stations!)

Stations:	+ 80 kHz	=	1090
	+ 20 kHz	=	1030
none? →	~~0~~		~~1010~~
	− 60	=	950
	− 170	=	840
	− 280	=	730
	− 340	=	670
	− 430	=	580

2.61 MHz Bd

C mon	5.16 – 4.90	2 V_{pp}	→ 7.69 → 174 (Rf gain)
	−5.75 – −6.73	[illegible] V_{pp}	
	−66 dBm 100 kHz →	355 nV/m	2.04

3.92

5.17 – 4.72	2 V_{pp}
−6.18 – −7.26	0.5 V_{pp}
−70 dBm 100 kHz →	224 nV/m

5.16 ~~4.94 = 5.15~~ 2/2/83

4.84 - 4.98 2 V_{pp}

-6.86 - -7.25 2 V_{pp}

-58 dBm → 891 nV/√

6.30 < : 5.11 - 4.82 2 V_{pp}

: 5.98 - 7.45 0.4 V_{pp}

-60 dBm 708 nV/√

7.50 c : 5.40 - 4.23 1 V_{pp}

-6.05 - -7.41 1 V_{pp}

-72 dBm 178 nV/√

2/1/83

with 390 Ω resistors

1.01	Cmon :	5.36 − 4.59	for 2Vpp
	Ωmon :	−7.35 − −8.41	800mVpp
2.61	Cmon :	5.47 − 4.63	for 2Vpp
	Ωmon :	−6.35 − −8.92	800mVpp
3.92	Cmon :	5.51 − 4.58	2Vpp
	Ωmon :	−6.65 − −7.61	800mVpp
5.16	Cmon :	5.08 − 4.88	2Vpp
	Ω	−7.04 − −8.40	400mVpp
6.30	Cmon :	5.34 − 4.86	2Vpp
		−5.64 − −7.19	400mVpp
7.50	Cmon :	5.92 − 4.02	1Vpp
		−5.84 − −6.63	400mVpp

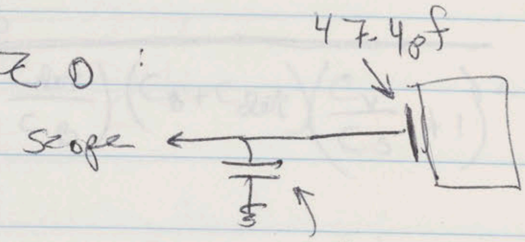
1.01 again fake mass Cmon : 5.31 − 4.56 for 2Vpp = 2.67 → RF gain = 60.3

3.39 → 76.5

1/31/63

RF Voltages on Cm

Monitored with X-Z 0 :



155.6 pf
58 pf
20 pf
233.6

$$\text{attenuation} = \frac{1/233.6}{\frac{1}{233.6} + 1/47.4} = 0.17$$

Sq 25 ← ; DriveUnit: Times nominal V431 gain

Sq 25	DriveUnit	Scope	corrected for attem	corrected for input to ~~[illegible]~~ amp
1.88	1.01	75 mV_{pp}	0.44	
6.0	2.61	240 mV_{pp}	1.41	
6.1	3.92	245 mV_{pp}	1.44	
8.4	5.16	335 mV_{pp}	1.97	
7.4	6.30	295 mV_{pp}	1.74	
6.4	7.50	255 mV_{pp}	1.50	

1/28/83

Cm Tube 34.5" Circum.
Em " 25.5"

X+Z 1.01

$$\frac{dV_{pp}}{dV_{CMON}} = \frac{V_B^{pp}}{\left(1+\frac{C_{det}}{C_B}\right)\left(C_B+C_{det}\right)\left(\frac{C_V}{C_S}+1\right)^2} \frac{dC_V}{dV_V}$$

$V_B = 60V_{pp}$

Cmm	V_{pp} @ RF OUT
~~4.91~~	
4.80	$-1V_{pp}$
4.91	0
5.03	$1V_{pp}$

ΩMON	
-7.63	$1V_{pp}$
-7.40	$0V_{pp}$
-7.78	$1V_{pp}$

2.67

1/28/93

X − Z 2.61

$V_B = 58 V_{pp}$

CMON

4.93 > 1V
5.02 > 1V
5.12

−8.16 > 1V → 1.4
−7.47 1.46
−6.79 > 1V → 1.5

ΩMON

Y + X 3.92

$V_B = 42 V_{pp}$

CMON

4.67 > 1V
4.88 > 1V
5.09

ΩMON

0.84 − 8.33 > 200mVpp
− 7.49
0.46 − 5.33 > 1Vpp
0.40

Y − X 5.16

$V_B = 43 V_{pp}$

CMON

4.88 > 1V
4.93 > 1V
5.01

ΩMON

− 8.07 > 500mVpp
− 7.27 > 1Vpp
− 6.47

Z ± Y 6.30

$V_B = 15.05 V_{pp}$

CMON

4.80 > 1V
5.06 > 1V
5.32

ΩMON

−6.31 > 100mVpp
−5.71
−5.45 > 100mVpp

1/26/83

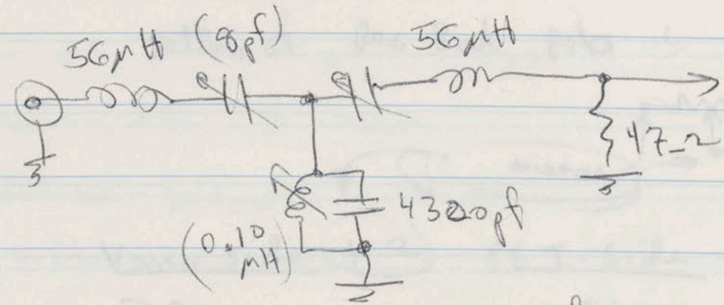
Z - Y 7.50

$V_{B} = 17V_{pp}$

CMO	6.23	
	5.14	> 1V
	4.23	> 1V
-2MO	-4.92	
	-6.18	> 200mV$_{pp}$
	-7.66	> 200mV$_{pp}$

1/17/83

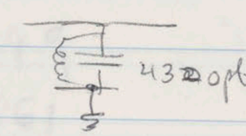
7.50 MHz RFIN – RFT8



(0.23µH) ← 2000pf

Coin = 16.7 for above ↑

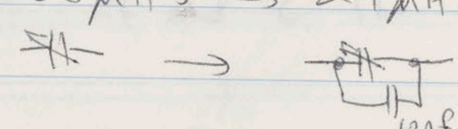
= 20.0 for



removed

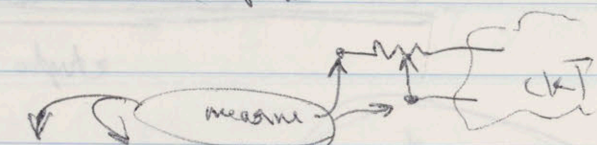
= 100. for filter shorted

Coin ≈ 43 for 56µH's → 27µH's



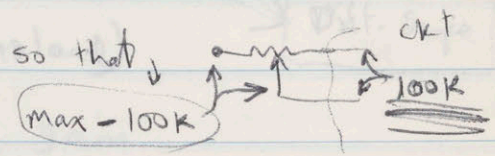
old (ORANGE) End Mass Bridge Boards:

setting of Res Bal pots:



Board	Varac side (kΩ)		FET side
1-02	732	<	854
2-62	882	<	905
3-91	969	>	925
5.14	954	>	899
6-32	983	>	861

CM Bridge Bds: → Set all ⏦'s (Ω BAL) on the units so that



→ Put all units in 180° Ω and C fb.

→ Check ±15V, ±8V supplies and op amp ckts

→ Set C ADJ for +5V on CMON

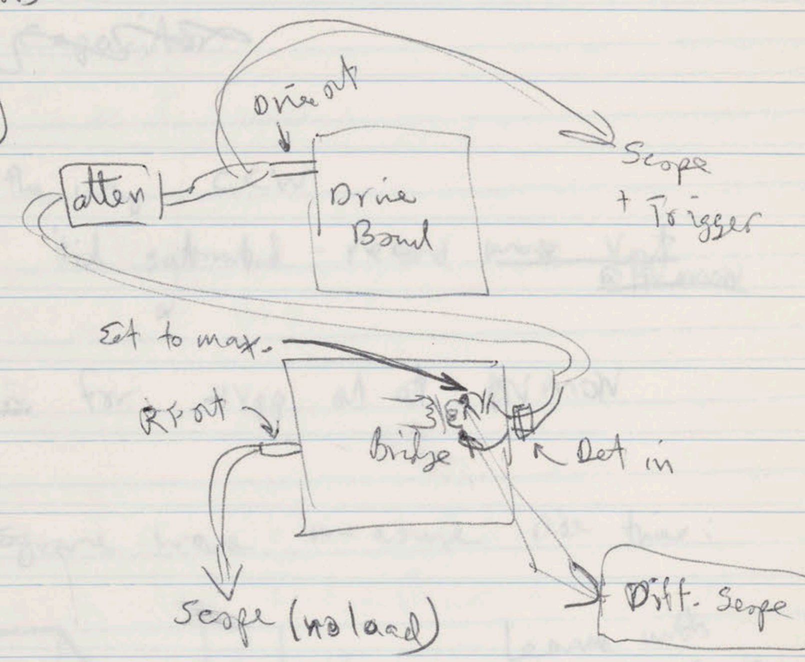
Ω ADJ for −7.5V on ΩMON

1/13/82

Preliminary RF Bridge Bd. check out

- set V431's to have -3.5V @ 2k's.
- adjust balance of outputs
- Set up below:

(No bridge caps in place)



- Tweak filter components and measure gain from Diff scope to RF out ...

Unit	Diff Scope in	RF out	Has 2N3904 followers (of 2N5912)	Gain	dB
1.01 MHz	3.5 mV$_{pp}$	1.7 V$_{pp}$	N	486	54
2.61 MHz	3.5 mV$_{pp}$	1.1 V$_{pp}$	N	314	50
3.92 MHz	8.5 mV$_{pp}$	1.8 V$_{pp}$	N	212	46.5
5.16 MHz	3.2 mV$_{pp}$	3.5 V$_{pp}$	Y	1093	61
6.30 MHz	7.0 mV$_{pp}$	3.7 V$_{pp}$	Y	529	54
7.50 MHz	17.5 mV$_{pp}$	2.2 V$_{pp}$	Y	126	42

1/12/83

~~HV amp~~

Adjust for HV mon = -5 V (~500V)

~~Pot on ~~120 pf~~ capacitor~~

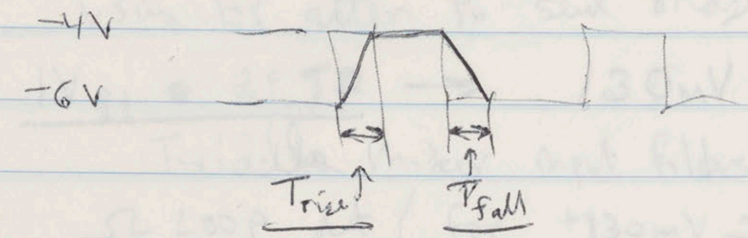
~~Input St.~~

① Adjust offset all the way CCW

② Adjust offset CW 'til saturated - record max Vout @ HV mon

~~Pot fin~~ measure Vin for 2Vpp out at HV mon

For ≈ 30 Hz square wave measure rise times:



Leave with Vout = 0. (or lowest)

Unit	Vout max	Vin for 2Vpp	Trise	Tfall	Both at 500V Quiescent HV current
old Endmass Z+Y/-Y	7.2V / 7.6V	7.5V / 7.5V	7ms / 7ms	3ms / 5ms	7.2mA
cm:					
X + Z	8.8	7.5V	6.5ms	1ms	7.6mA
X - Z	7.5	7.5V	6ms	2.5ms	
Y + X	7.4	7.5V	5ms	7.5ms	7.9mA
Y - X	7.4	7.5V	6ms	4ms	
Z + Y	7.3	7.5V	6ms	3ms	7.9mA
Z - Y	7.4	7.5V	6ms	2.5ms	

200 / 100 / 50 — 50

1.01 MHz DRIVER

1/11/82

Driver at: ≈ $7V_{pp}$ across 5/7 Ω

Mixer One Drive 3.3 Vpp
Phase shifters 1,2: Set To mid range

Mixer Two Drive 3.3Vpp
Phase Shift 3: M1 ⊥ to M2

RF IN to RF TP Gain ≈100 at peak frequ.
Using HP atten to send Bridge Drive in to RF-IN
$1V_{pp}$ @ RF TP → 130mV V_{DC} at mixer OA(s)
Twiddle mixer input filters for max - not very sens.
Ω LOOP at (for +130mV Ω mo) = −3.5V DC

Gain ≈ −30
Should be $-\frac{56K}{2.2K} \approx -25$ OK

C LOOP The same.

Reset ϕ shift 1,2.

Left to do: Noise Check ...
Correct b gain and WRC

~~(2) Check 5534 offset control~~
~~(1) Modify ±15V supply: 75K shunt~~

2.61 MHz DRIVER Bd. 1/11/83

Driver out: 6 V_{pp} across 47 Ω

~~M~~ixer ~~(1)~~ One (-2) Drive : 3 V_{pp}

Phase shifters 1,2 : Set to mid range

Mixer Two Drive : 3 V_{pp}

Phase Shift 3 : Max 1 MC

RF IN to RF TP:

5539 offset adj

Gain ≈ 75

			Loop out
1 V_{pp} @ RF TP →	CM	110 mV DC	→ 3.0V
	ΩM	120 mV_{DC}	→ 3.2V

Reset ϕ shift 1,2 to mid range.

3.92 MHz DRIVER Bd.

Driver at 5 V_{pp} across 47Ω

Mixer one (-2) Drive : 3 V_{pp}
Phase shifters 1, 2 : set to mid range
Mixer two (c) Drive 3 V_{pp}
φ3 2m ⊥ cm.

RF IN to RF TP
5539 offset adjust
Gain ≈ 100

		MO	Loop at
N_{pp} out of RF TP →	C	80mV	2.0V
	-2	80mV	2.0V

Reset φ1,2 to mid range.

1/11/83

5.16 MHz DRIVE

Driver Q4 : 7 V_{pp} across 47 Ω

Mixer One Drive : 2.6 V_{pp}

ϕ 1, 2 : mid range

Mixer Two : 2.6 V_{pp}

ϕ 3 : 2m ⊥ cm

RFIN to RFTP

5539 offset adj.

Gain ≈ 70

		MO	Loop out
1 V_{pp} @ RFTP →	C	75mV	2.0V
	Ω	70mV	1.6V

Reset ϕ1, 2 to mid range.

1/11/83

7.50 Drive Board

Drive Amplitude into 47Ω : 7Vpp

Mixer one : 2.5Vpp

φ, 1, 2 ✓

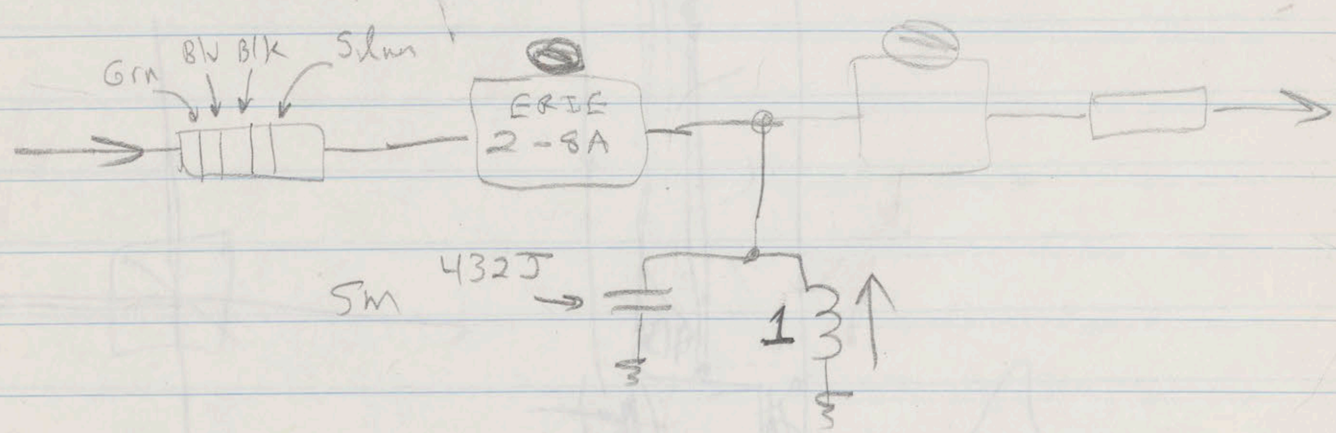
two : 2.5Vpp

φ3 ✓

RFIN to RFTP:

5539 offset adj.

Add new components:

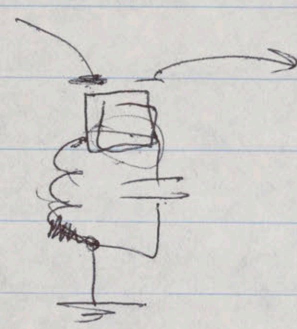


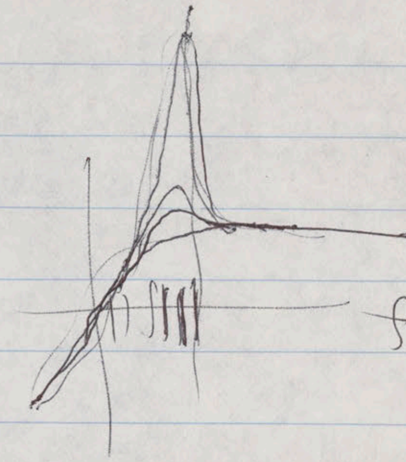
Gain ≈ 17

Replace ~~5~~ ~~3110~~ 310N,

1Vpp @ RF TP

	Mo	Loop out
C	32mV	0.80V
Ω	32mV	0.80V

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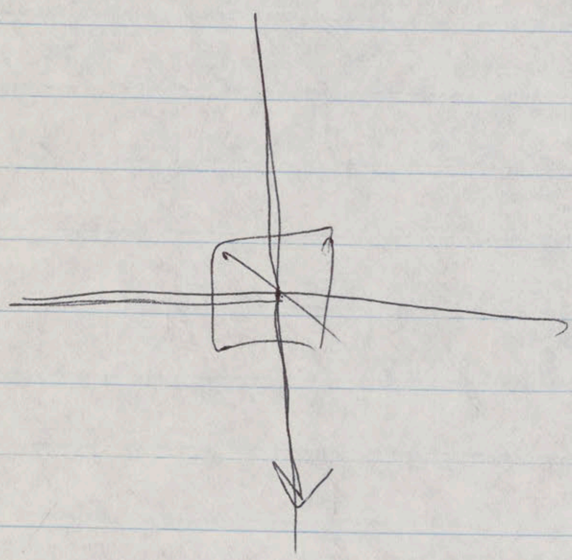

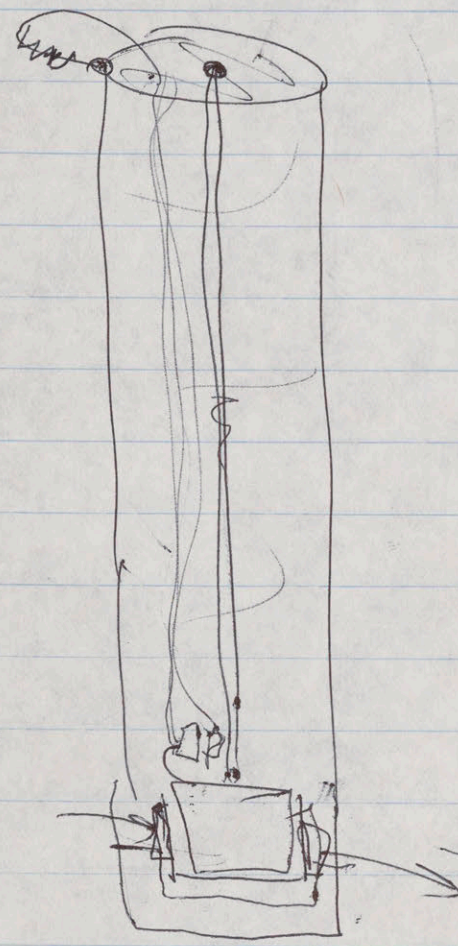

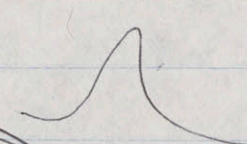

1/11/83

6.30 MHz Drive Bd.

Drive OUT into 47Ω = (5.2 V_{pp})

Mixer one : (2.5 V_{pp})

ϕ1, 2 : mid range

Mixer two : (2.5 V_{pp})

ϕ_3 : ~m 1 cm

RF IN to RF TP

5539 offset adj.

Gain ≈ (50)

1 V_{pp} @ RF TP →

	mo	Loop out
C	45mV	1.05V
Ω	50mV	1.25V

Reset ϕ1,2 to mid range.