The Race is on, NAB 1975 27NOV2014RAG

By the end of 1974, we had the “Bean” RMS gain Control, and not much else

“The Race was on”

Jack committed the funds, and I committed the time to show a new Product at the
April, 3 1975 National Association of Broadcasters Convention in Las Vegas!!!

We needed to design and build a "complete" limiter less than 3 months!
Not possible,

So, we came up with a scheme the could produce a “display “Multi-Limiter that would function

The Circuitry would be on Wire-wrap cards in a frame mounted in a Display Pedestal
On the top of the Pedestal, would be Dummy Metal, with Meters and fake controls
From the Booth Visitors viewpoint, they would think they saw a completed unit!

As I remember there were two… another with no Guts below, on a second pedestal

This scheme only solved the Visual Problem; something needed to go in the Box; that worked
And could be described in a “One Sheet”… we gave ourselves to the middle of March

The limiter needs many parts, and features to work
And there needed to be two versions, one for AM & one for FM

The sketches show System and Circuit Development

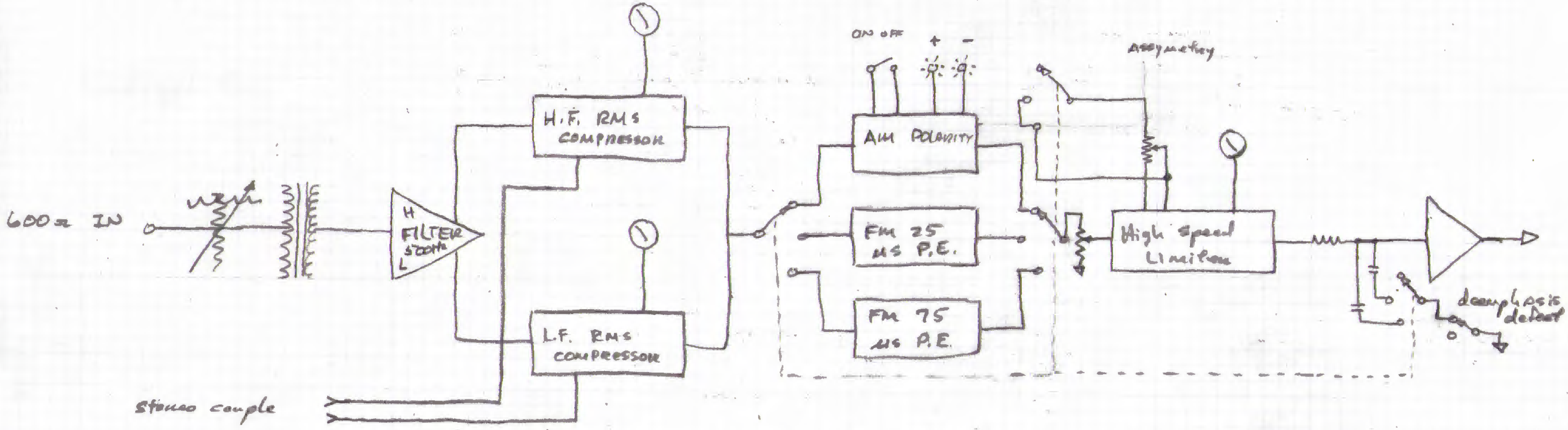
The Puzzle pieces are:

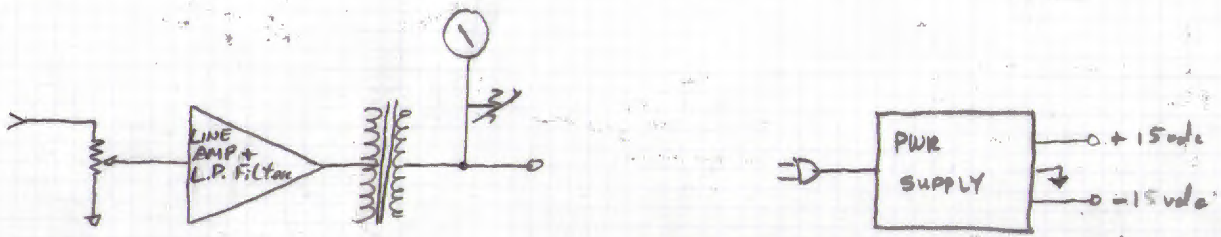
Block Diagram
Input Filtering
Split Frequency Band, RMS Compressor
“Fast Limiter”
AM Signal Processing, Polarity Flipping
FM Signal Processing, Emphasis

The “Blue lines” show what was on the Wire-Wrap Cards in the Pedestal

MultiLimiter, very early Concept Drawing
From DEC1974 or JAN1975

Notice, one box does it all, AM & FM
Also "Split Band", frequency domain RMS processing





For proper operation, extraneous audio must be filtrated out

Components such as Low Frequency A/C sounds, Needle Drops (Remember phonograph Records?)
Also some Stations/Networks used low frequency Keying 20 to 40Hz...

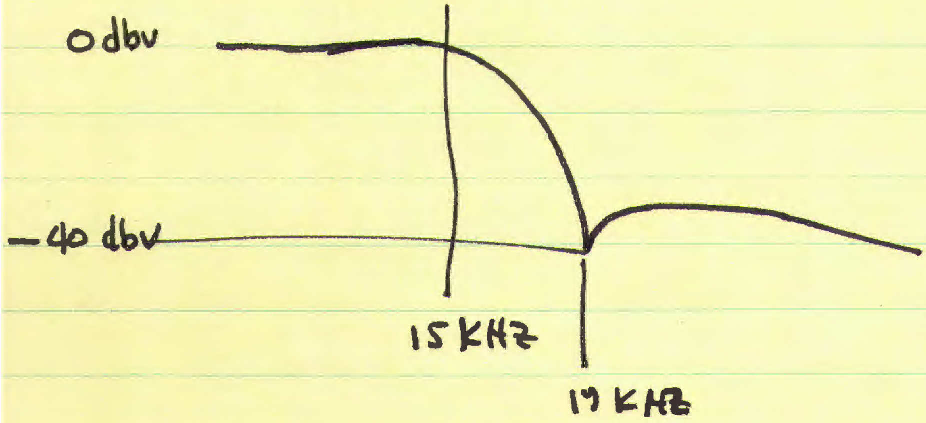
The High Pass Filter is of a Standard Design
The only difference being the inductors are replaced with simulated inductors (Gyrators)

The initial Design was for a cutoff of 50Hz
Later reduced to 40 Hz
And later increased to 90Hz for better RMS performance, and better transmitter efficiemcy

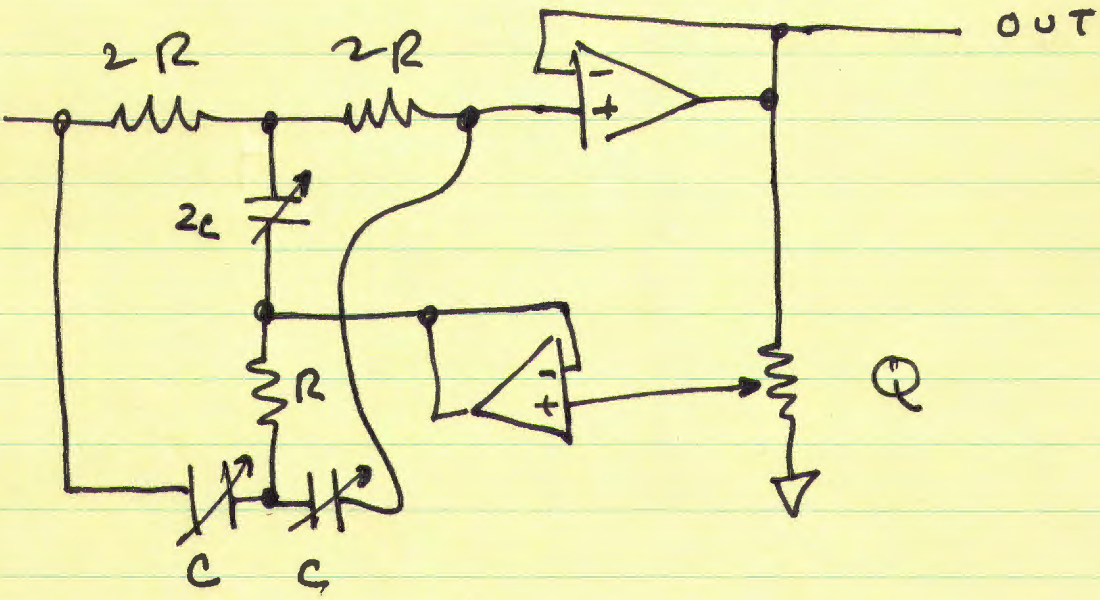
1

Low pass filter. Sharp cutoff..

19 KHZ --- notch.



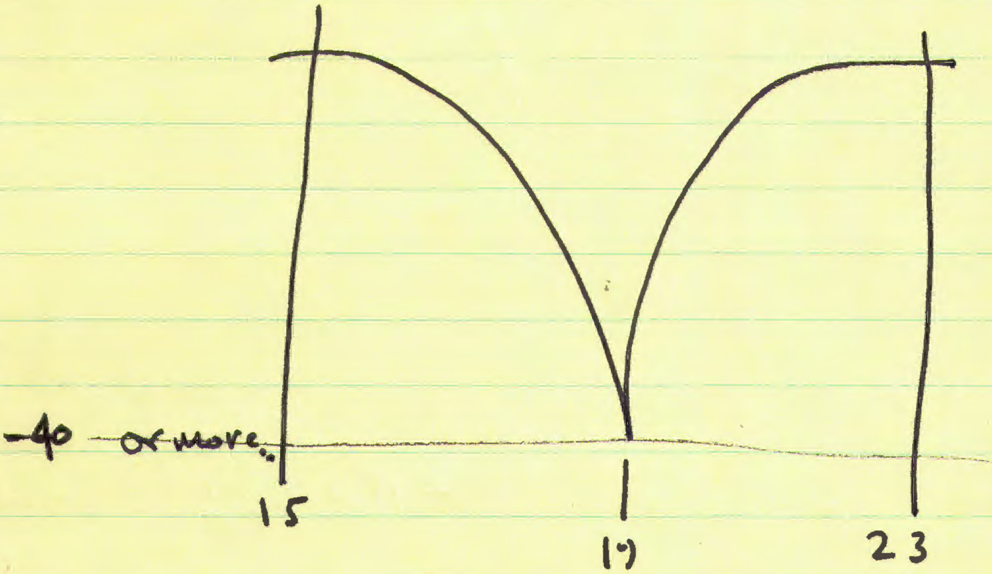
Consider - first a notch filter for ~~15 KHZ~~ 19 KC.



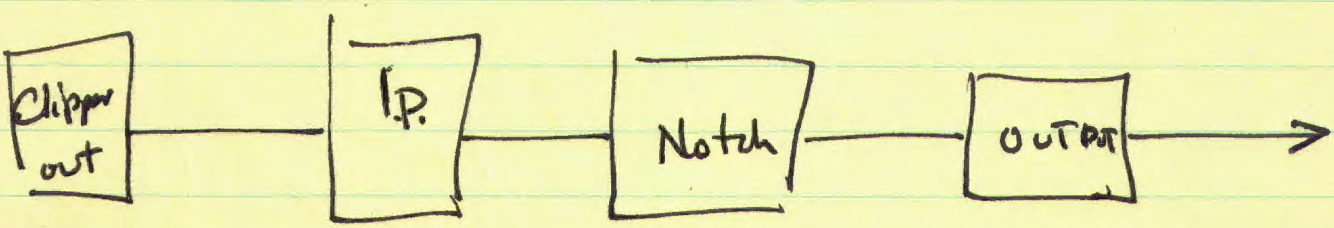
where ~~RC~~= $f = \frac{1}{2\pi R_1 C_1}$ let C= .001 ?

$R = \frac{1}{2\pi f C} = 8376.58\,\Omega$ ok ...

Fny Notice this could give us a notch.. with sematrical sides... - say a depth of 40 db.

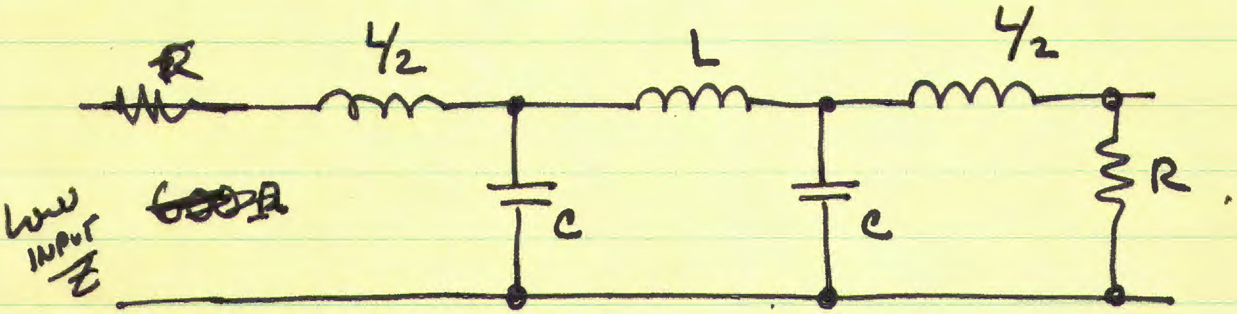


to help... other low pass.. filter suggest..

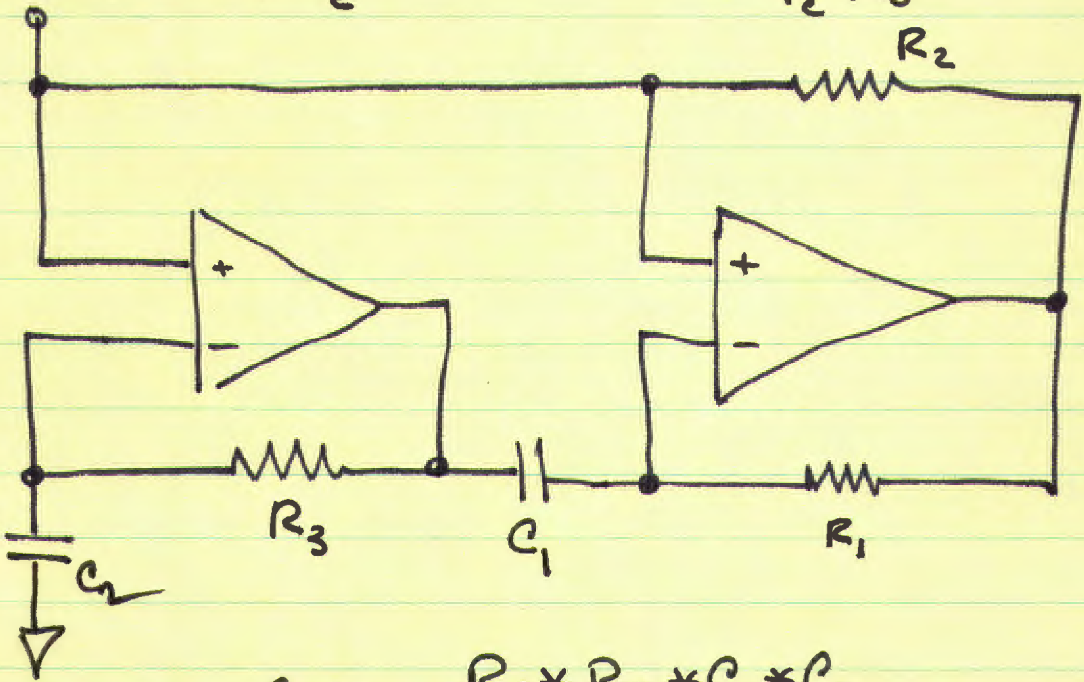


~~Low~~ High pass at least 40 db/octave..

filter section



$$L = \frac{R_o}{\pi f_c} \qquad C = \frac{1}{\pi f_c R_o}$$



$$C_R = \frac{R_1 * R_3 * C_1 * C_2}{R_2}$$

let $R_1 = R_2 = R_3$ and $C_1 = C_2$
then

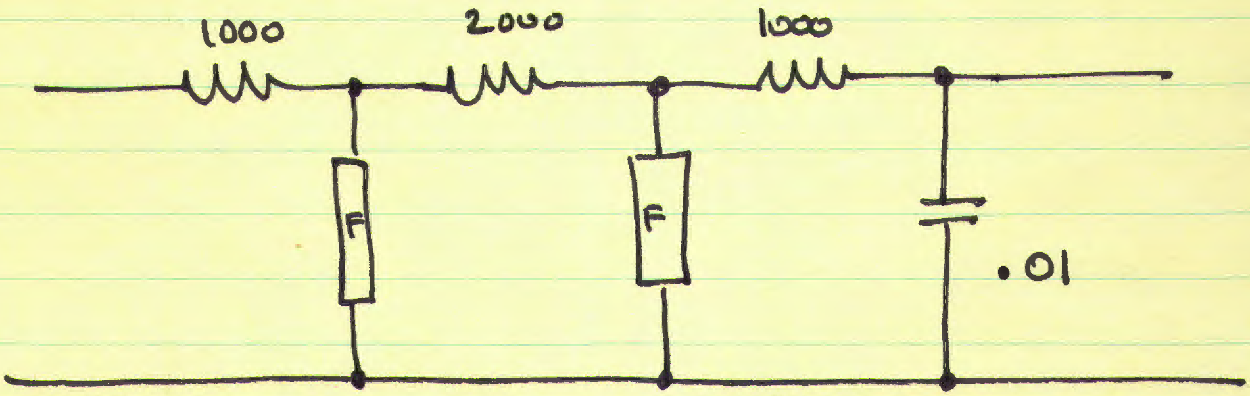
$$C_R = \boxed{RC^2}$$

let L = 2000 henrys.

then $\underline{R_0} = L\pi f_c = 2000\pi\ 15000 = 9.42 * 10^7$

$$C = \frac{1}{\pi f_c R_0} = \frac{1}{\pi * 15{,}000 * 9.42 * 10^7} = 2.25 * 10^{-13}$$

Eq. circuit



for (F)

let C = .1 or 10^{-7}

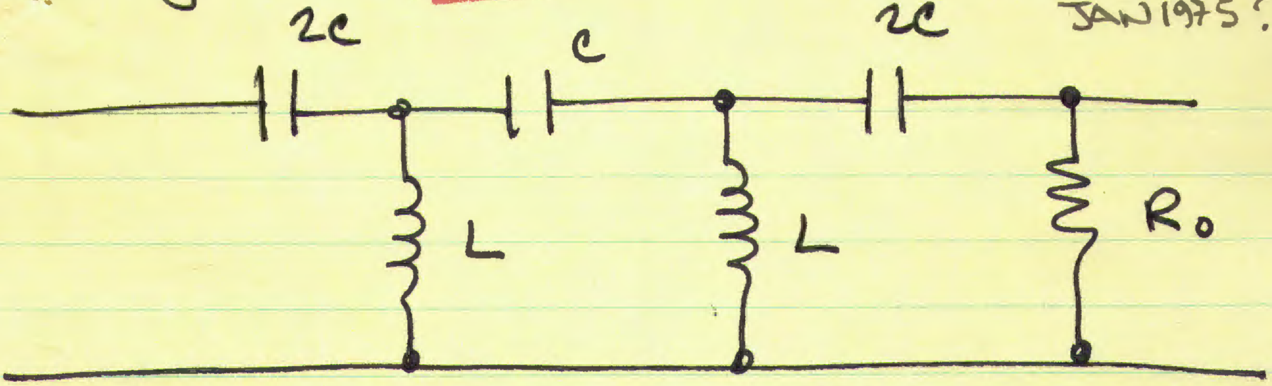
$$R = \frac{C_R}{C^2} = \frac{2.25 * 10^{-13}}{10^{-14}} = ~~2000~~\ \Omega \quad 22.5\ \Omega$$

let C = .01

$$R = \frac{C_R}{} = \frac{2.25 * 10^{-13}}{10^{-16}} = 2250\ \Omega$$

Try 50 cps ~~toss~~ High Pass (1)

JAN 1975?



where $C = \frac{1}{4\pi f_c R_o}$

and

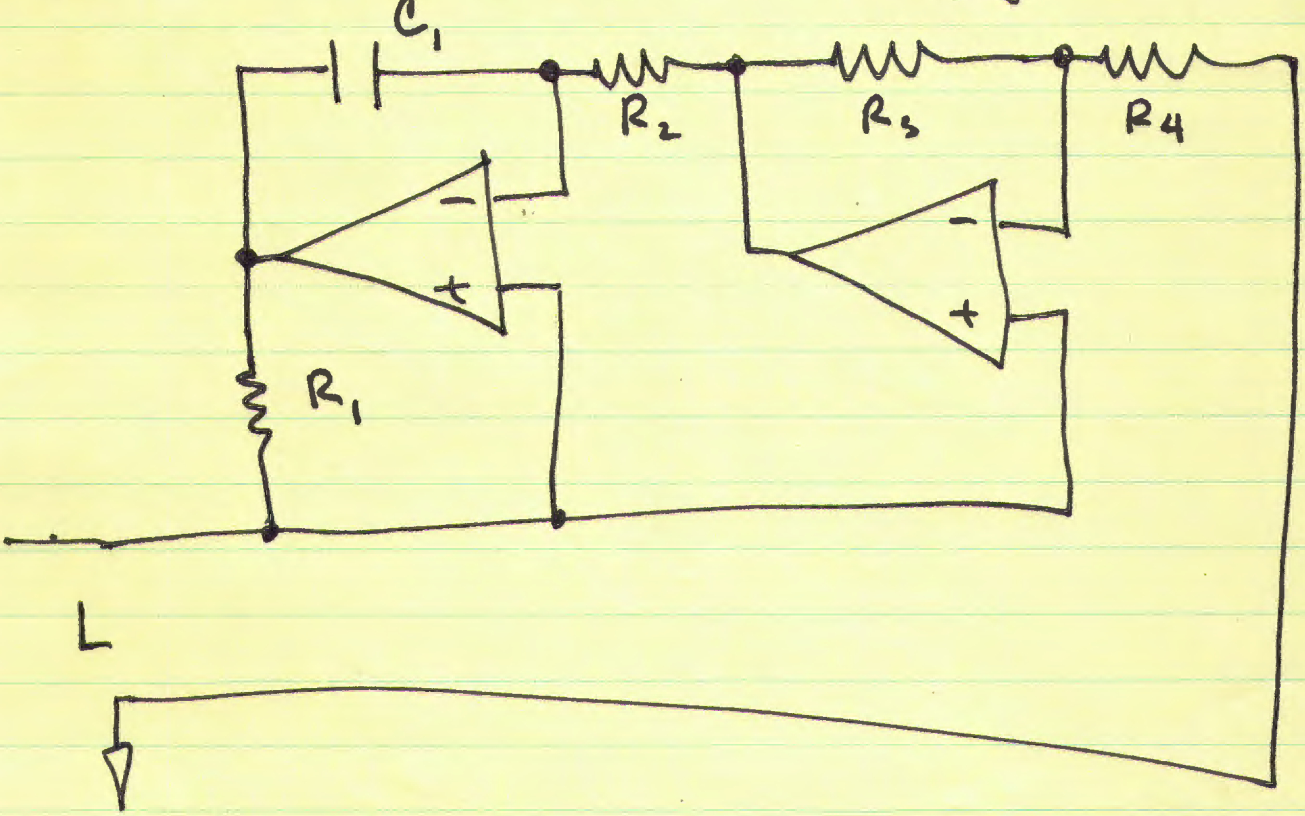
$$L = \frac{R_o}{4\pi f_c}$$

let $C = .1$ mfd $2C = .2$ mfd

$$R_o = \frac{1}{4\pi f_c C} = \frac{1}{4\pi * 50 * (10^{-7})} = \underline{15.9\text{K}}$$

$$L = \frac{15.9\text{K}}{4\pi * 50} = 25.3 \text{ henrys..}$$

for L use a gyrator circuit



where $L = \frac{R_1 * R2 * R4 * C1}{R_3}$

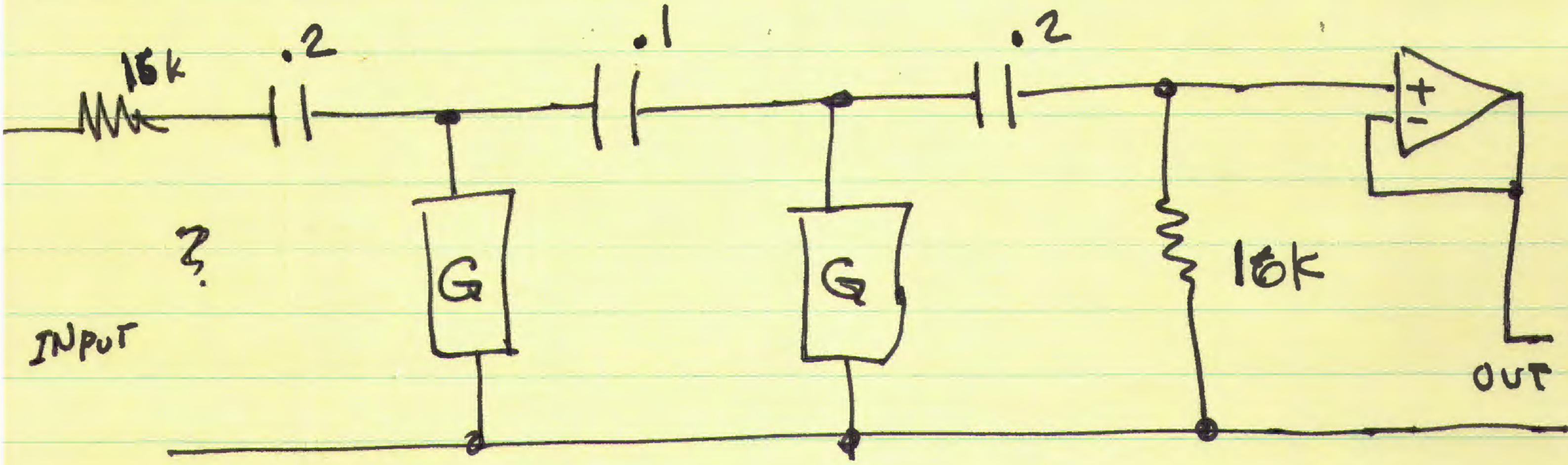
~~[illegible]~~ let $R_1 = R_2 = R_3 = R4$

then $L = R^2 C$

Let $C = .1$ mfd.

then $R = \sqrt{\frac{L}{C}} = \sqrt{\frac{25.3}{10^{-7}}} = \underline{15.9K}$

Try This circuit..



Works extremely well ... !!!

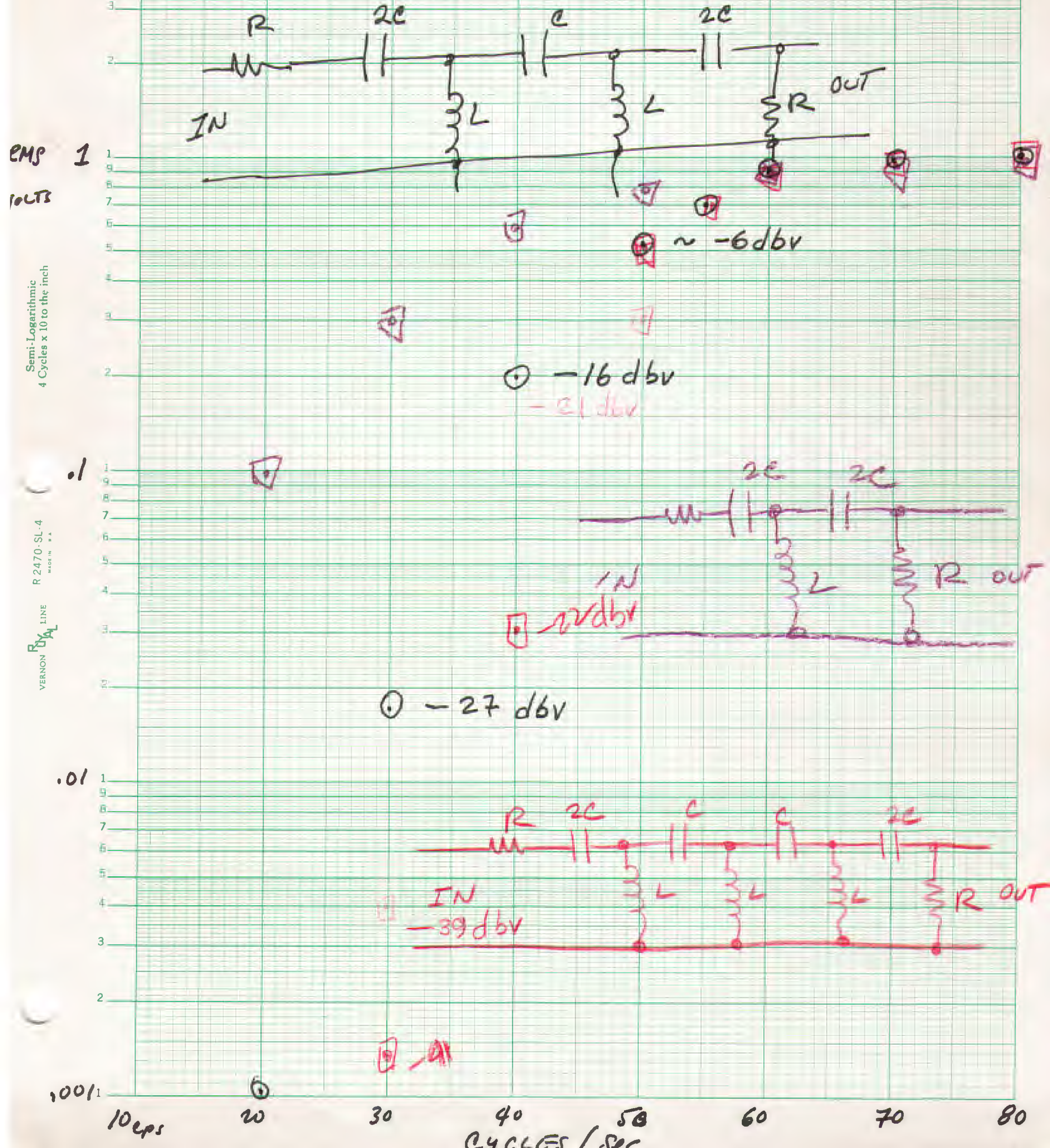
however - cutoff freq. is too high.
to original formulae.

make ~~&~~ L larger.. if R_o larger
~~C larger~~. R larger.

choose R = 18 k Ω ... try

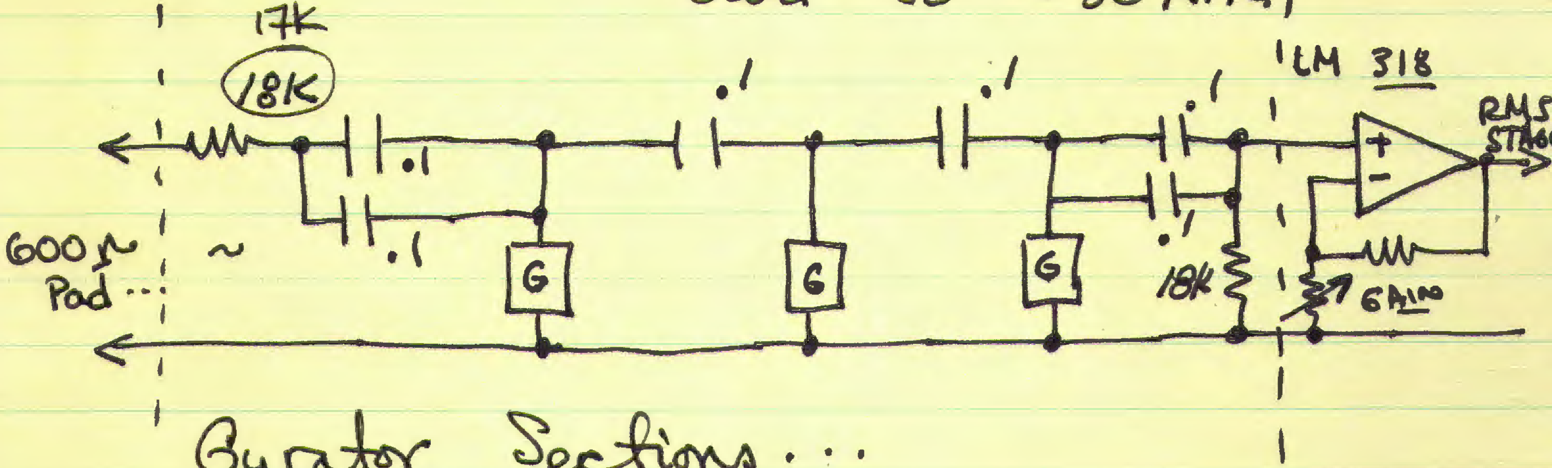
Notice the output high Z.
is ½ the voltage (-6db) of input..
Can be made up in follower.

Gyrator High pass filter

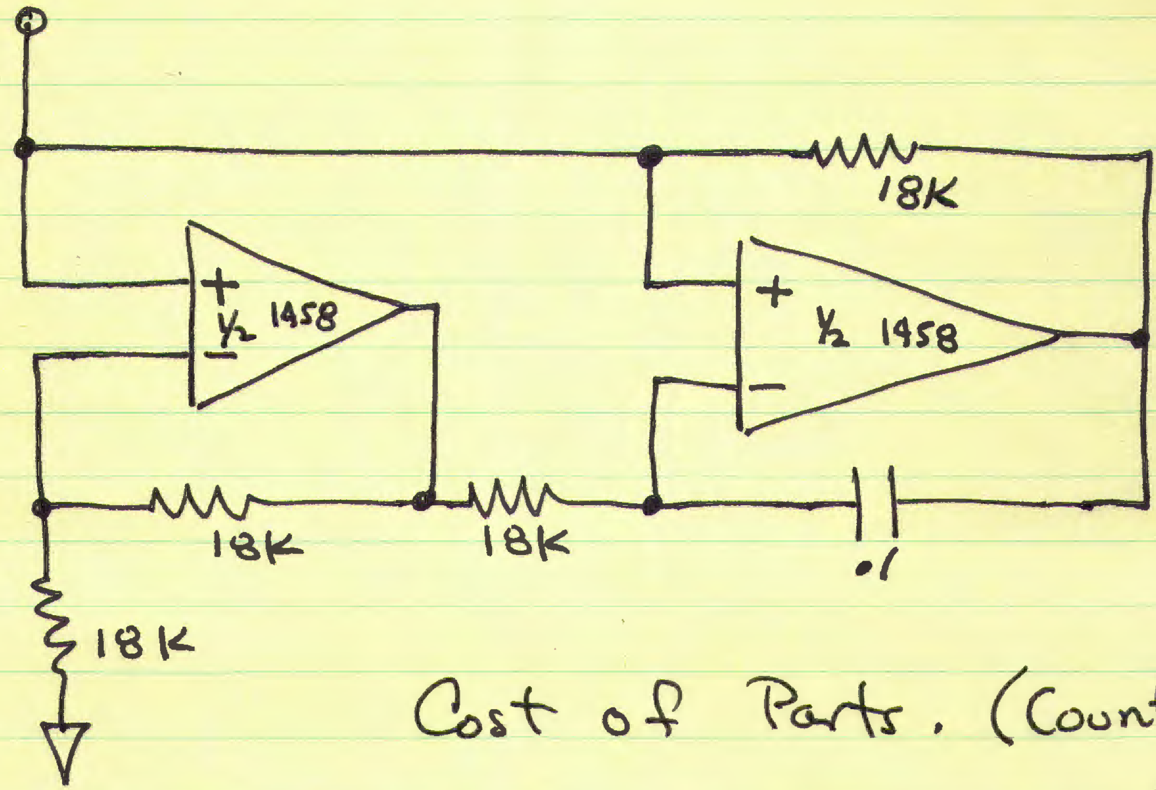


Suggest Circuit

Good to ~30 KHZ,



Gyrator Sections...

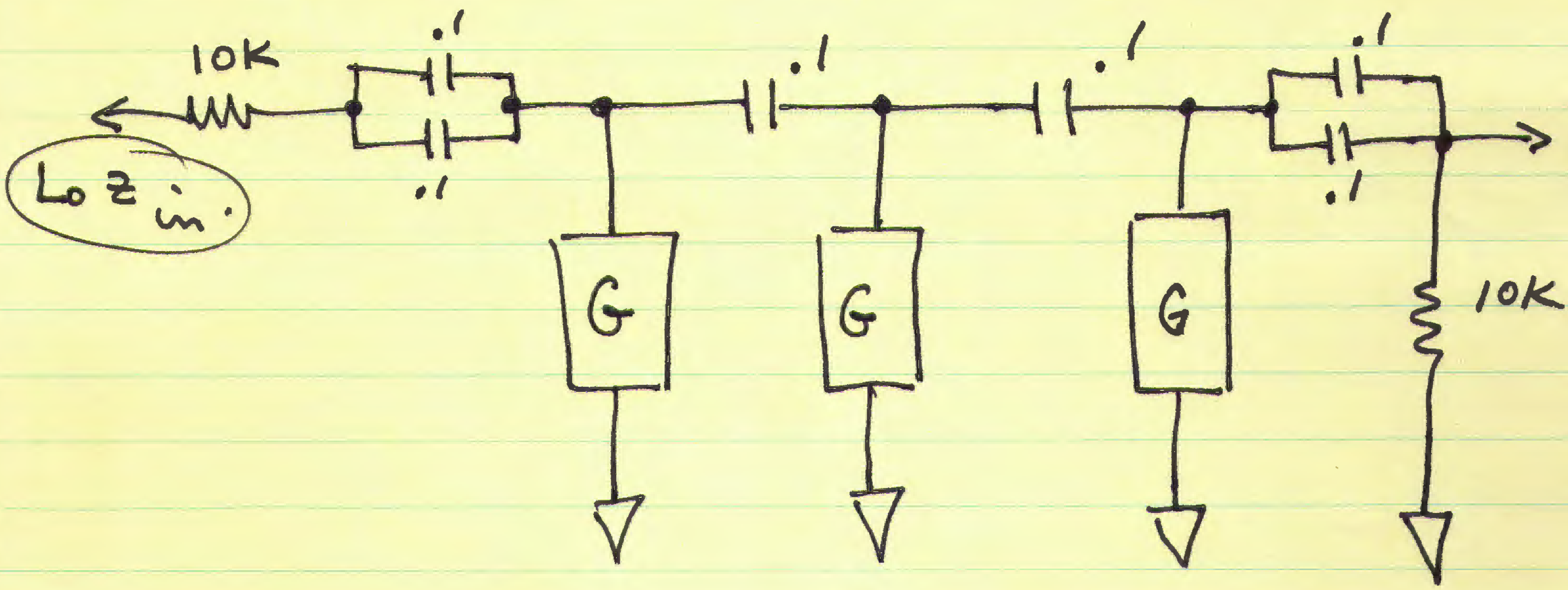


Cost of Parts. (Count)

14	—	18K Ω	~ .56
9	—	.1 mfd	~ 1.80
3	—	1458	~ 2.25
			4.61

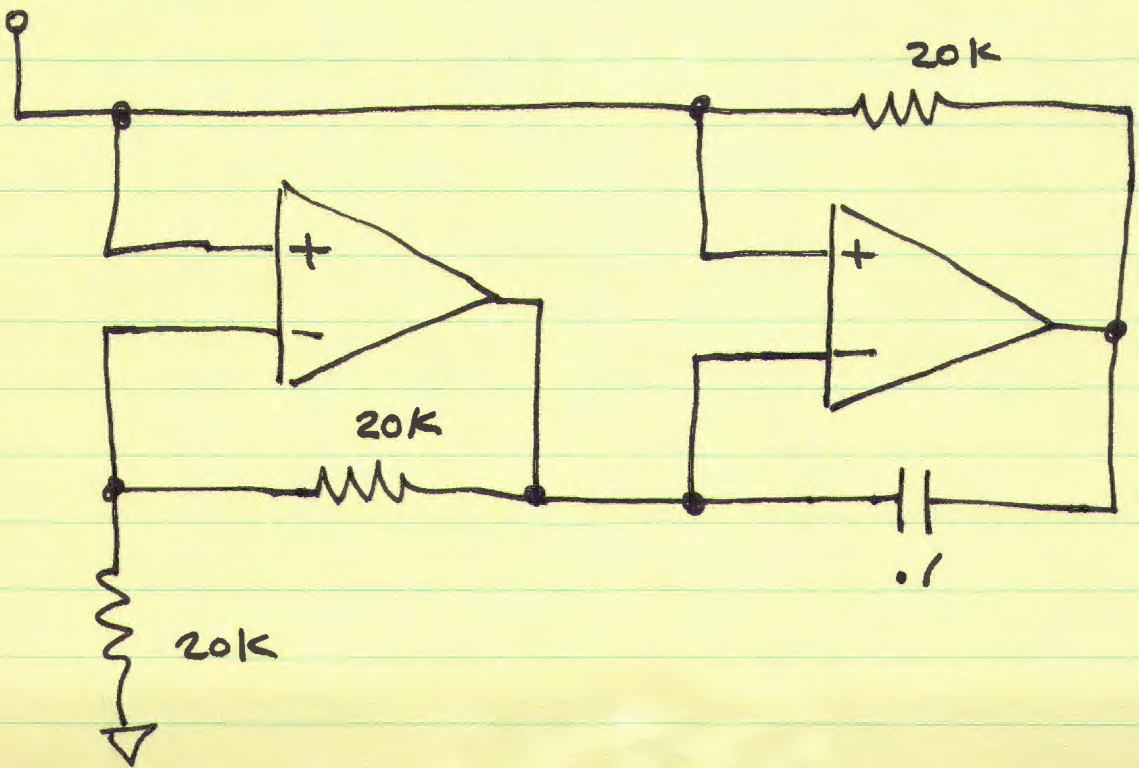
under = $5.00 =

High Pass filter.



Aprox. -7 db.. in pass band.

Gyrator..



Split frequency Band RMS compression was the norm in 1975
The initial design used this technique

Separating the 'Low" and 'High' frequencies in the processing chain, and combining later has several advantages (and disadvantages)

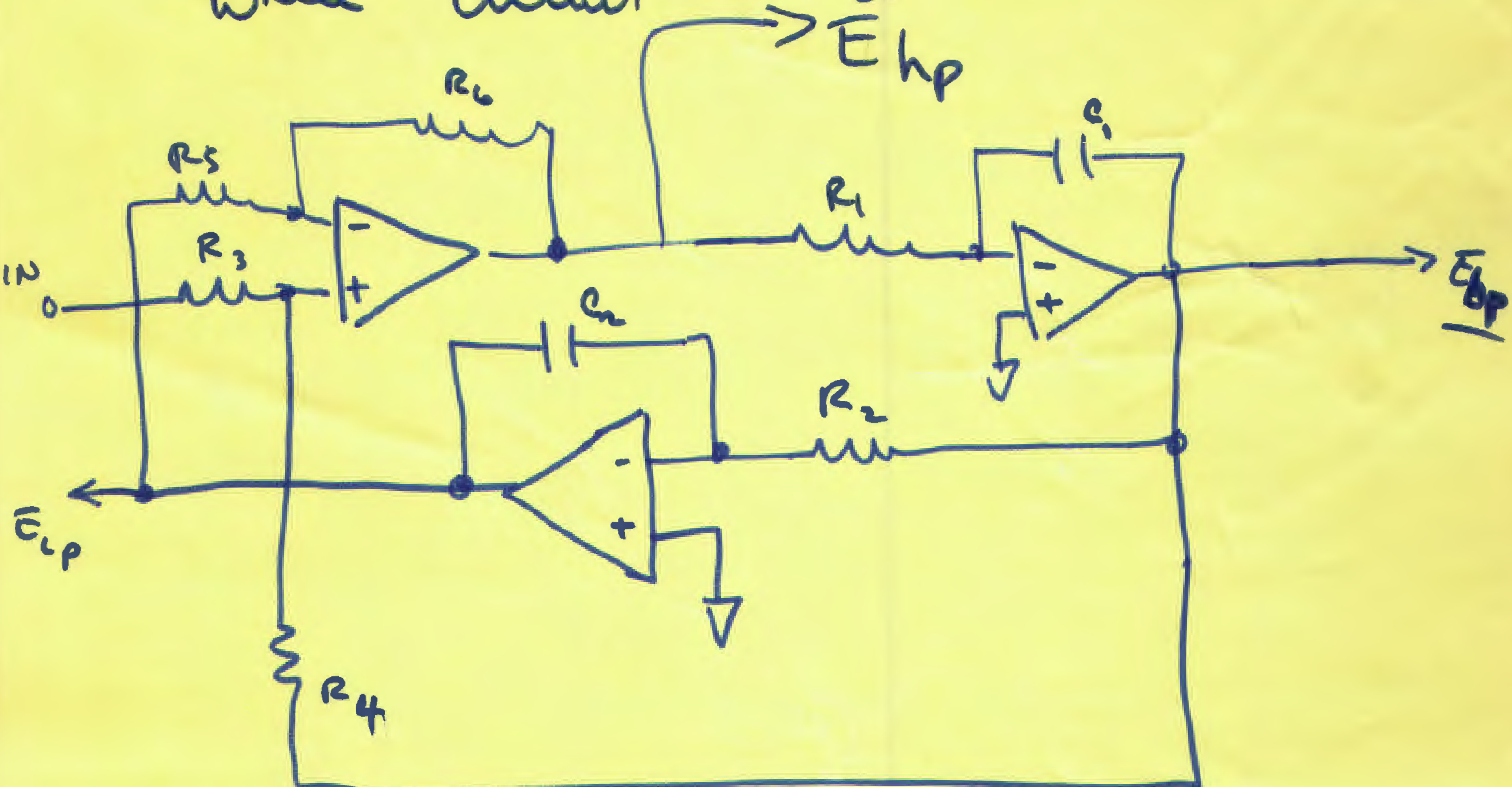
Consider two audio tones of similar amplitude, one at 100Hz the other at 1000Hz
The two tones sum, the 1000Hz tone appears to 'ride' on the 100Hz tone

The Level Detection would see the envelope, of the composite signal and compress more than desired... that is the amount of compression would depend on the frequency content... not desirable here...
Only necessary in the Limiter stages...

By splitting the Frequency Bands this characteristic can be somewhat improved
At the expense of adding coloring the summed audio

Band split for R.M.S. limiter
will ~~use~~ try state variable filter at
center freq. of 600 cps.

where circuit is



With formulae:

$$H_0 = \frac{R_4}{R_3}$$

$$\omega_0 = \left(\frac{R_6}{R_5 R_1 C_1 R_2 C_2} \right)^{1/2}$$

$$Q = \frac{1}{\alpha} \left(\frac{1 + R_4/R_3}{1 + R_6/R_5} \right) \left(\frac{R_6 R_1 C_1}{R_5 R_2 C_2} \right)^{1/2}$$

if we choose $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R$
and $C_1 = C_2 = C$

We have:

$H = 1$ — Gain of 1 ok

$\omega_0 = \left(\frac{1}{R^2C^2}\right)^{1/2} = \frac{1}{RC}$

$Q = 1$ ok

---

we would like a freq. of 600 cps.

or = $\omega_0 = 2\pi f = 3769.91$ rad/sec

trial for $R = 10k$

$C = \frac{1}{\omega_0 R} = \frac{1}{3.769 \times 10^3 * 10^4} = 2.65 * 10^{-8} = .0265$ mfd

ok choose $C = .022$ mfd. the R:

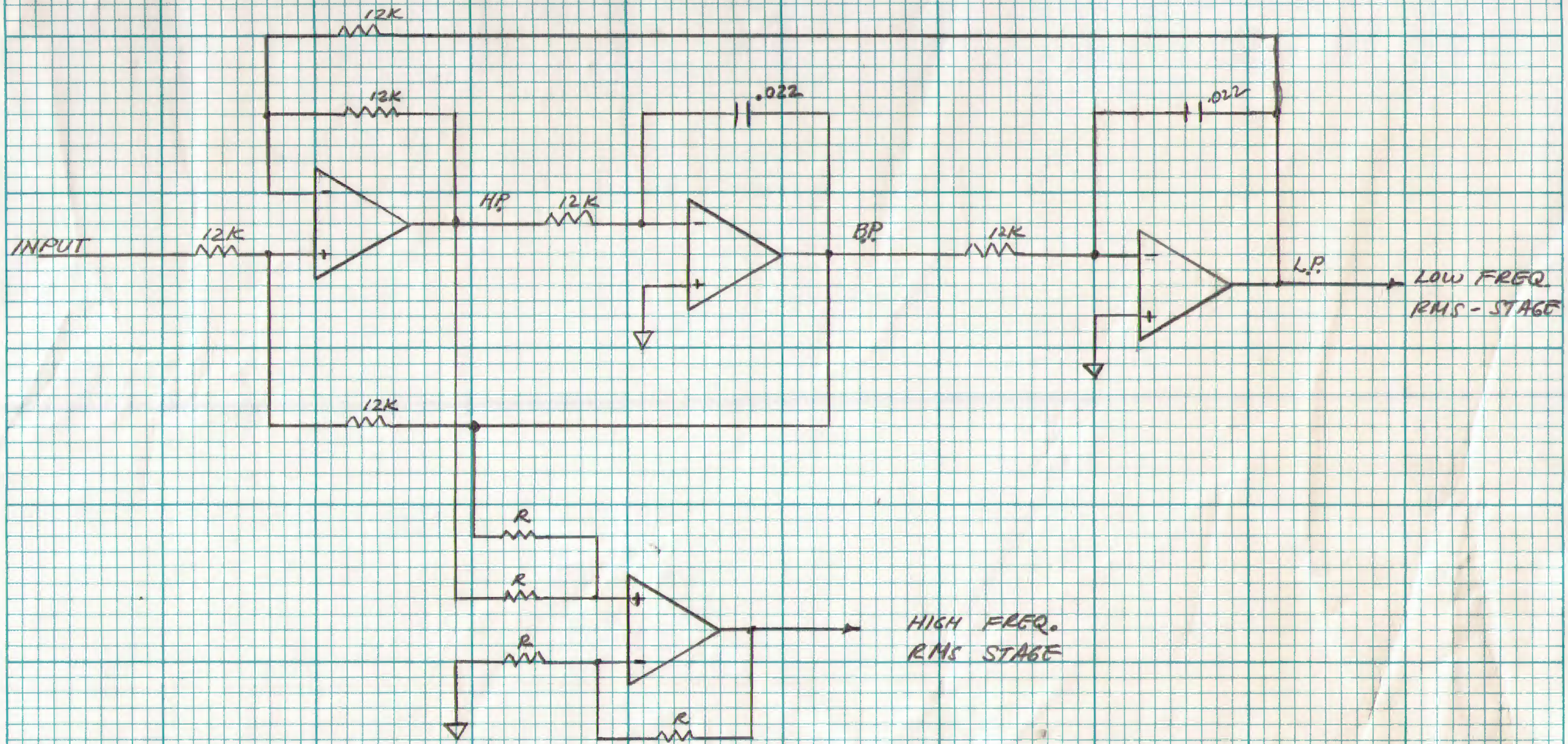
$R = \frac{1}{\omega_0 C} \approx 12K\,\Omega$

Works good.

must add - h.p. and b.p. function together. . . .

then when h.p. b.p. and l.p. are summed there is very little ripple over entire range.

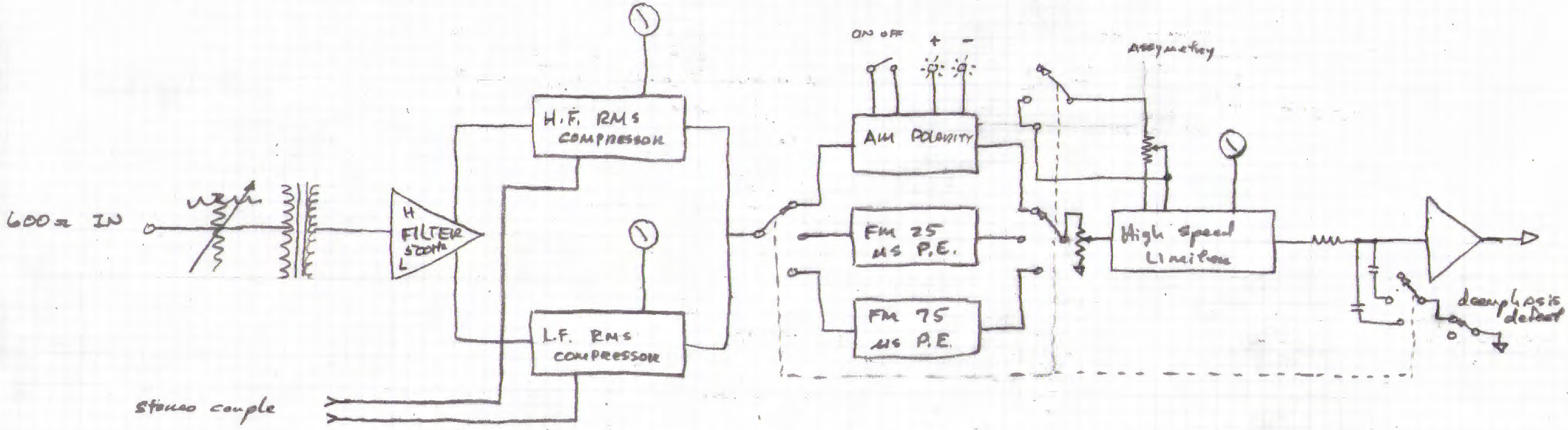
Some drop on high end probably mismatch in 10k - resistors.

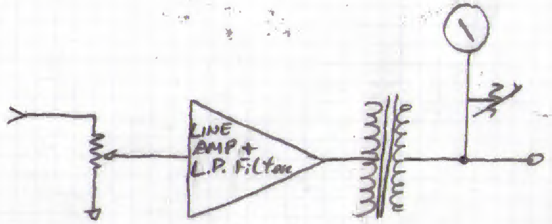


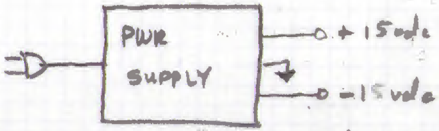
NOTE → OUTPUTS
MAY BE USED DIRECTLY TO
DRIVE RMS "BEANS"

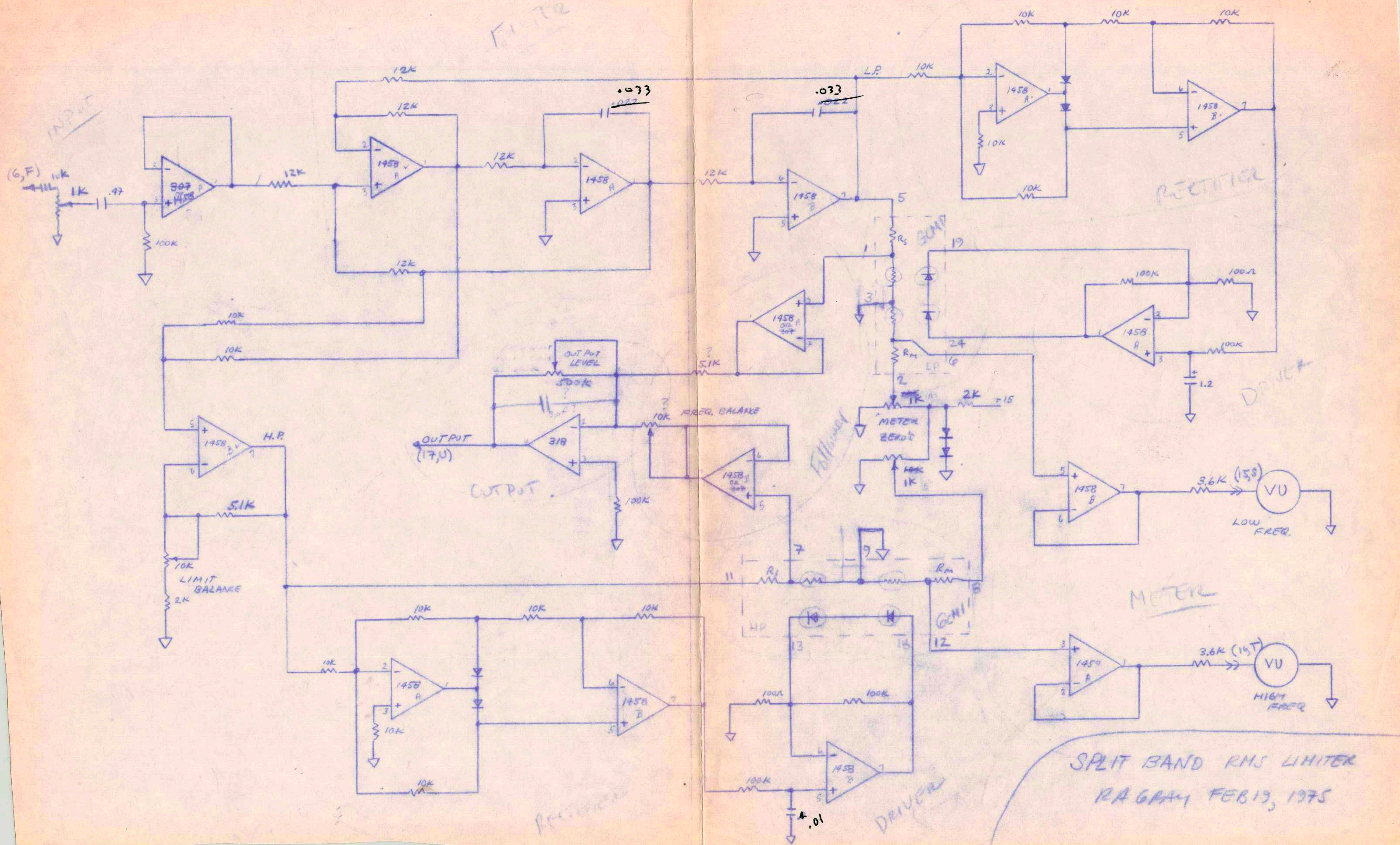
FREQ. SPLITTER FOR
SPLIT BAND RMS LIMITER.

RAG MAY FEB 17, '75


600Ω IN
H
FILTER
500Hz
L
H.F. RMS
COMPRESSOR
L.F. RMS
COMPRESSOR
stereo couple
ON OFF
+ −
AM POLARITY
FM 25
µs P.E.
FM 75
µs P.E.
Assymetry
High speed
Limiter
deemphasis
defeat


LINE
AMP +
L.P. Filter


PWR
SUPPLY
+15vdc
−15vdc



SPLIT BAND RMS LIMITER
RA GRAY FEB 19, 1975

Alignment procedures for
Split band -

1. Short input

2. Set both VU meters to zero - or 100%

3 connect sine ocs. to input set output
to 1 volt P-P

4 Set gain reduction pot to mid range

5 connect oscillizcope - (dual trace)
L.P. output of filter and and H.P.
output of fiter -

6 adjust freq for equal output
of both L.P. and H.P. channels

7. Adjust output of ocs.
till Low freq. VU meter reads
~ -7 db -

8. Adjust Limit balance till
till High freq. VU meter read the
same as Low freq. VU meter
(Balanced - gain reduction)

9. Adjust ocs to 100 cps
to read output of [illegible] -

10 Adjust ocs to 10,000 cps.
set freq balance till for same
output as in step 10.

11. adjust output pot to desired -
level -

The apparent Loudness of the Broadcasted signal is the Peak-to-Average amplitude
The trick is to reduce the amplitude of the peaks, without significantly changing the character
Or adding discernible distortion

The RMS Compressor reduces the Dynamic Range of the inputted signal
So more aggressive techniques may be used to reduce the peak-to-average amplitude

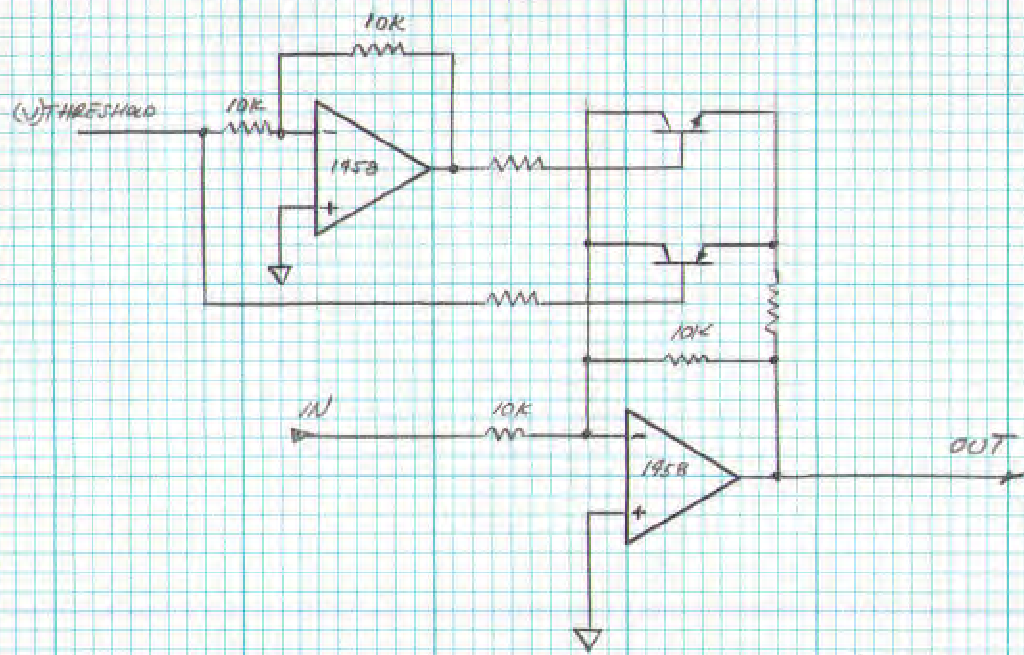
The next step is to take off the peaks... fast by gently ("Contoured Clipping")

I preferred a logarithmic Feed-Forward limiter... easy to implement
Jack preferred the FET Gain Reduction stage, similar to the UREI approach
The latter allow for more control, of attack and release times...

Finding suitable FET's was not easy...
We needed a fairly wide dynamic control range
Without introducing significant distortion, of the overall signal

The approach I proposed for a 'Fast' control element

Never explored!!!



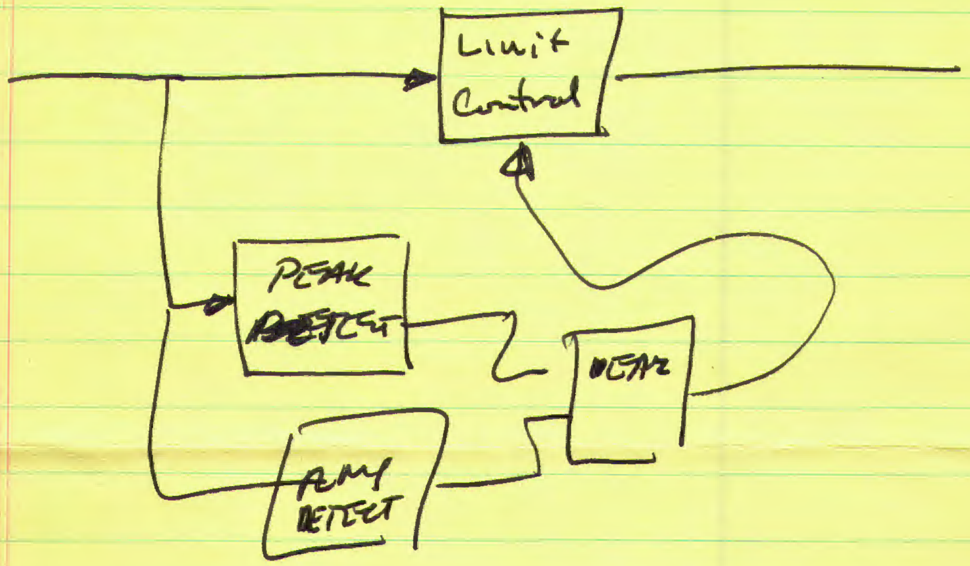
SYMETRICAL LOG CLIPPER

FEB 6, 1975

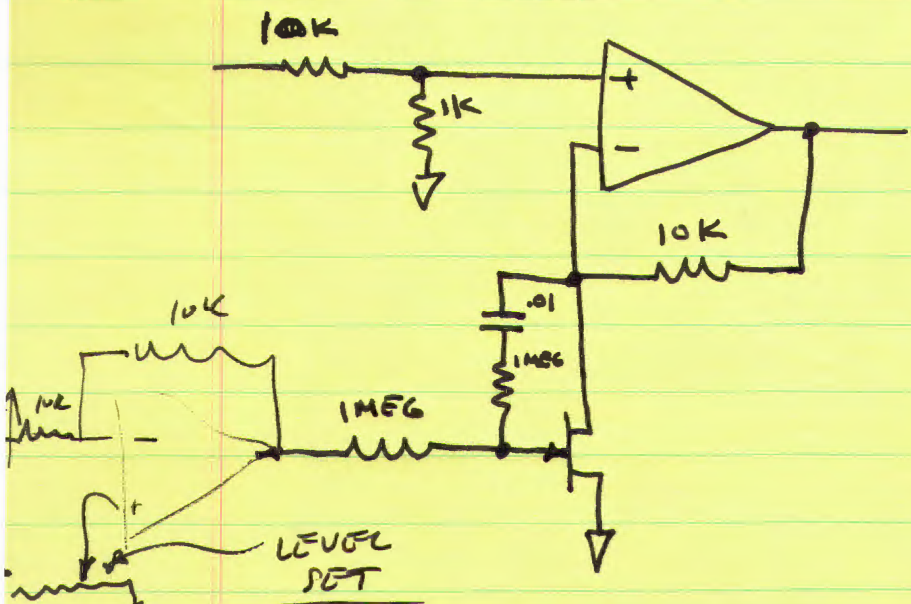
High speed limiter.

Need a limiter - ~~that~~ can "ride the gain" over a small range - and also do peak limiting.

Suggest

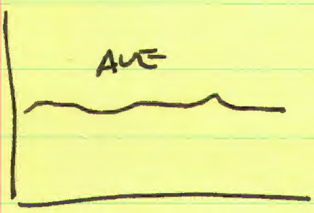


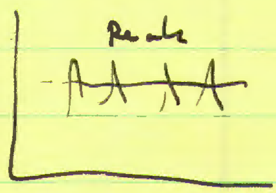
Schematic - limit control



Using a simple average controller - ie full wave rect. and filtering - tracking is hard to achieve ... however level set does work satisfactorily

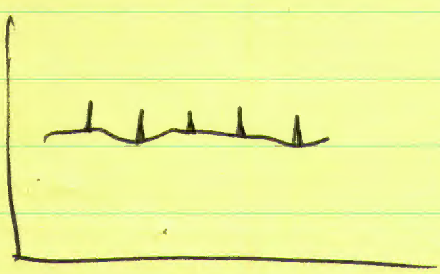
try - peak detector.
and average detector such that input looks like -

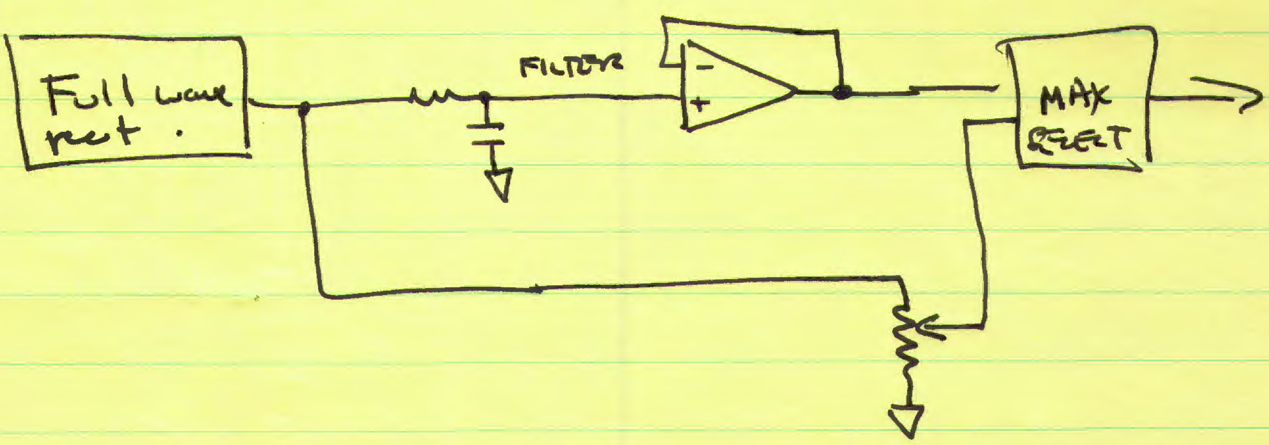




1

thus feed to control.





Circuit seems to work ok —

Problem seems to be
non-linear ~~FET~~ gate.
— also need to work on
ave. attack timing. —
and peak theshold and
loop gain —

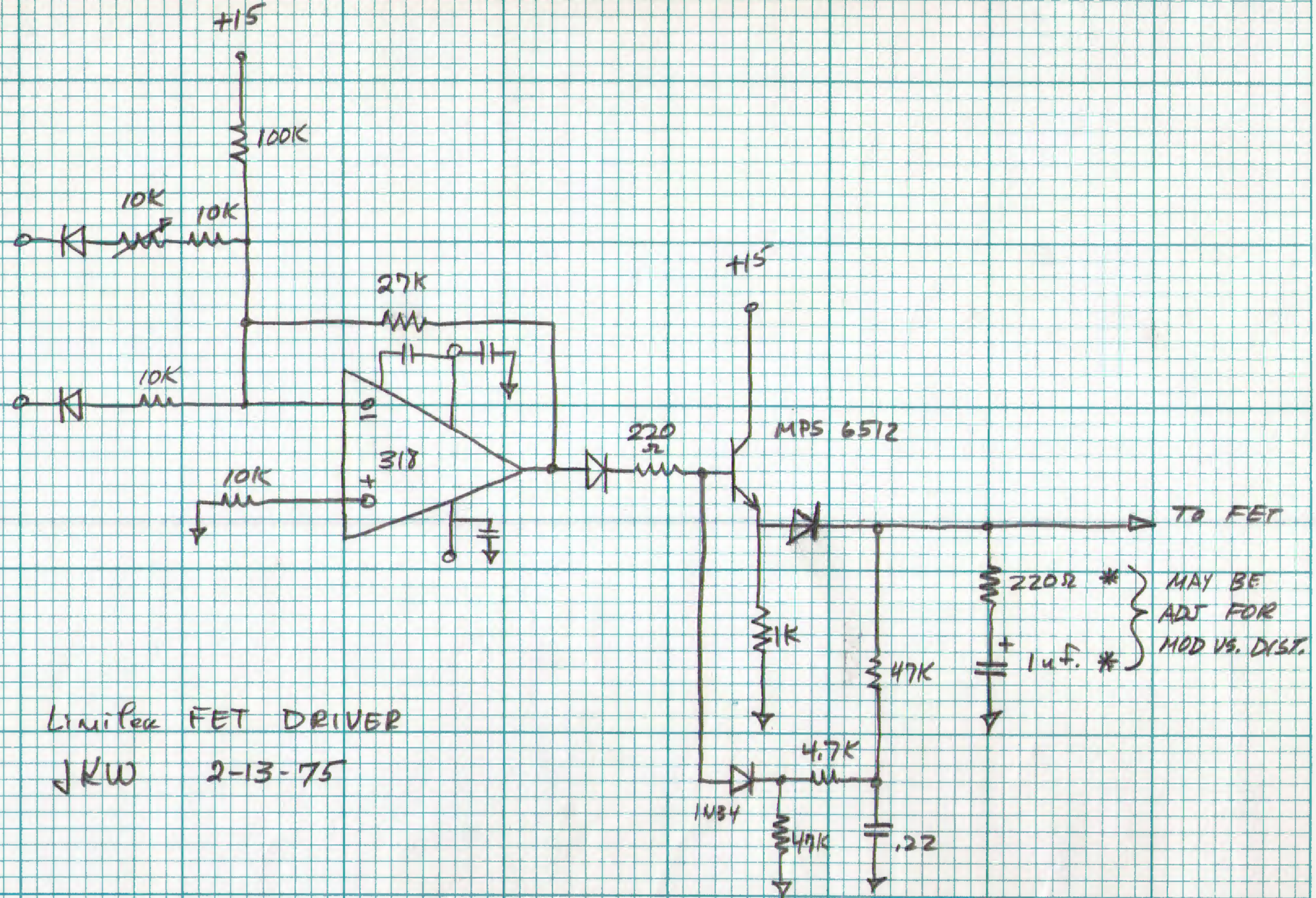
As the feedback resistor
increases

Several circuit were tried — one using feed back proved to be most interesting

Gain — exp. and comp. were excellent. however peak limiting were very hard to achieve..

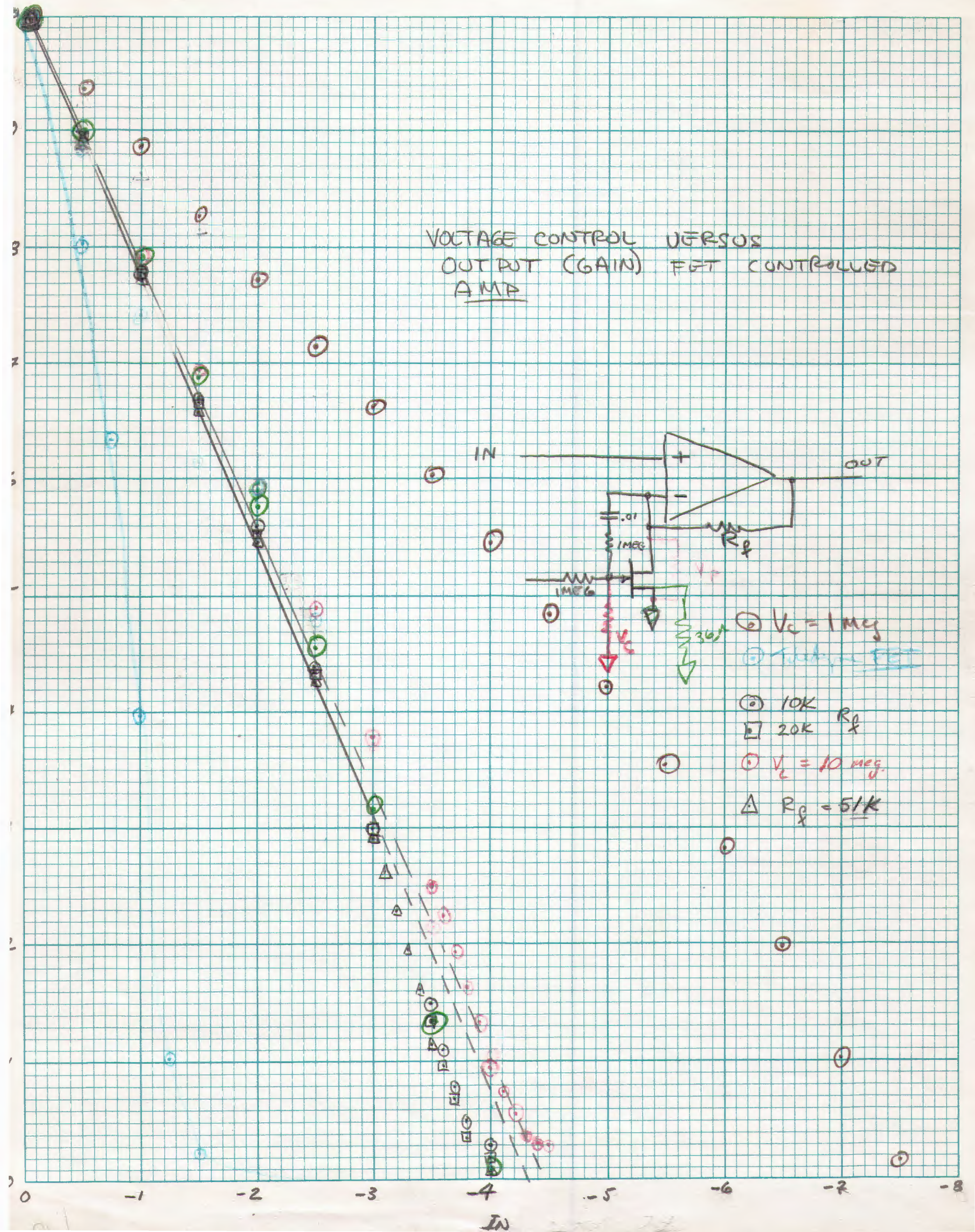
Jack W. came up with a new circuit which may eclipse further development.

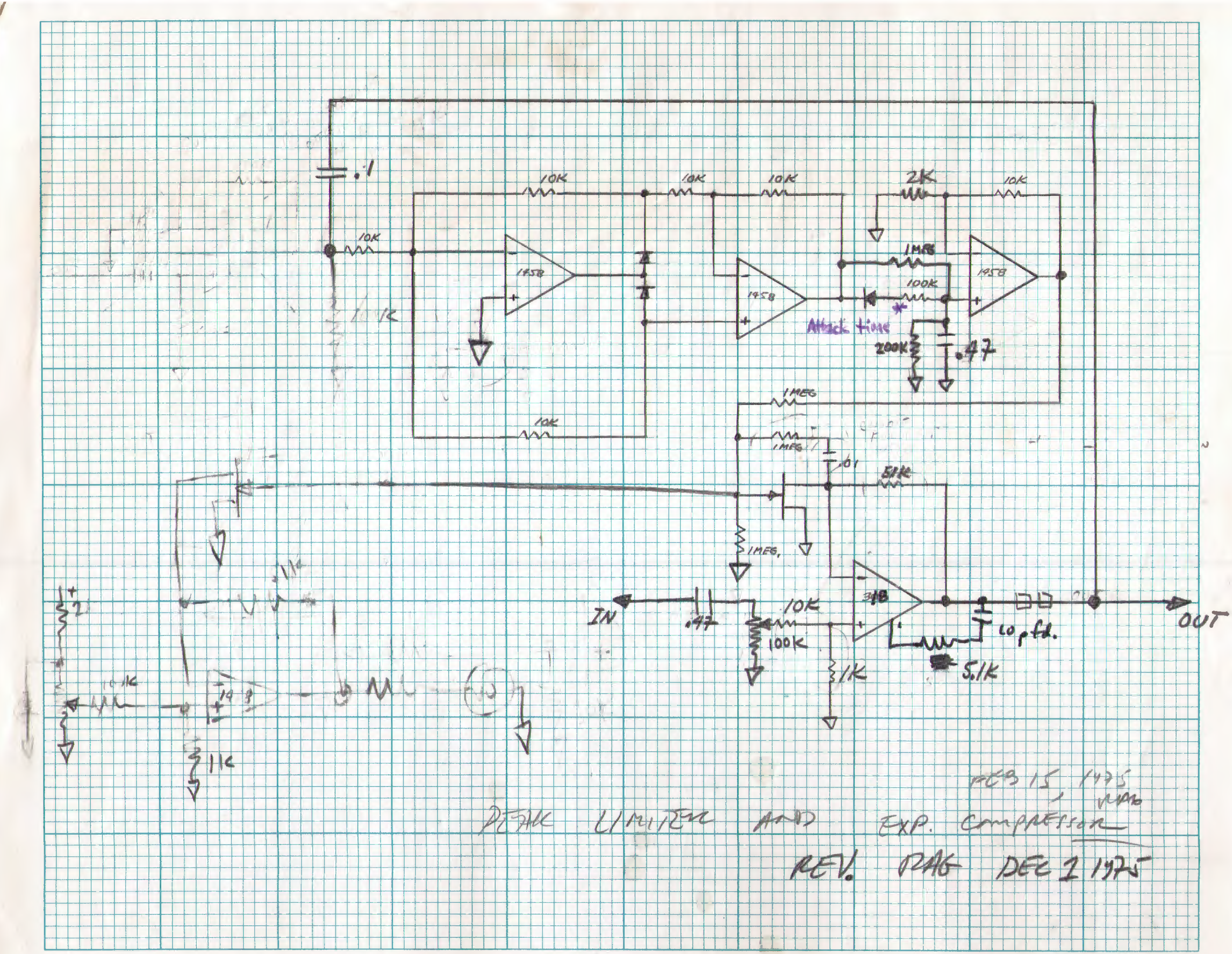
Will go with Jacks circuit & only Resistor in network changed to biasing 3 diode (1N914 drops)



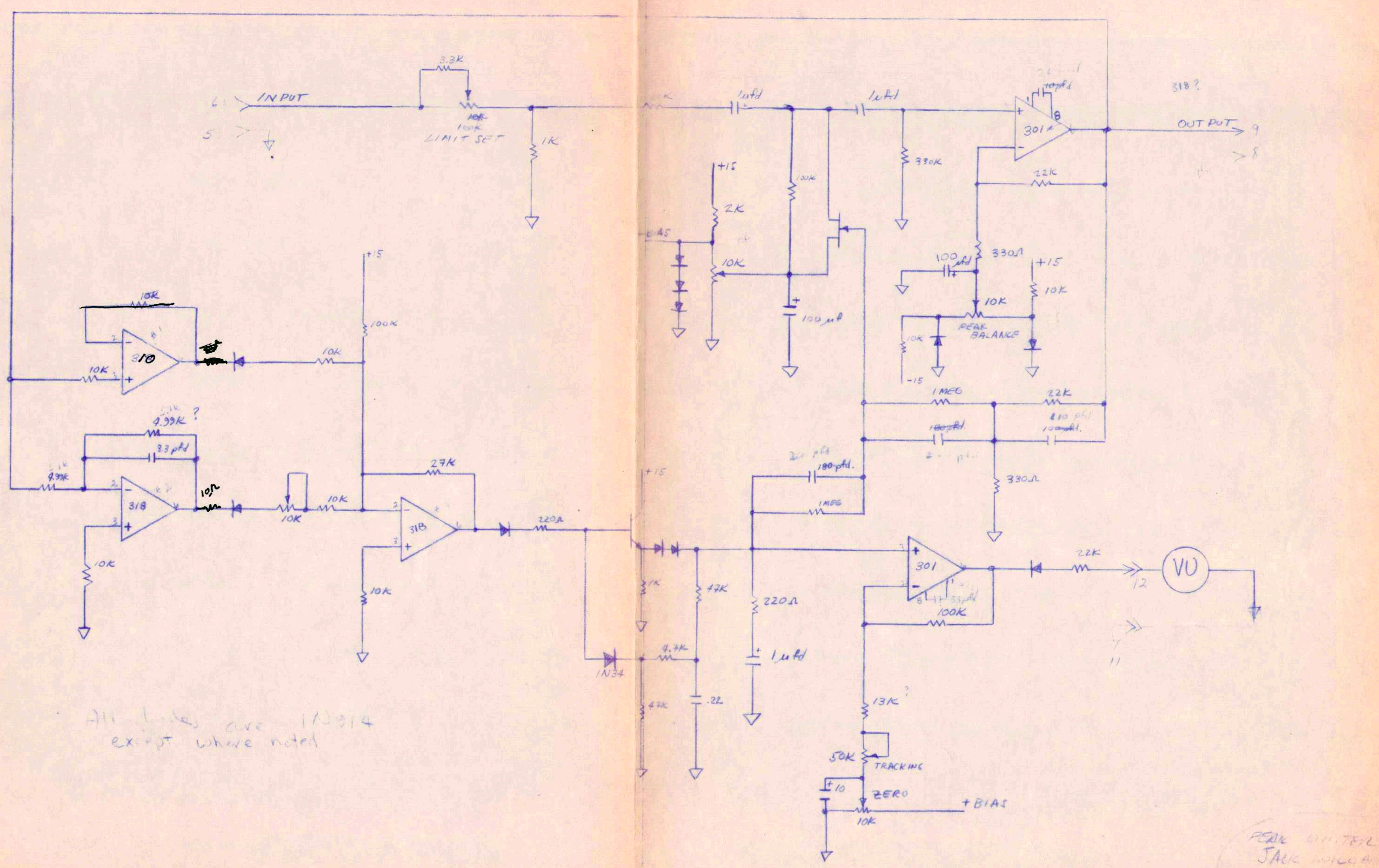
Limiter FET DRIVER

JKW 2-13-75


VOLTAGE CONTROL VERSUS
OUTPUT (GAIN) FET CONTROLLED
AMP
IN
OUT
.01
1MEG
R_f
1MEG
V_c
V_c = 1 Meg
10K
20K
R_f
V_c = 10 meg.
R_f = 51K
0
-1
-2
-3
-4
-5
-6
-7
-8
IN



.1
10K
10K
10K
10K
2K
10K
1458
1458
1458
1MEG
100K
Attack time
200K
.47
1MEG
10K
1MEG
1MEG
.01
51K
1MEG.
IN
.47
10K
100K
1K
318
10 pfd.
5.1K
OUT
1K
FEB 15, 1975
PEAK LIMITER AND EXP. COMPRESSOR
REV. RAG DEC 1 1975


INPUT
3.3K
LIMIT SET
1K
1ufd
330K
301A
OUTPUT
22K
+15
2K
100K
10K
100 ufd
330Ω
PEAK BALANCE
-15
318
10K
100K
9.99K
33 pfd
27K
1MEG
180 pfd.
220Ω
1N34
4.7K
47K
.22
1 ufd
301
VU
13K
50K
TRACKING
ZERO
+BIAS
All diodes are 1N914
except where noted

TYPE	REVISION	CODES	GEOMETRY	CASE
FD1780	Ø	DFN	DFN 2.5	TO-71

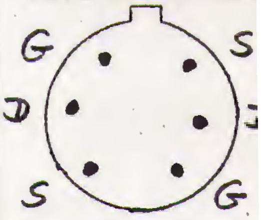
UNIT MARKING: FD1780

PACKAGE MARKING: FD1780

CUSTOMER: Pacific Recorders

CUSTOMER DWG/SPEC NO. ______ REV. ______

BOTTOM LEAD CONFIGURATION



SPECIAL INSTRUCTIONS:

Finding suitable FET's was not easy!!!

STATUS

SEQUENCE	TEST SYMBOL	TEST TYPE	TEST CONDITIONS	PROD. LIMITS MIN.	PROD. LIMITS MAX.	PROD. LIMITS UNIT	CUST. LIMITS MIN.	CUST. LIMITS MAX.	CUST. LIMITS UNIT
1	I_{GSS}	PC	$V_{SG}=15V$, $V_{DS}=0$		500	pA		1	nA
2	BV_{GSS}	PC	$I_G=1\mu A$, $V_{DS}=0$	26		V	25		V
3	I_{DSS}	PC	$V_{DS}=10V$, $V_{GS}=0$	4.5	14	mA	4.0	15	mA
4	V_P	PC	$V_{DS}=10V$, $I_D=1\mu A$		5.8	V		6.0	V
5	R_{DS_1}	P	$V_{GS}=-1.5V$, $I_D=100\mu A$		1.9	KΩ		2.0	KΩ
6	R_{DS_2}	P	$V_{GS}=-1.0V$, $I_D=1mA$	310		Ω	300		Ω
7	$/R_{DS_2}$	P	" " " "	.82	1.0		.80	1.0	
8	C_{iss}	Q	$V_{DS}=15V$, $V_{GS}=0$, $f=1MHz$					8	pf

BASIC: 23 Mar 76

PREPARED BY: D Adkins

APPROVED BY: PROD. EVAL. SA

PROD. CONT. SA

Q.A.

REL.

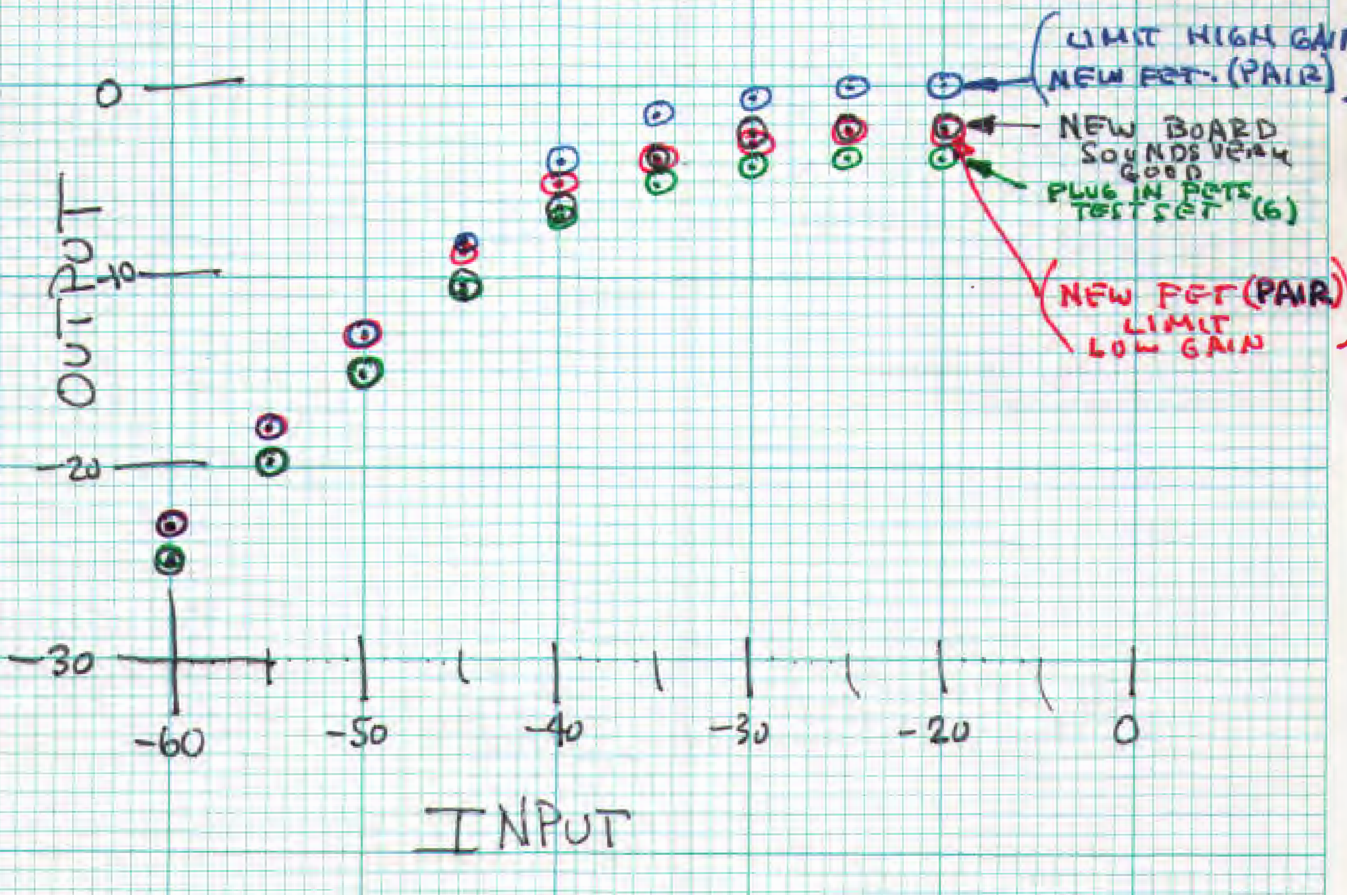
COMPUTER

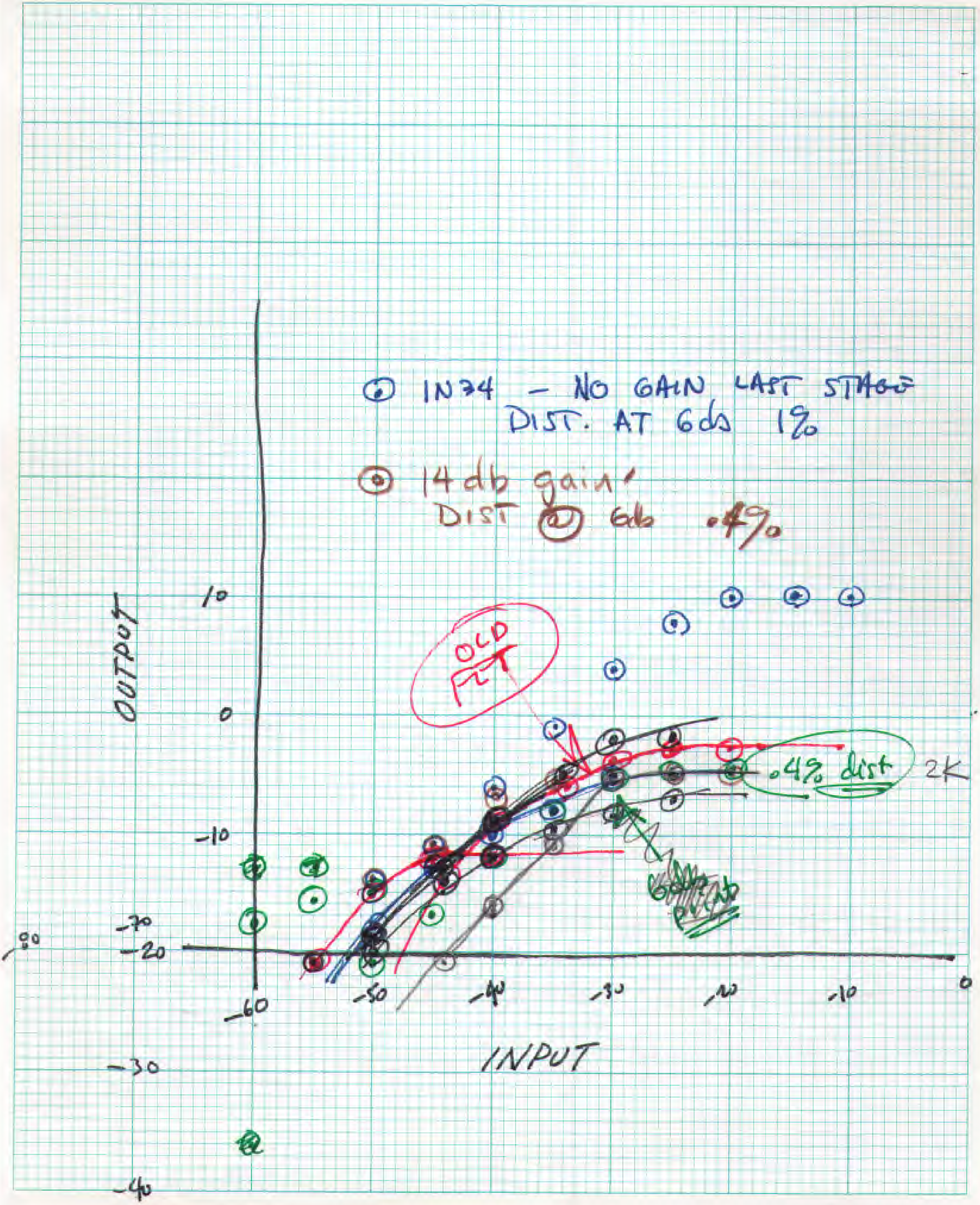
REVISION

PAGE ___ of ___

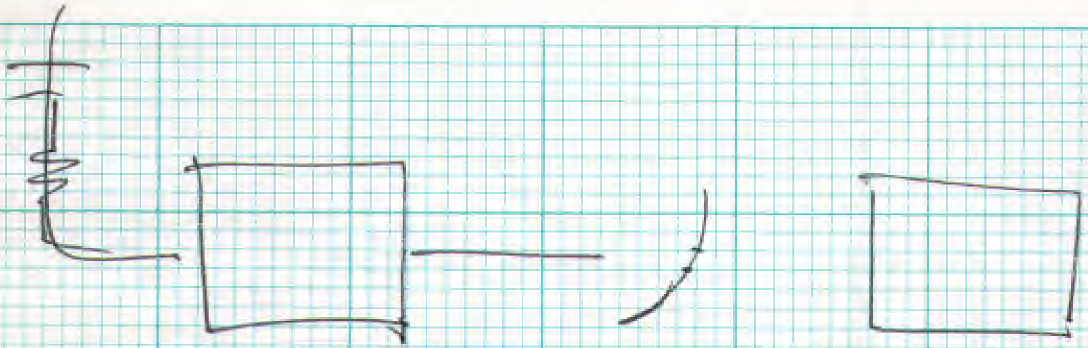
3/15/76

SOLITRON DEVICES.





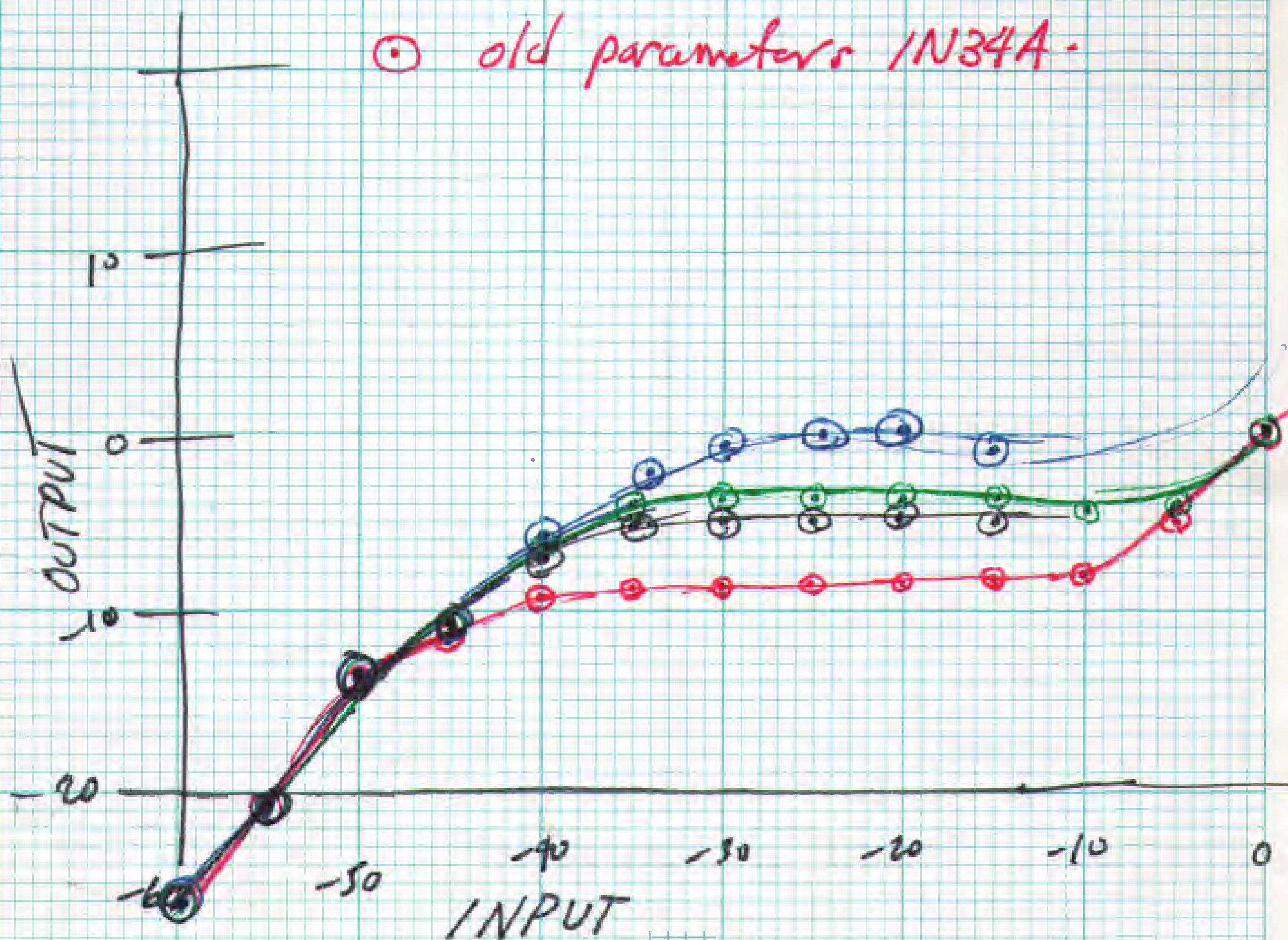
IN34 – NO GAIN LAST STAGE
DIST. AT 6db 1%
14 db gain
DIST @ 6db .4%
OLD PLT
.4% dist
2K
OUTPUT
INPUT
10
0
-10
-20
-30
-40
-60
-50
-40
-30
-20
-10
0

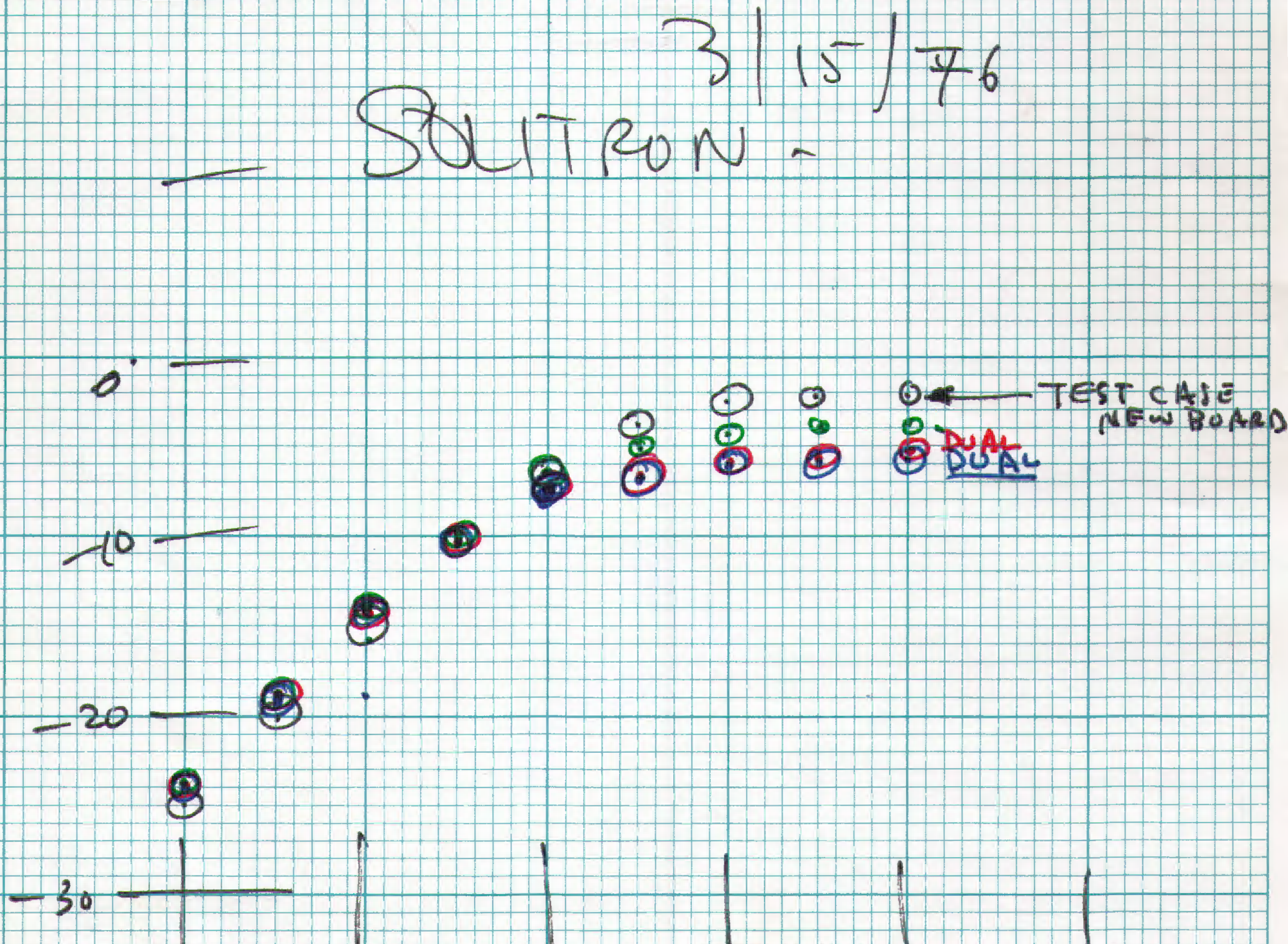


6 -

~~10db~~ 6 ..

FAST LIMITER



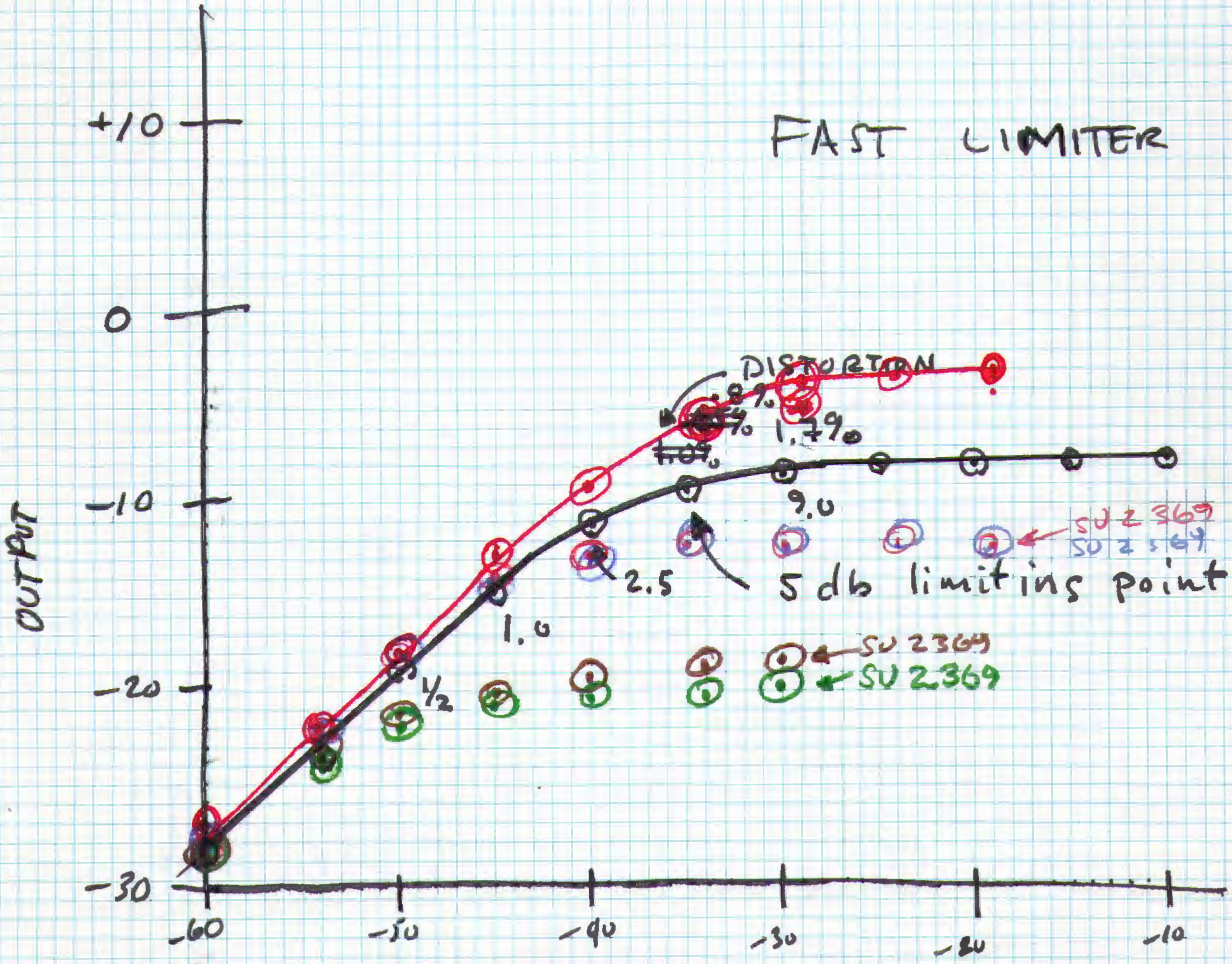


3/15/76
SOLITRON
0
-10
-20
-30
-60
-50
-40
-30
-20
-10
TEST CASE
NEW BOARD
DUAL
DUAL

INFORMATION SETUP 2/29/76..

GAIN FAST LIMITER *10 or 20db.. 2N4303
For 6db RMS is 5db Fast. limiting
Clipping level for 5db Fast
+6db

All Tests 1KHZ



FM TOTAL GAIN 50db S/N Full gain · input -30
66db.

AM Broadcast, Signal Processing

The signal chain in audio broadcasting is "Capacitor", or "Transformer" Coupled
The D.C. component is not present (Unlike NTSC Video Modulators)

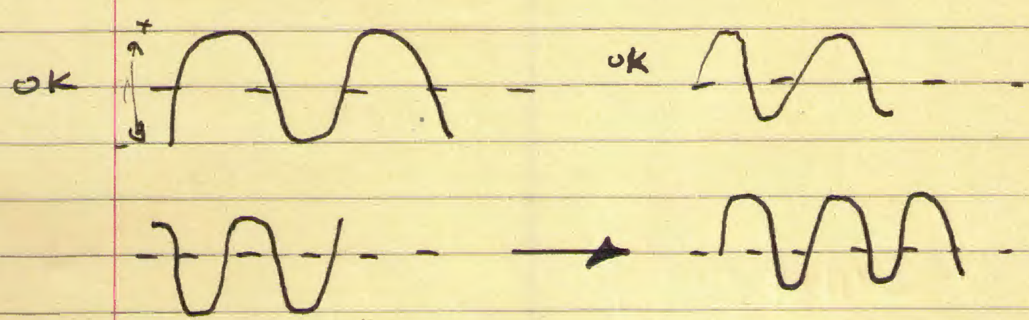
The AC signal has it zero reference the Average signal value
However complex audio signals are often asymmetrical, that is the
peaks on one side are greater than the other...
This characteristic is often associated with a particular musical instrument of Persons Voice

AM broadcasting has the general Modulation equation of Carrier-Modulation (Both AC Signals)
It is not Possible to have Negative Peaks... Broadcasted signal would clip,
causing severe (and illegal) 'splatter', spurious signals
However the positive peaks are allowed to be 125% of the carrier signal

So it is desirable to match the Audio Signal positive peak Asymmetry as Positive Modulation
So an Automatic Polarity Switch is employed...
To avoid a discernible artifact, switching takes place during a lull in the programming material

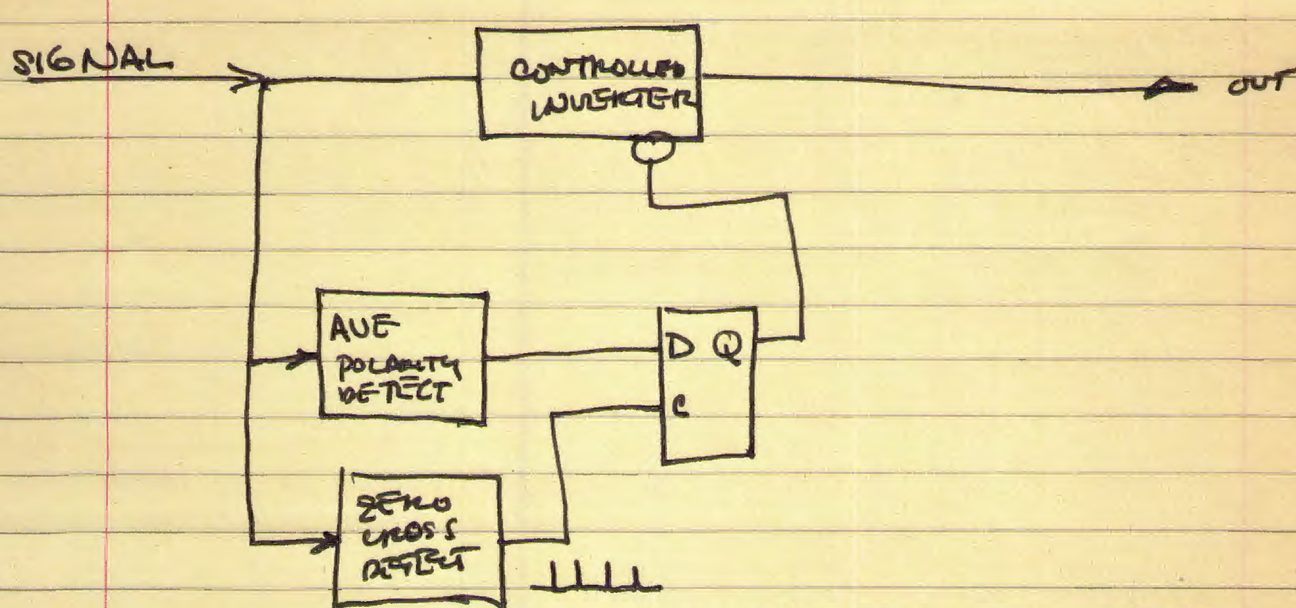
The final step, somewhere downstream, is the Clip the result...
to assure compliance, even if the the phase is wrong!

Problem: provide automatic polarity switching of signal to provide asymetrical swing with high peak positive ...

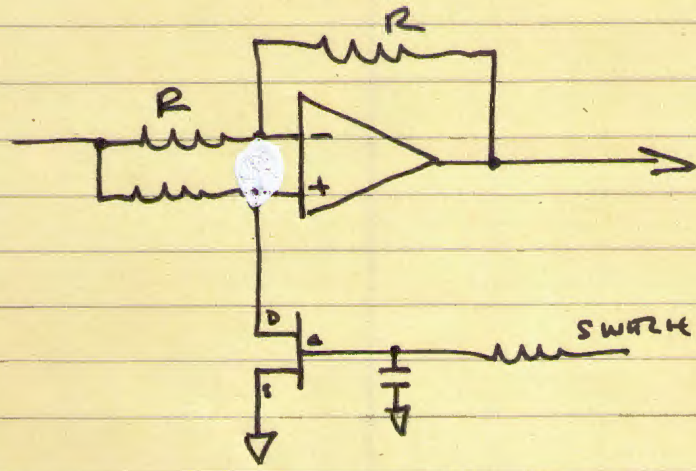


Notice this is not a level shift, but a polarity reversal!

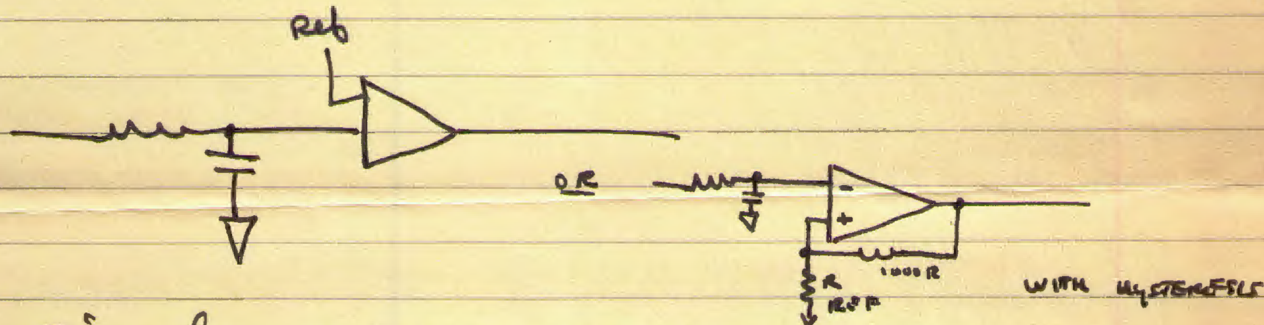
Reversal must be accomplished on a zero crossing



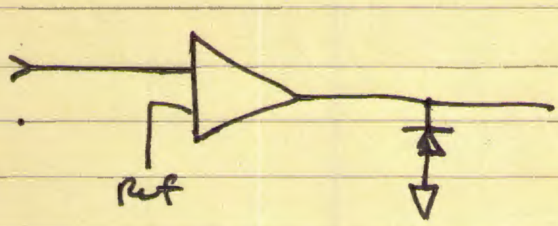
Simple realization of controlled inverter -

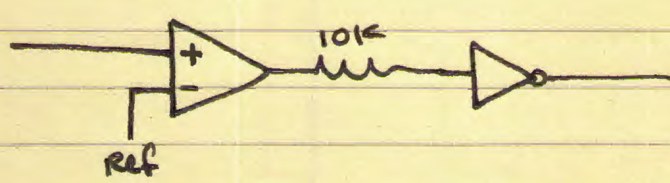


simple polarity anilyzer

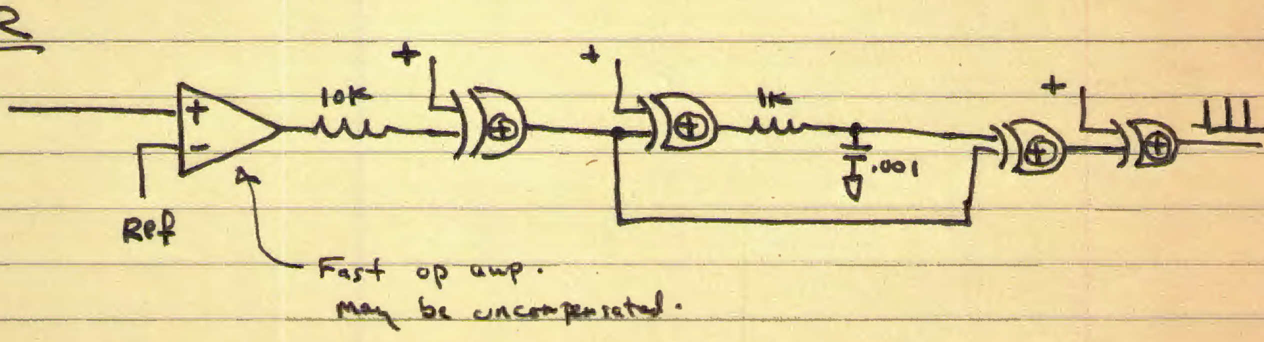


simple zero cross

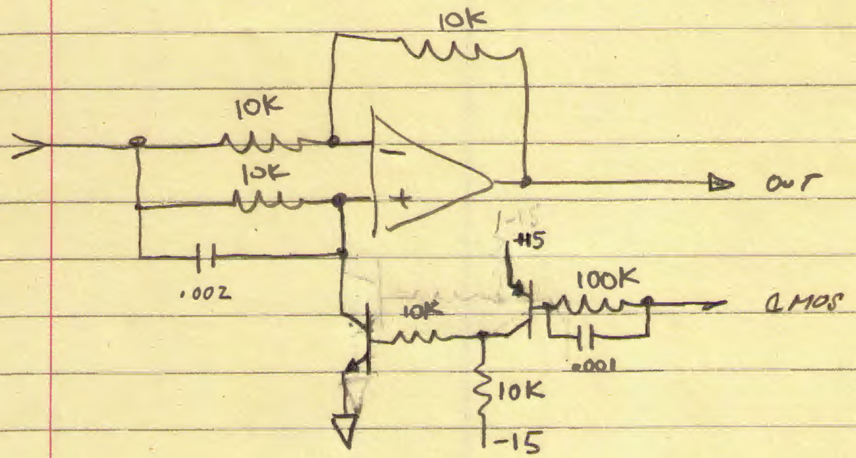




OR



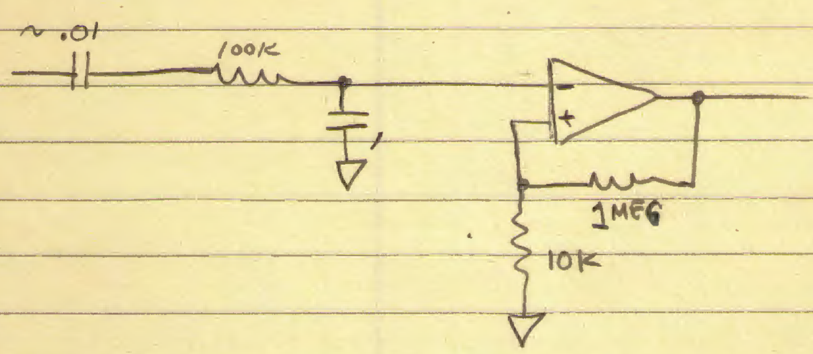
Redo of inverting amp



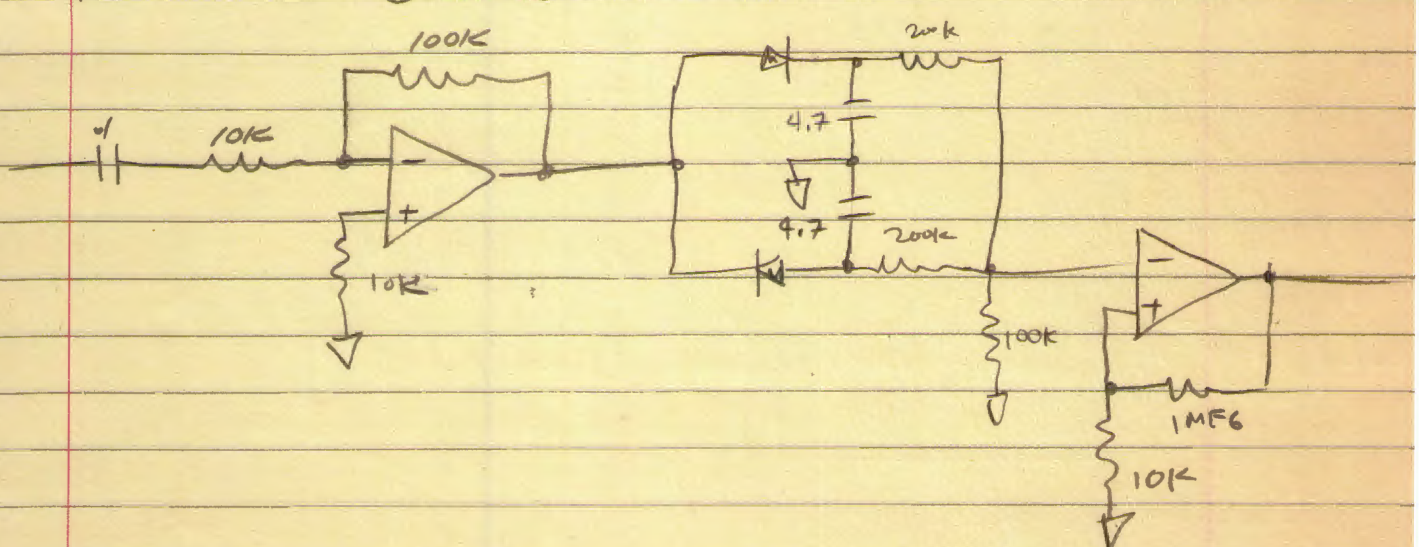
less than .005 volts offset

Now we need a circuit to determine which peaks are higher. . . neg or pos.

we could use . .



However circuit

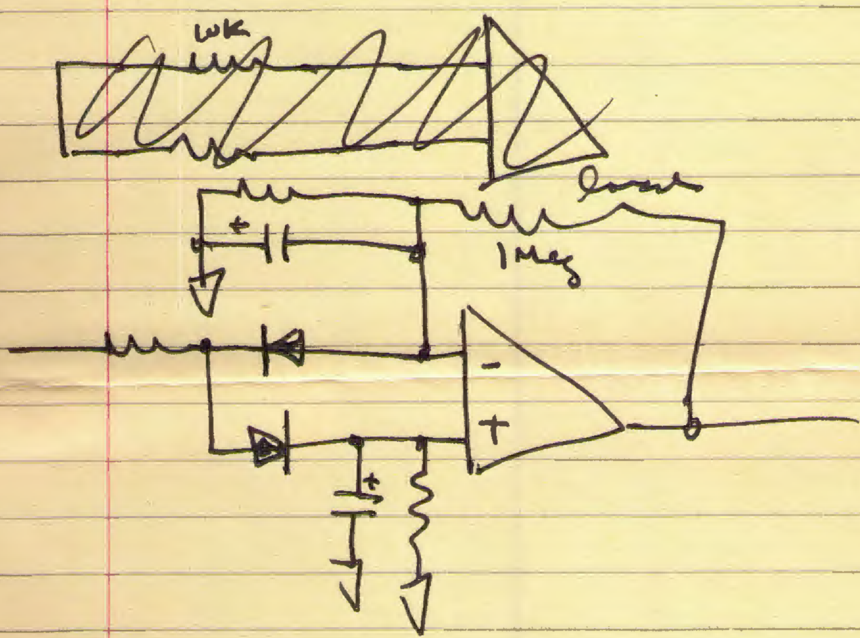


January 27 -

The thing sounds like a ping-pong match.

I must only allow phase reversal - during a quiet time - need a lull detector.

Try



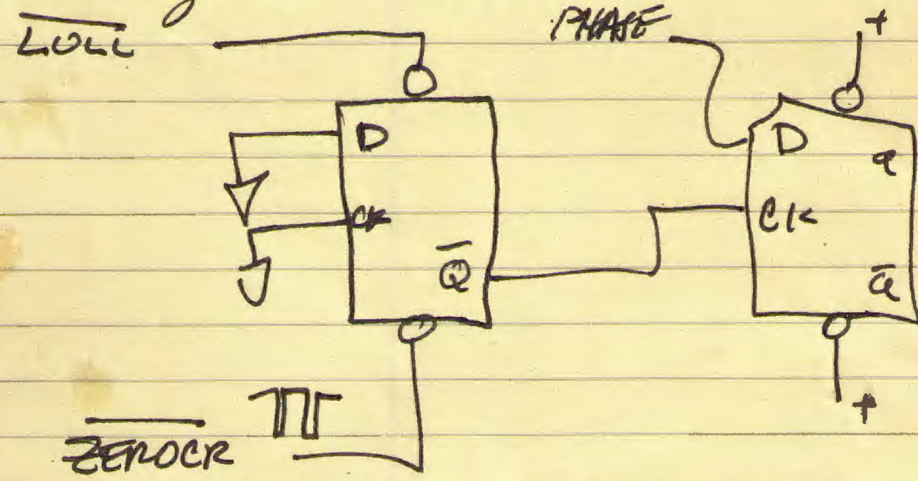
If signal below diode threshold output goes to ground. (see 1 meg?)

If signal either pos or neg above threshold ~~too~~ out. signal goes high.

See Rev. Jan 28 -
works very well.

Suggest circuit changes - and things to try . . .

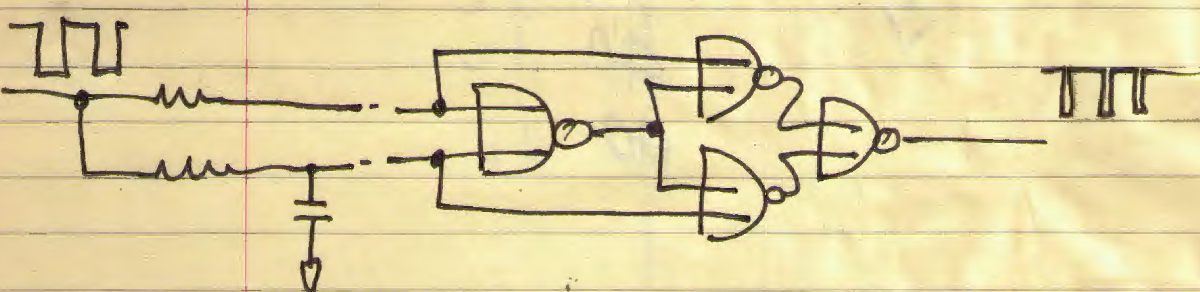
Logic for "anding" Loll detect, and zero cross



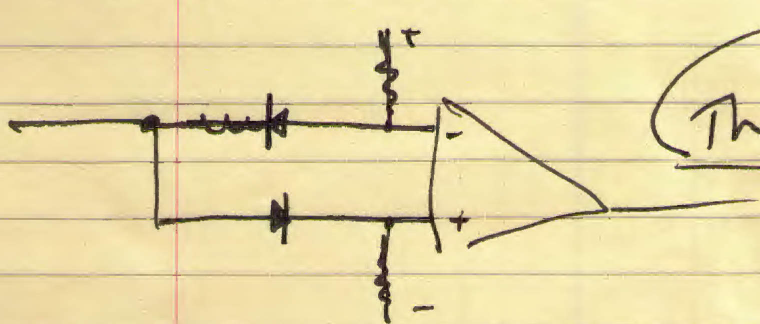
This circuit uses propty of 7474 – such that when both clear and preset are low both output are high.

Then we need exclusive nor gate – or equiv.

May be obtained from 74L02 Nor gate –



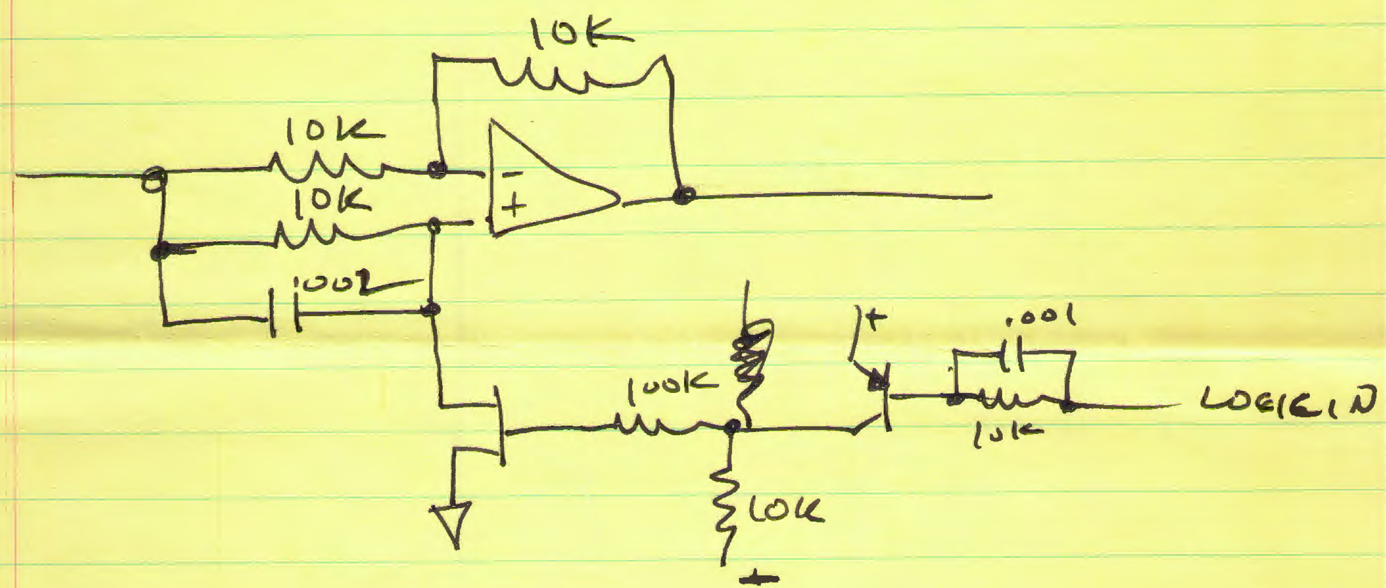
OR we might use another 301



Try this

A small amount of noise is attributable to dc offset switching.
— solution use — blocking cap. input.

also overshoot — in switch
solution shunt capacitor on input to positive input —
new circuit



Might ~~add~~ also try no zero cross detection circuit — just null —

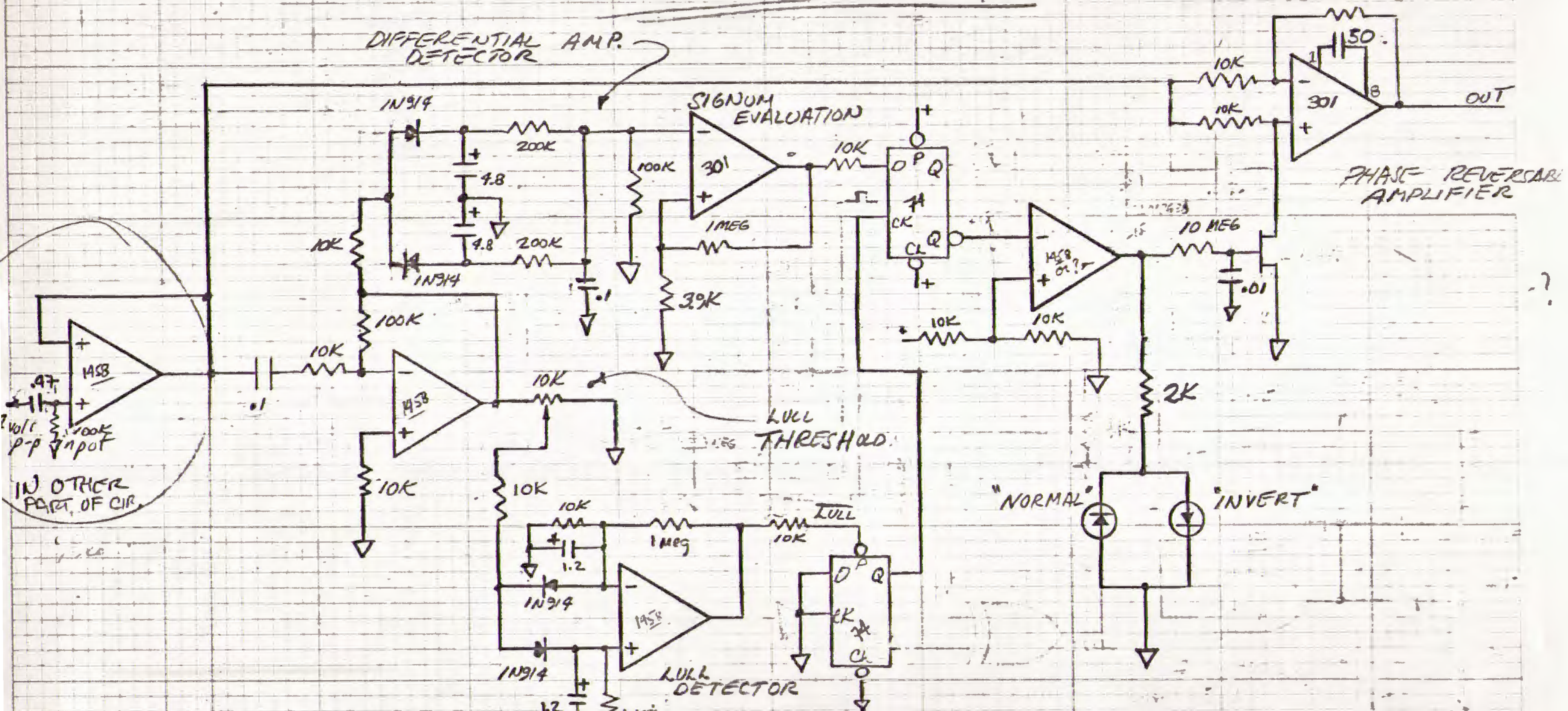
It would seem ~~that~~ the "pop" when switching this can be improved by slowing the phase switching time — ie — a tradeoff between — distortion and and pop is achieved —

notice also if we use this tradeoff — zero cross detection is superfluous

AUTOMATIC POLARITY (WITH ZERO CROSS SWITCHING)

RAIGRAY JAN. 25, 1975 REV. JAN 28 – LULL DETECT.
REV FEB 5. REV. JAN 30.
REV FEB 4

PRELIMINARY

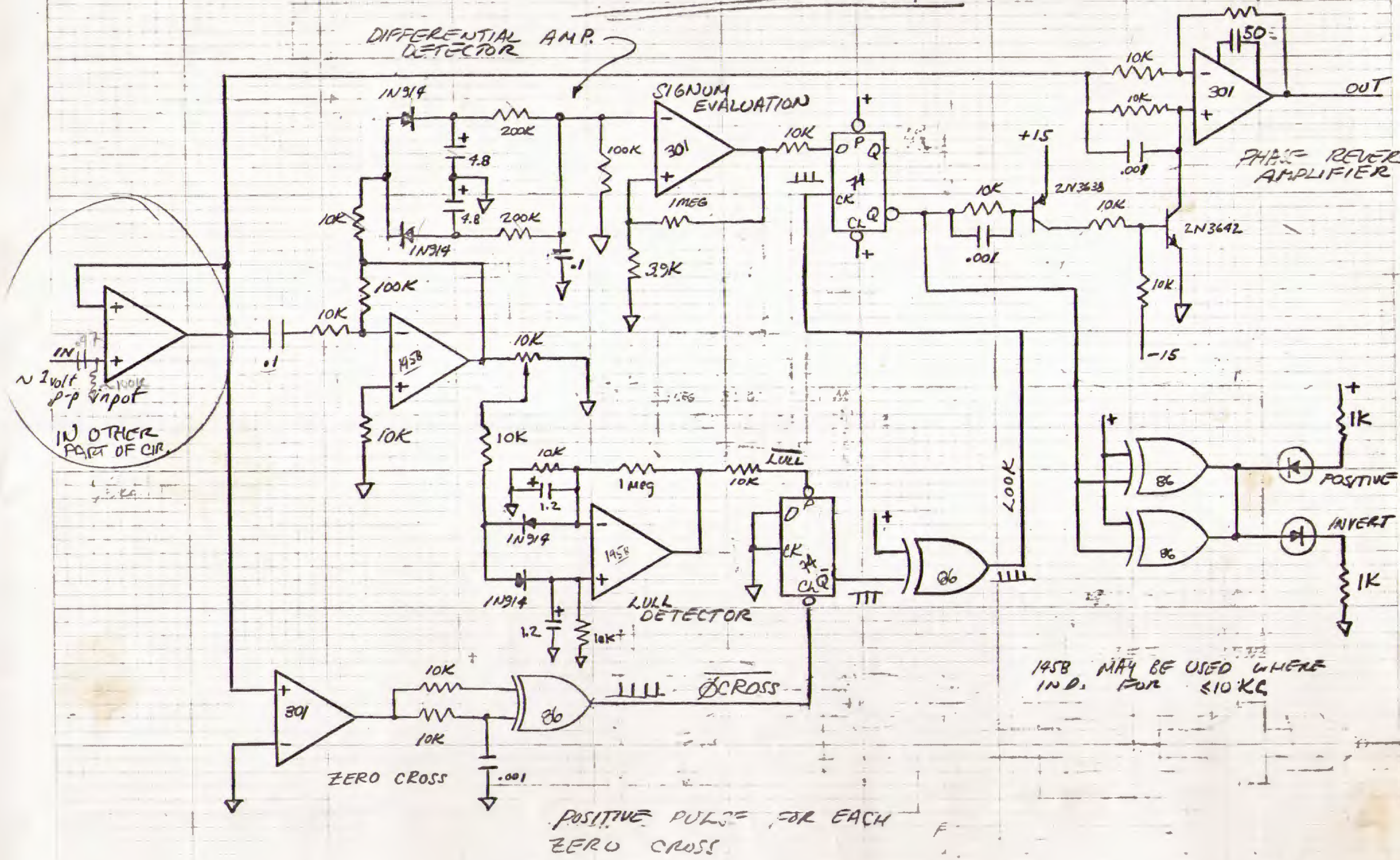


1458 MAY BE USED WHERE INR. FOR ≤10 KC

AUTOMATIC POLARITY (WITH ZERO CROSS SWITCHING)

RA GRAY JAN. 25, 1975 REV. JAN 28 - LULL DETECT.
REV. JAN 30.

PRELIMINARY

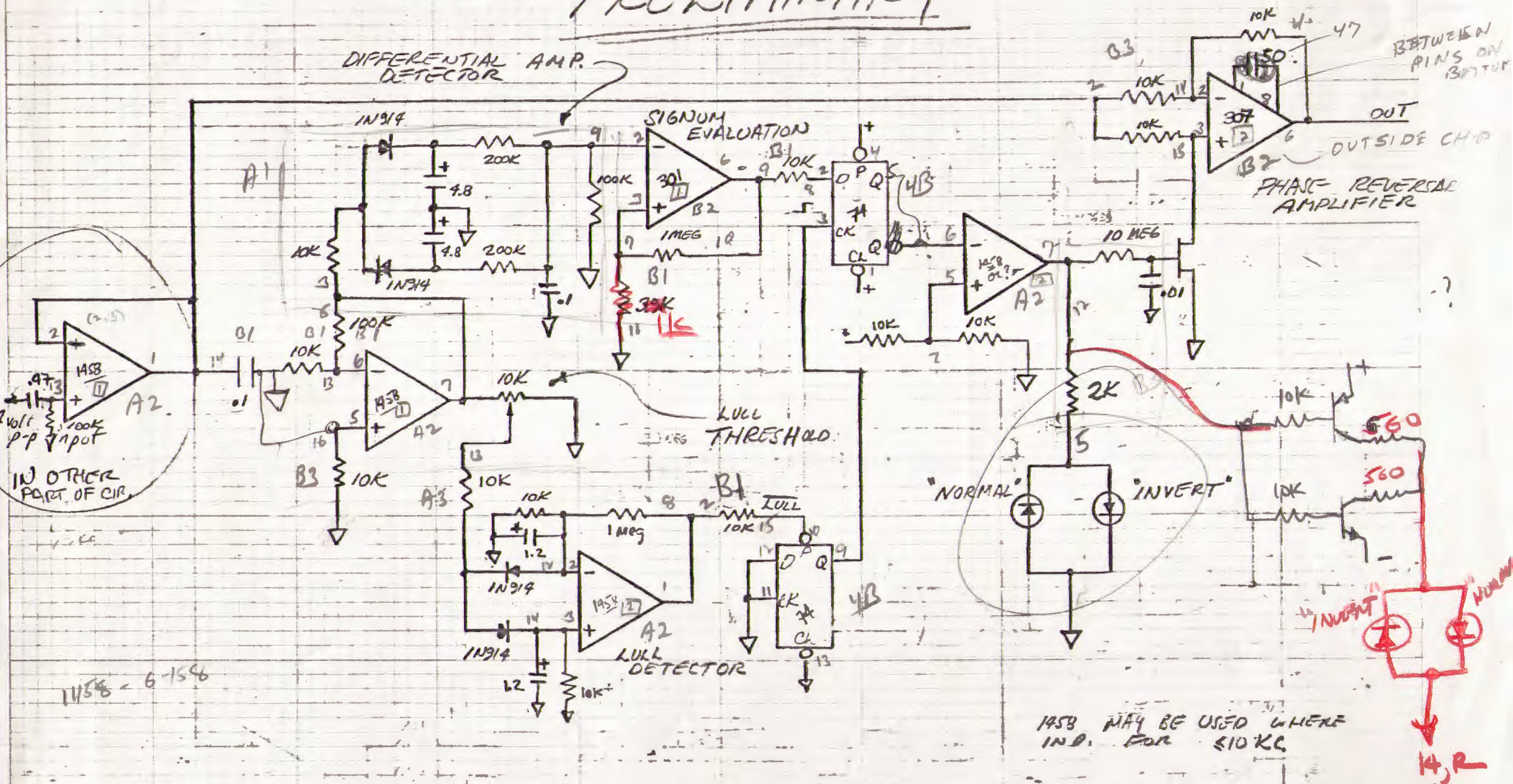


AUTOMATIC POLARITY (WITH ZERO CROSS SWITCHING)

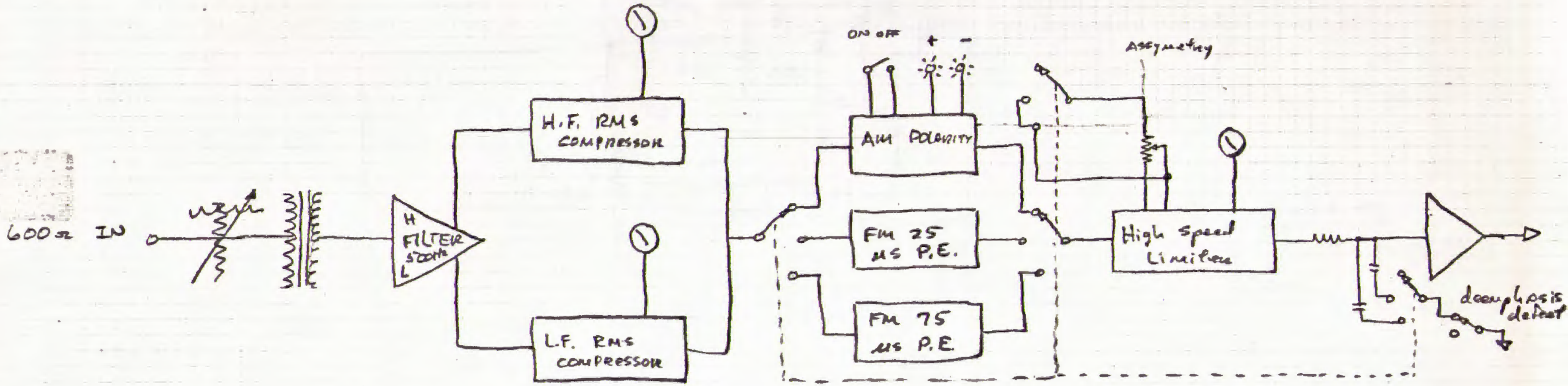
RA GRAY JAN 25, 1975 REV. JAN 29 – LULL DETECT.

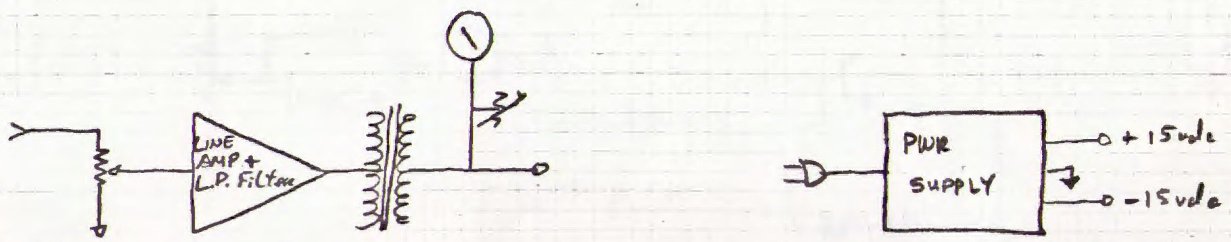
REV FEB 5. REV. JAN 30.
REV FEB 4

PRELIMINARY



Repeated here for clarity

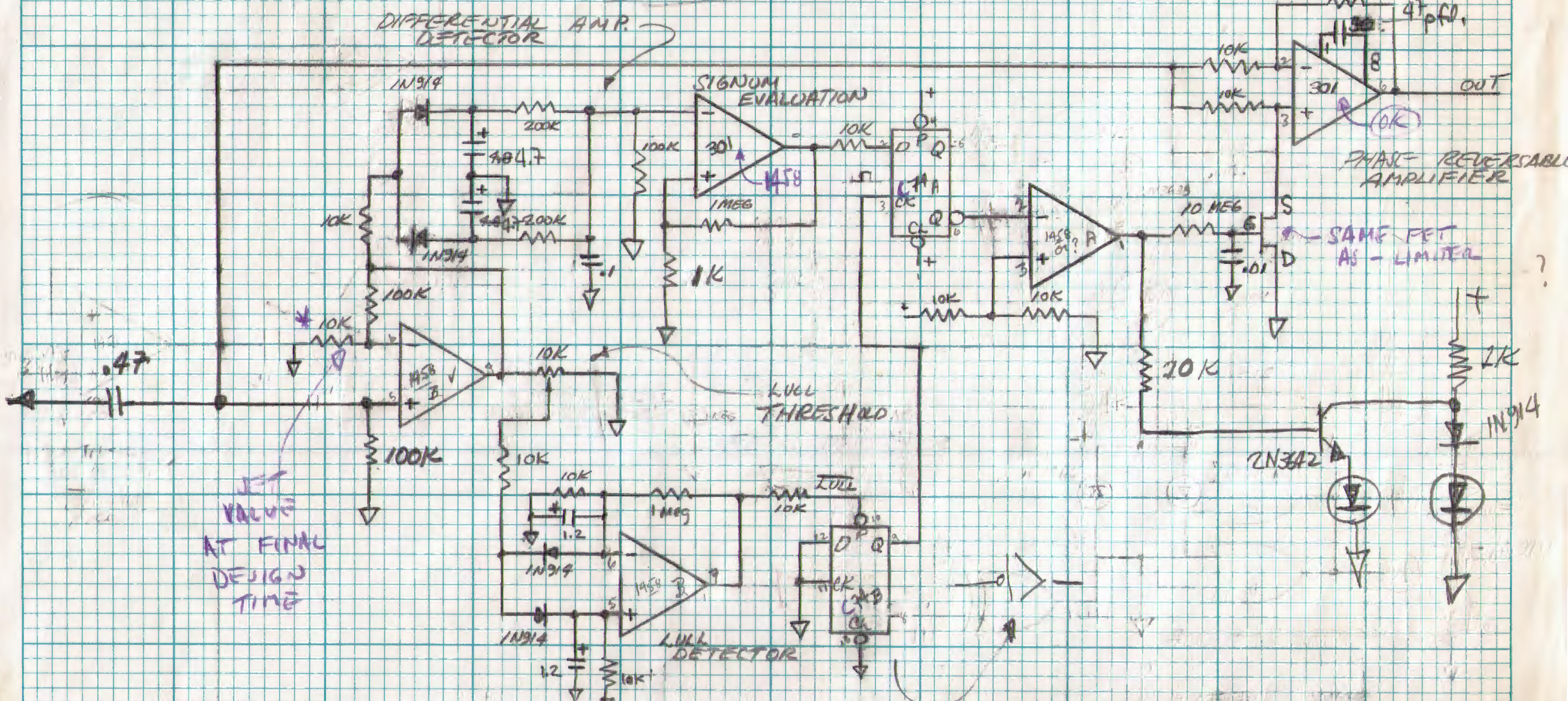




AUTOMATIC POLARITY (WITH ZERO CROSS SWITCHING)

RAGRAY JAN. 25, 1975 REV. JAN 28 - LULL DETECT.
REV FEB 5. REV. JAN 30.
REV. FEB 9 REV FEB 4

PRELIMINARY



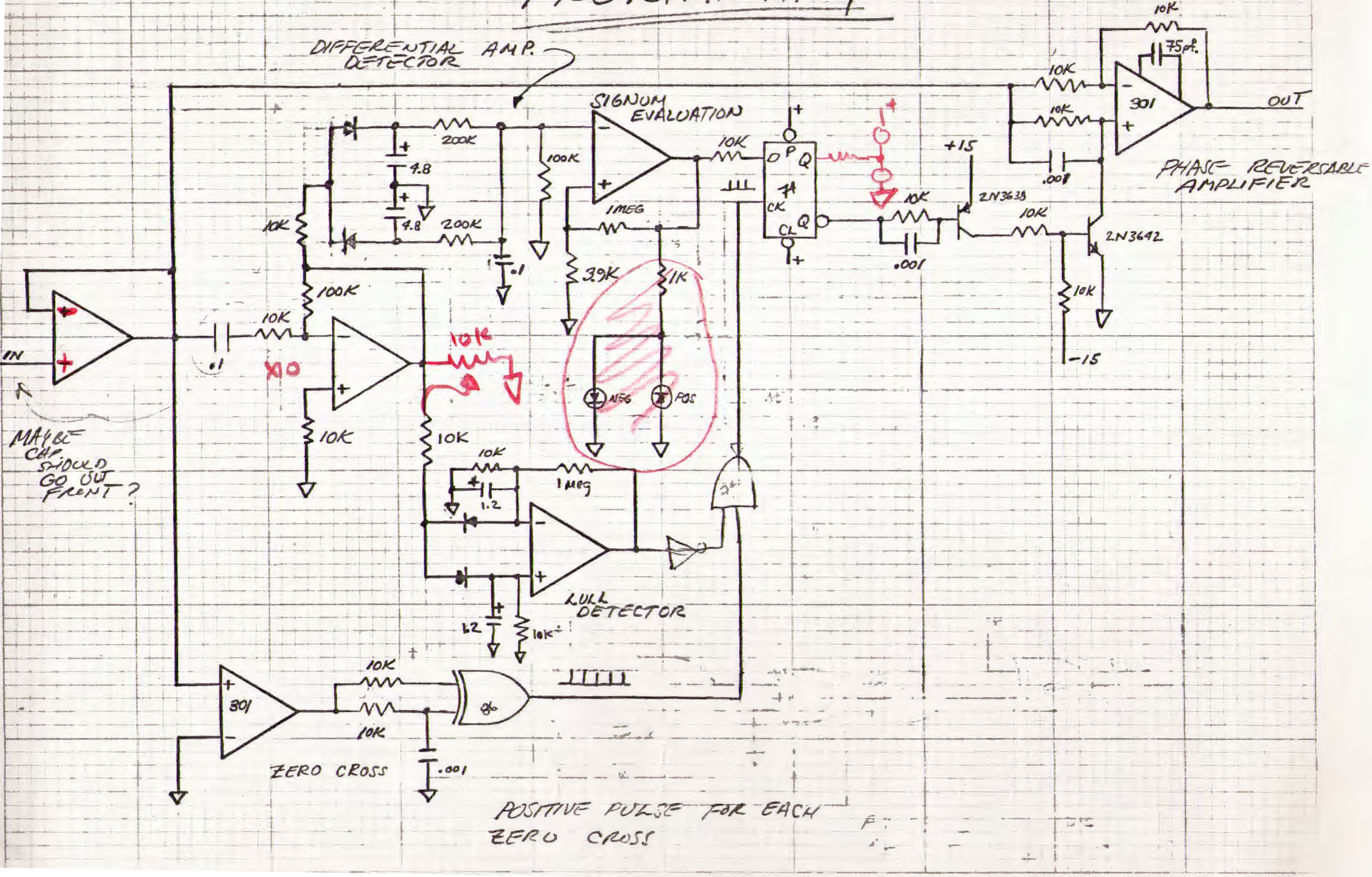
1458 MAY BE USED WHERE IN R. FOR ≤10 KC

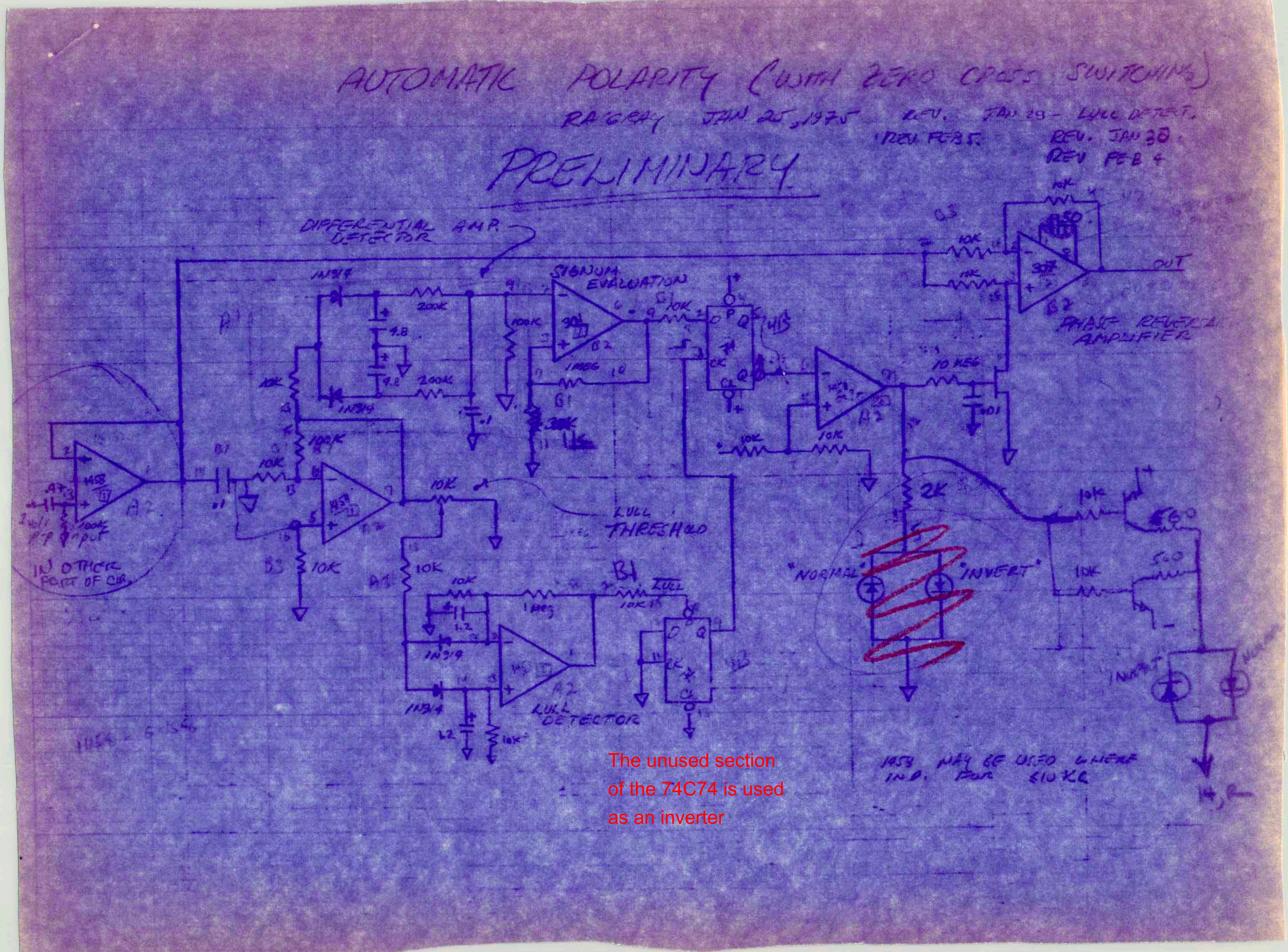
AUTOMATIC POLARITY (WITH ZERO CROSS SWITCHING)

RA GRAY JAN. 25, 1975 REV. JAN 28 - LULL DETECT.

UNOPTIMIZED

PRELIMINARY





The unused section of the 74C74 is used as an inverter

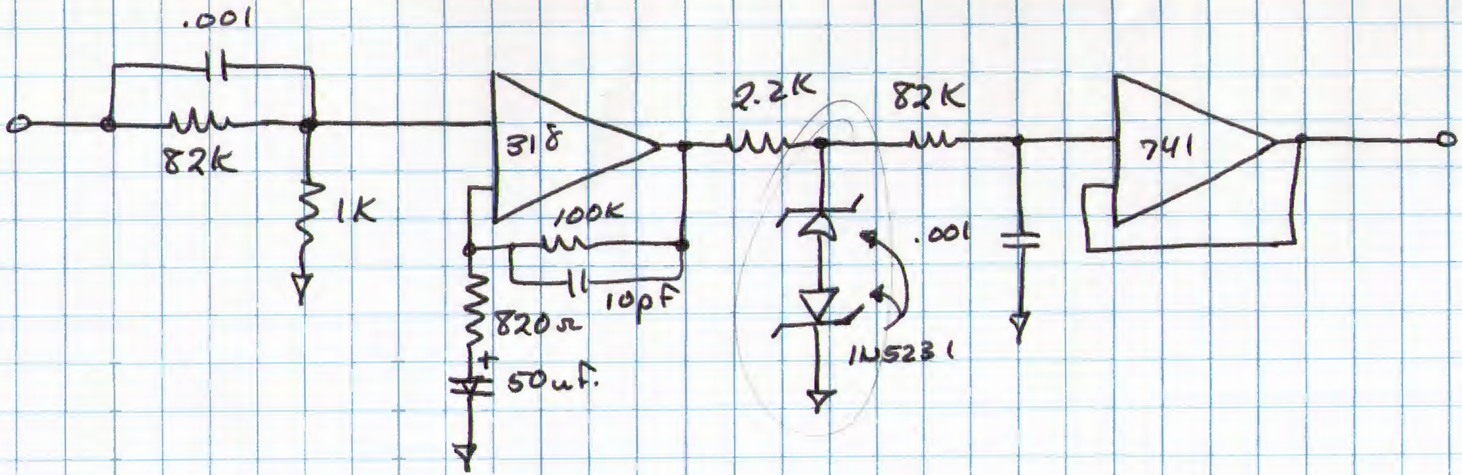
FM Broadcast, Signal Processing

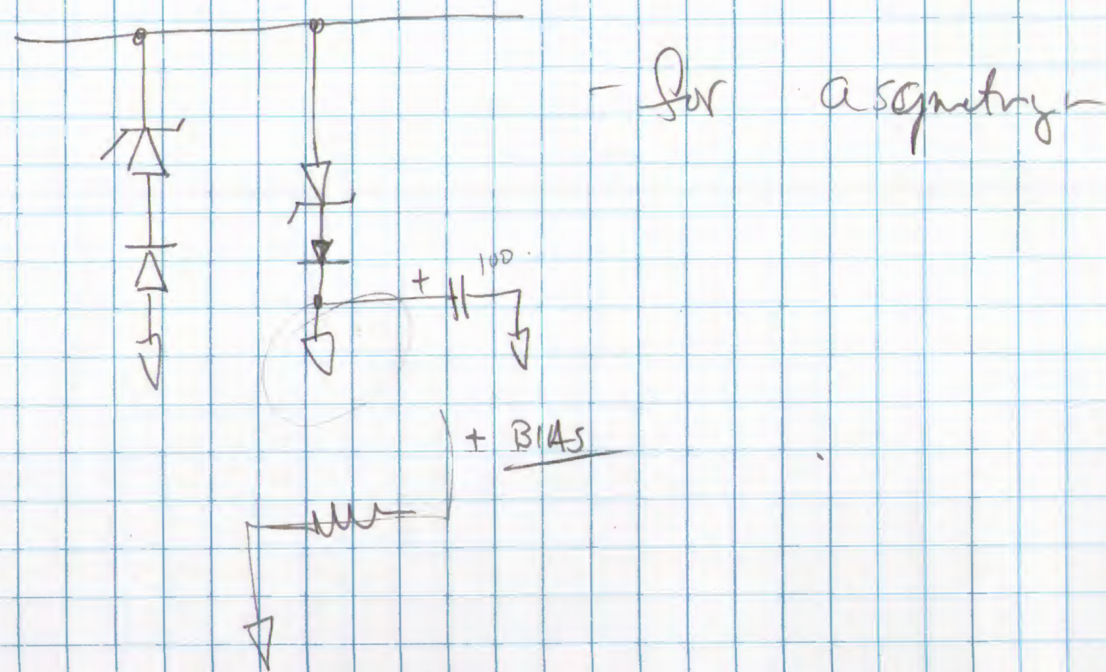
FM Audio Signals are "Pre-Emphasis", high frequencies accentuated before transmission
And de-emphasized in the Radio Receiver

To assure the Audio Signal is Properly Limited at the transmitter
It is necessary to pre-emphais, in MultiLimiter, do signal processing
And then return the signal to 'normal' audio for the transmitter
(And option could be to not Pre-emphasis in the Transmitter, and not de-emphasize in the Limiter)

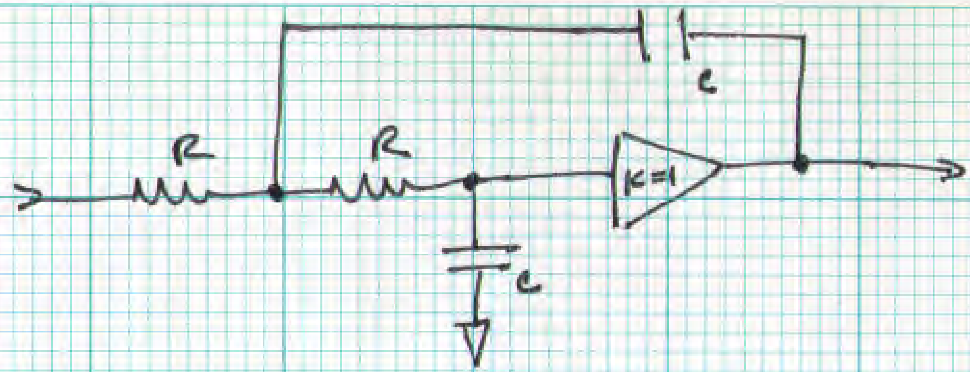
Several Pre-emphasis standards are supported:
None
25uS, for Dolby "B" Systems??? (Never adopted as a Standard)
75uS, U.S., Standard Broadcast Channel(s), U.S. NTSC Television Audio

Extremely simple Brute Force circuit!!!





Low Pass filter,
Remove audio that should
not be processed



for 15KC or 9.42×10^4 rad/sec

$\omega_0 = \frac{1}{RC}$ choose $C = .001\ \mu fd$.

then $R = \frac{1}{.001 \times 10^{-6} * 9.42 \times 10^4} = \sim 10K\Omega$

for $10K\Omega$ ~ 15.9 KC

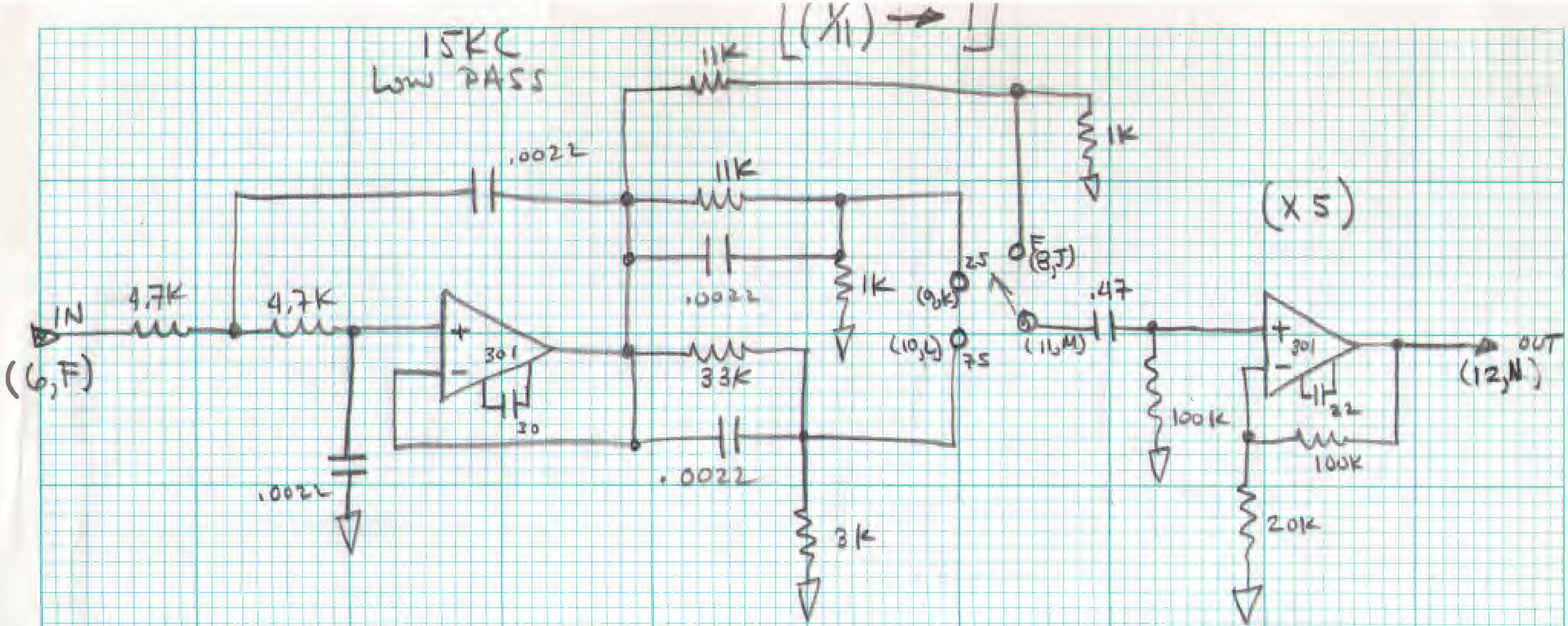
choose .0011 μfd.

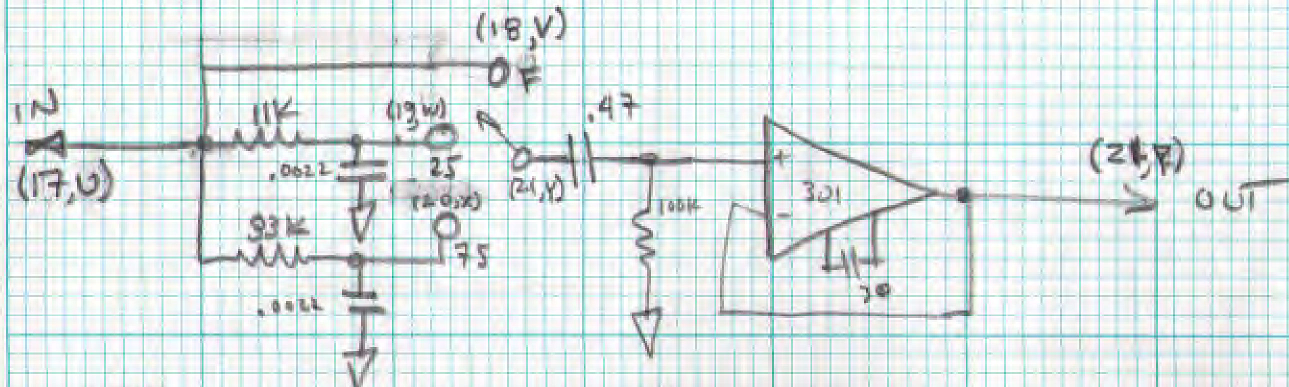
10K and .0011 ~~μf~~ μfd – we have ~~14~~.5KC
ok –?

$R = \frac{1}{.0022 \times 10^{-6} * 9.42 * 10^4} = 4.83K$ –

OR For 4.7K

$\omega_0 = \frac{1}{.0022 \times 10^{-6} * 4.7K} = 15.4\ KC$





MULTIMETER

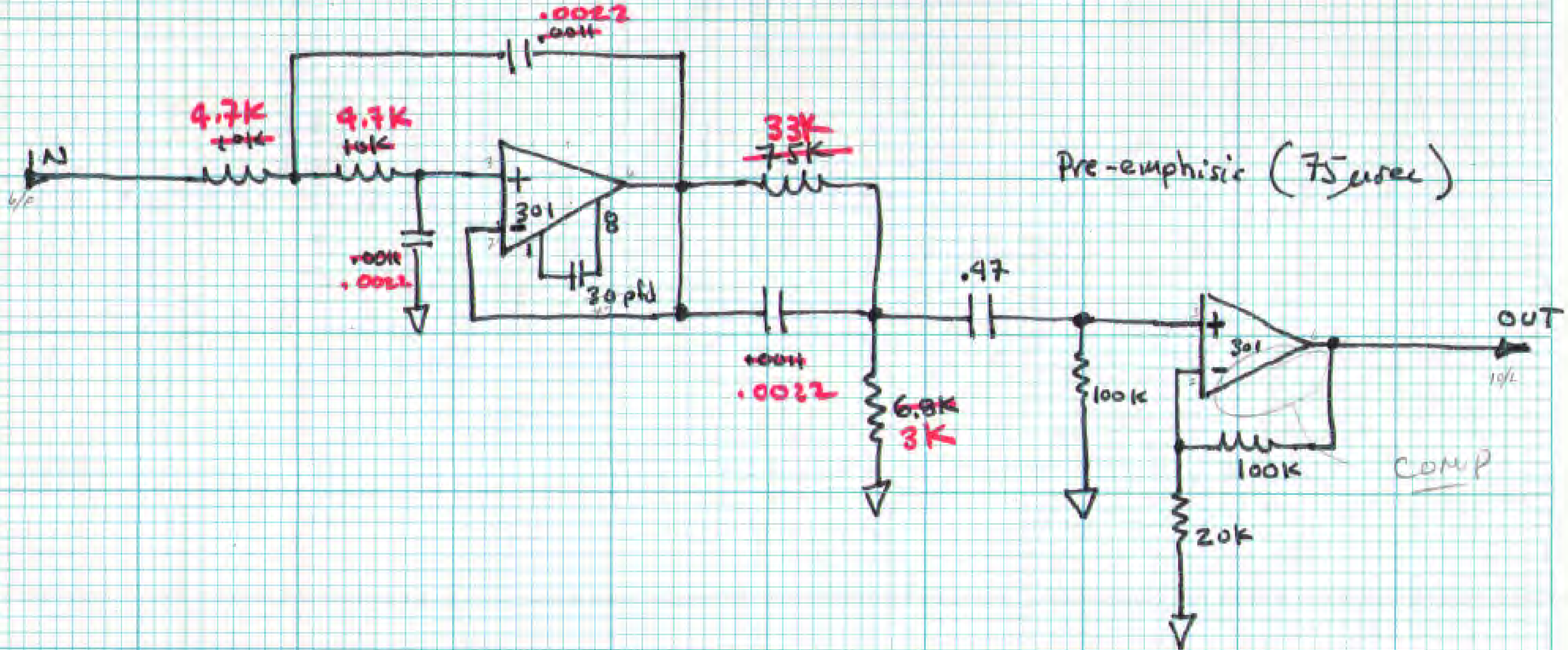
SWITCHABLE EMPHASIS -

DIAGRAM

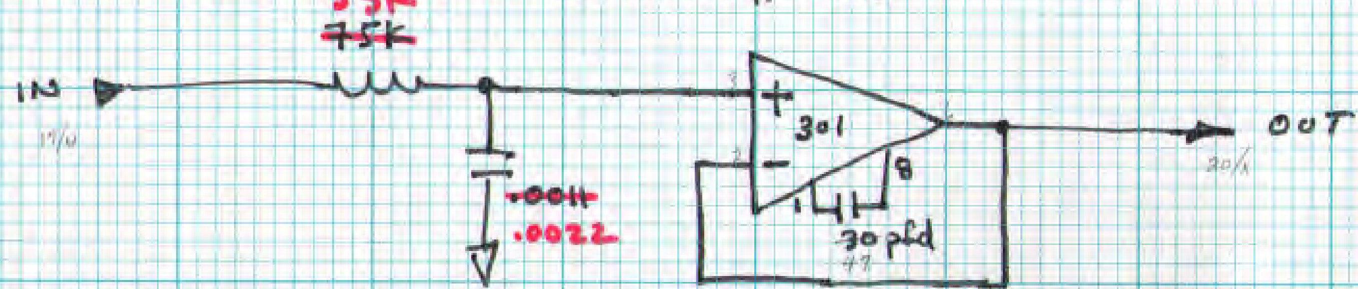
3/16/75

15KC low pass

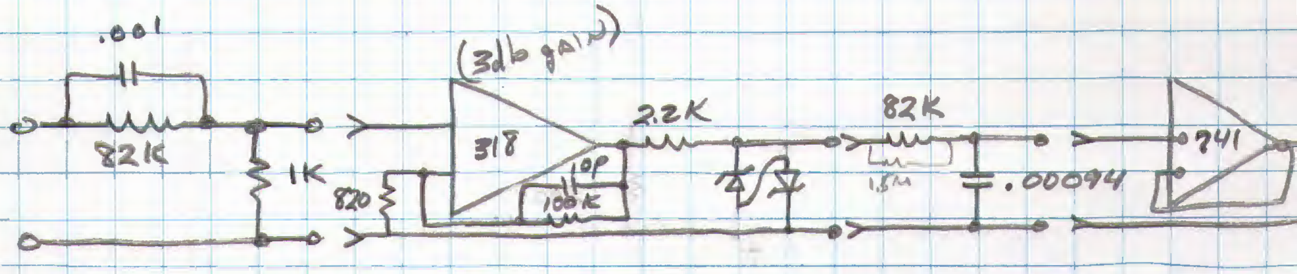
Pre-emphisis (75 µsec)



De-emphasis



Multilimeter
pre emphisis
de emphisis
for FM
P.A. Gentry
3/10/75

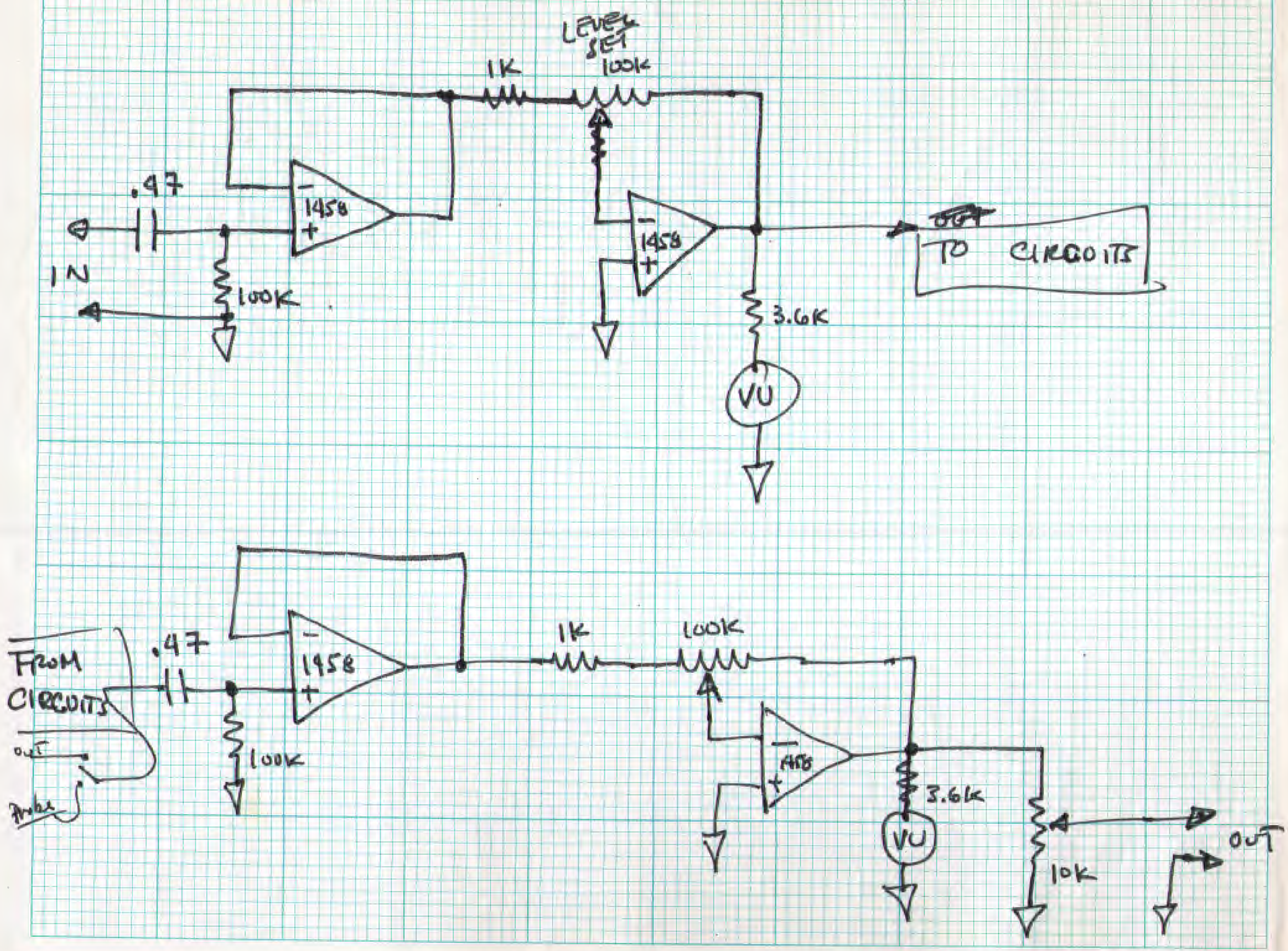


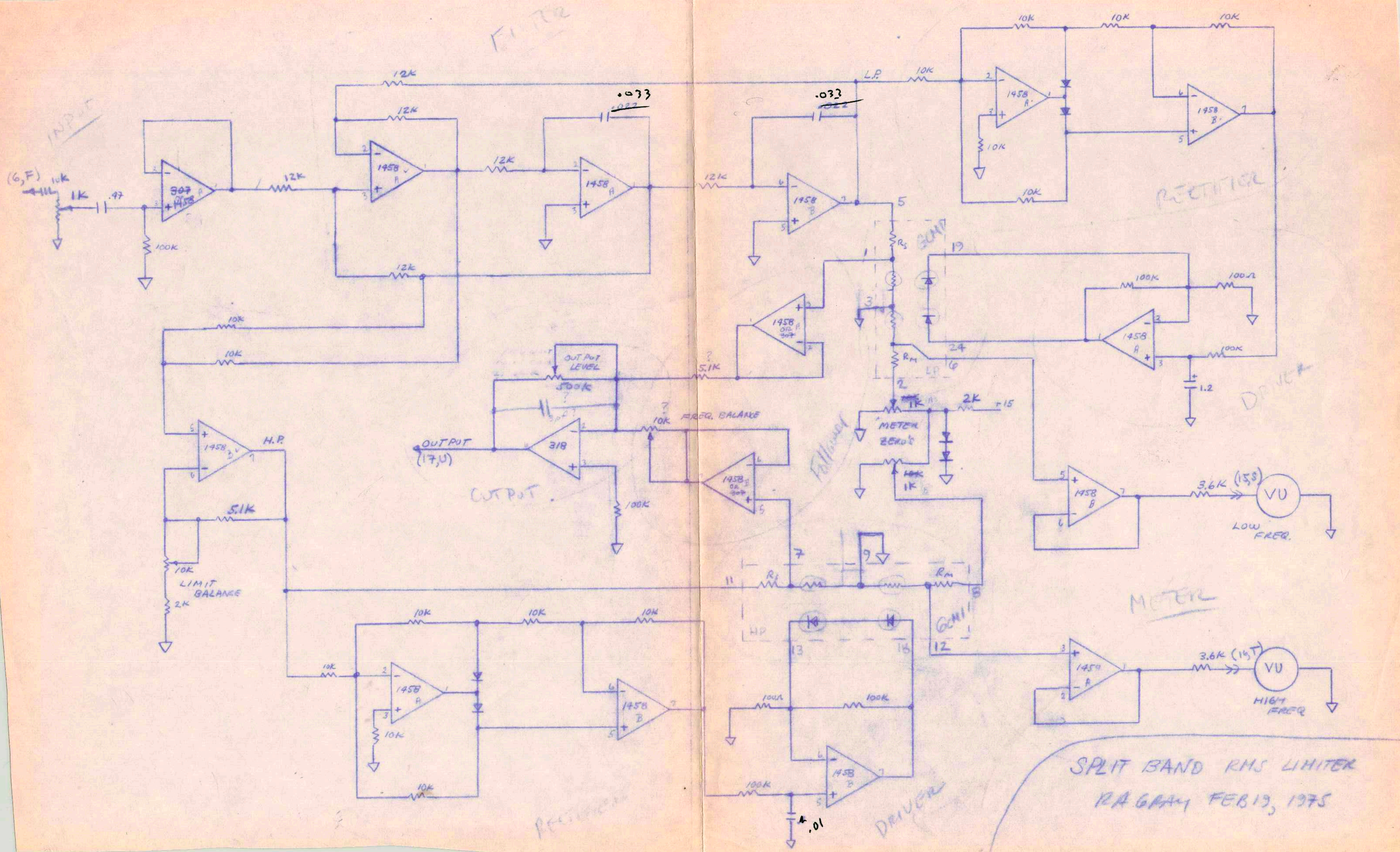
	circuit	75us std	AMP	circuit	AMP
100 Hz	0	0	0	0	0
200 Hz	0	.05			
300 Hz	0				
400 Hz	.1	.2			
500 Hz	.2				
600 Hz	.4				
700 Hz	.5	0.5			
800 Hz	.6				
900 Hz	.8				
1 KHz	.95	.9	0	0	0
1.5 KHz	1.9			0	
2 KHz	3	2.8		-.05	
2.5 KHz	4			-.1	
3 KHz	5	4.8		-.1	
3.5 KHz	5.9			-.15	
4 KHz	6.7			-.15	
4.5 KHz	7.5			-.15	
5 KHz	8.3	8.2	0	-.2	
5.5 KHz	9			-.2	
6 KHz	9.6			-.2	
6.5 KHz	10.3			-.25	
7 KHz	10.8	11.4		-.25	-.1
8 KHz	11.9			-.3	
9 KHz	12.7			-.3	
10 KHz	13.6	13.7	0	-.3	-.2
11 KHz	14.4			-.35	
12 KHz	15			-.35	-.25
13 KHz	15.8			-.4	
14 KHz	16.4			-.4	-.3
15 KHz	17	17.1	0	-.4	
16 KHz	17.6		0	-.45	-.3
17 KHz	18.2		0	-.45	
18 KHz	18.6		0	-.45	
19 KHz	19.1		-.05	-.5	
20 KHz	19.5		-.1	-.5	-.3

The Wire wrap Version for NAB 1975
The Input High Pass filter is not shown

Some drawings are shown previously in this section

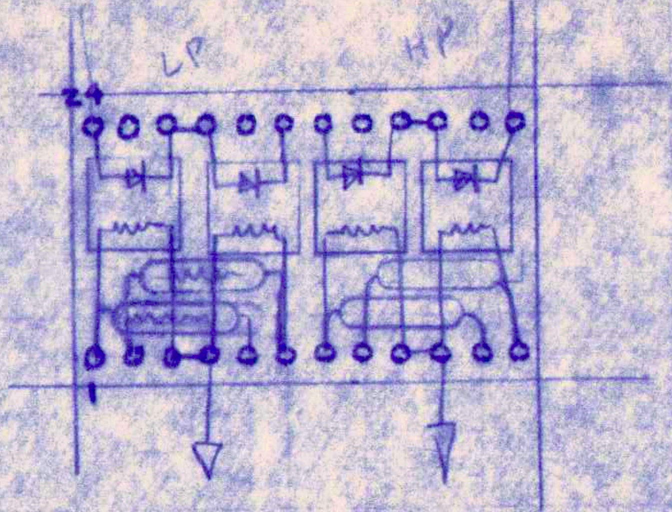
The NAB Model, had no Fancy Input or Output Sections!!!

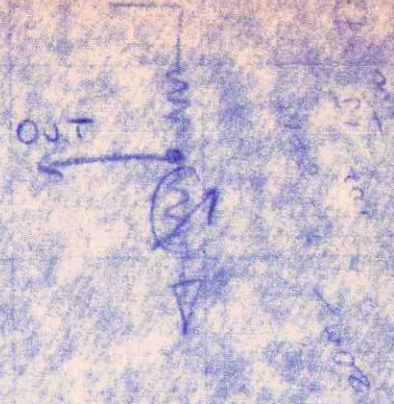




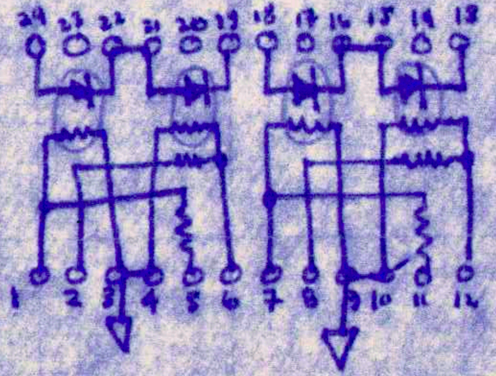
SPLIT BAND RMS LIMITER

RA GRAY FEB 19, 1975



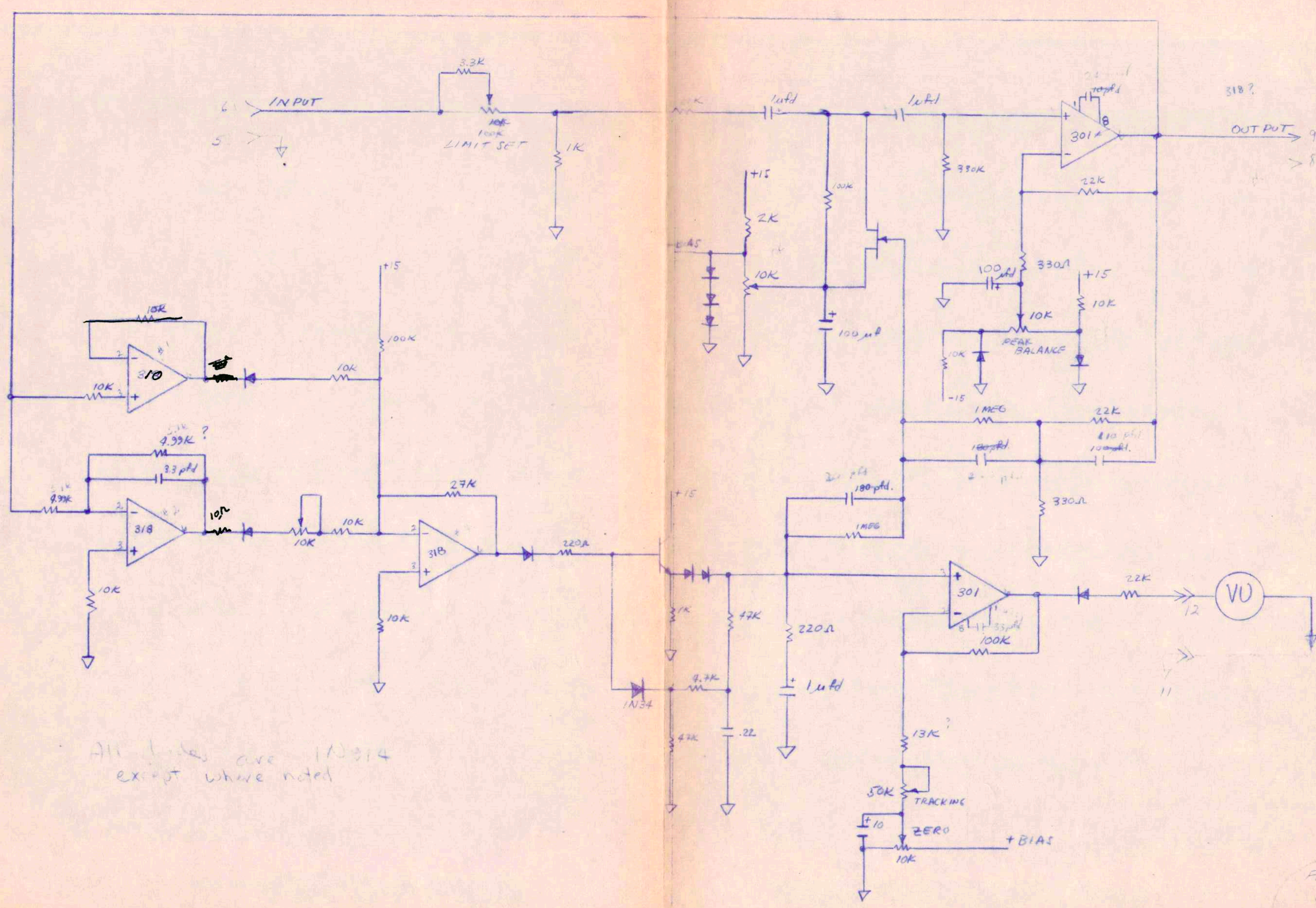


2X



MULTIUMETER

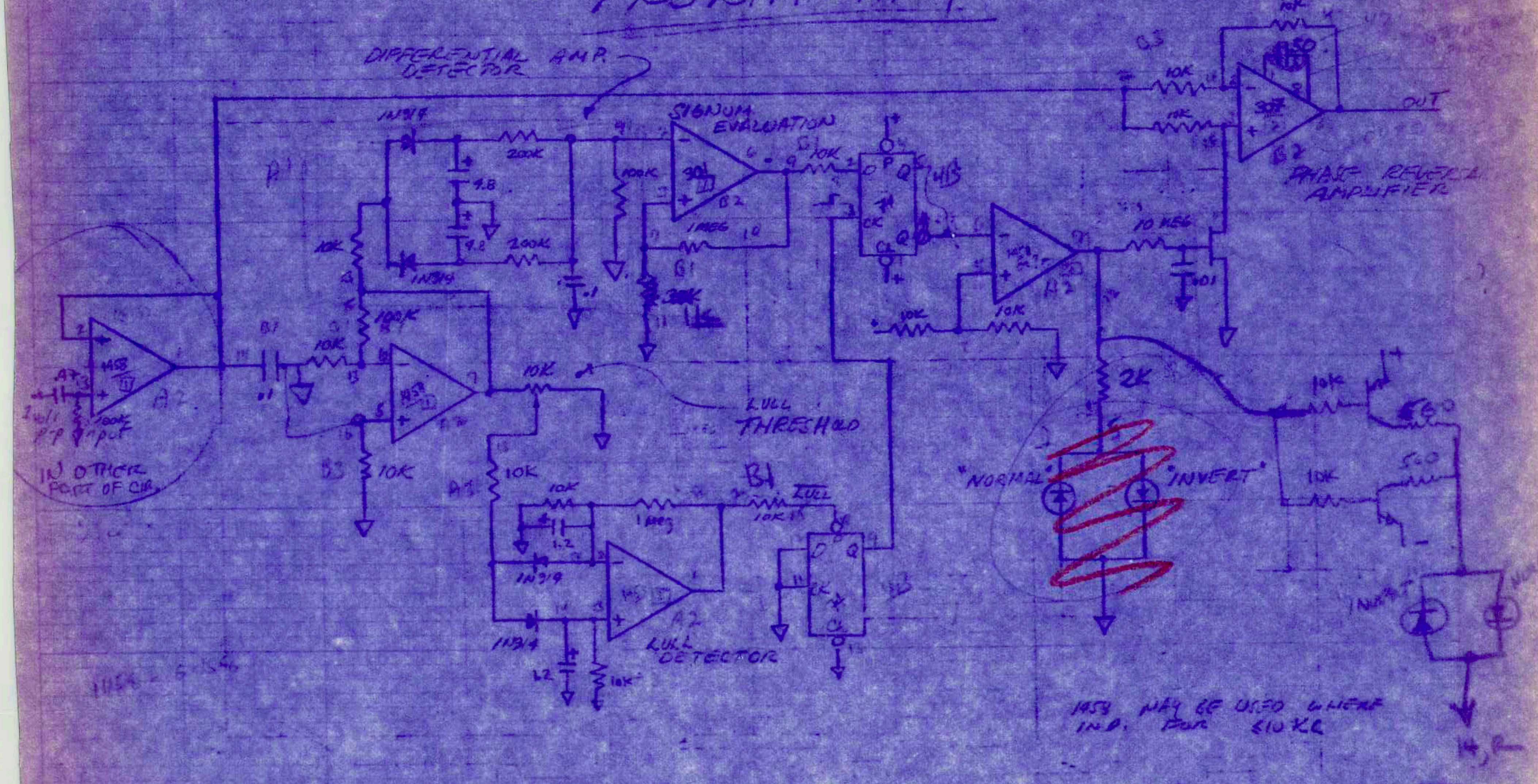
GAIN CONTROL MODULE
(GCM)
LAYOUT
DIAGRAM 3/12/74

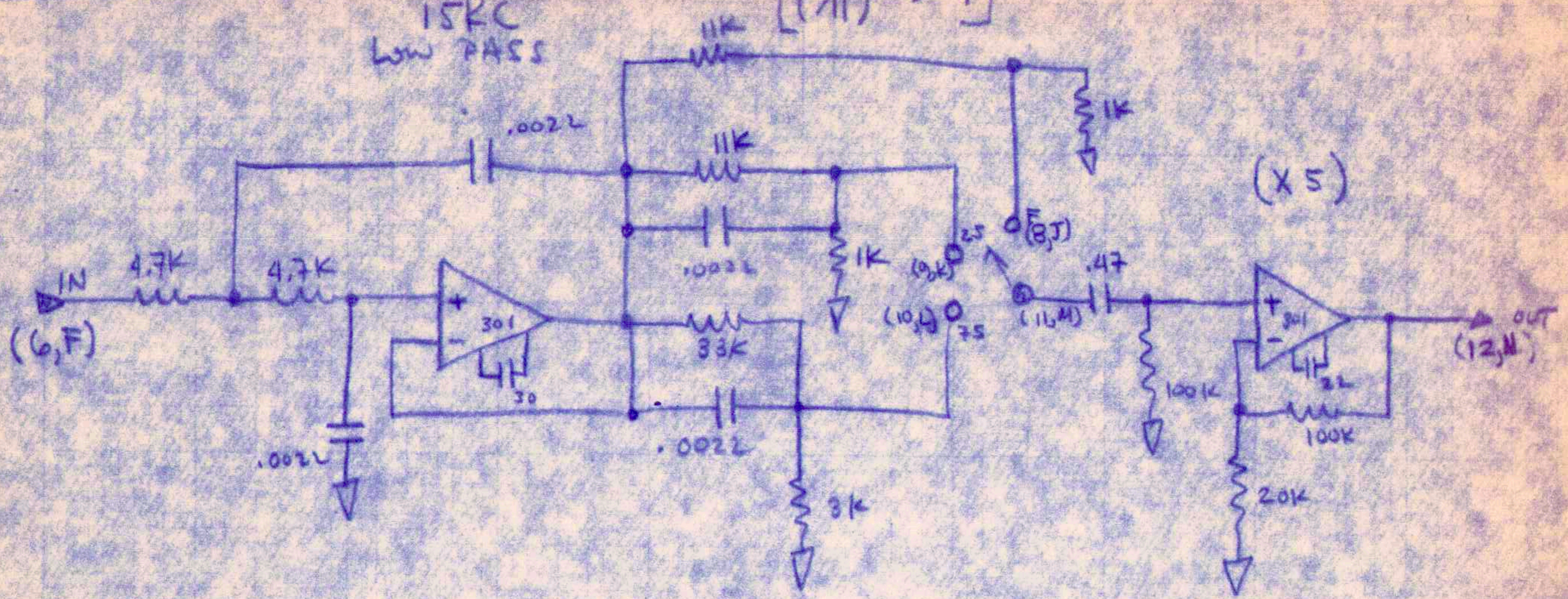

INPUT
3.3K
100K
LIMIT SET
1K
1ufd
330K
301A
OUTPUT
22K
+15
2K
10K
100K
100 ufd
330Ω
PEAK BALANCE
-15
1MEG
330Ω
318
4.99K
3.3 pfd
10Ω
27K
220Ω
1N34
4.7K
47K
.22
220Ω
1 ufd
301
100K
13K
50K
TRACKING
ZERO
+BIAS
VU
All diodes are 1N914
except where noted

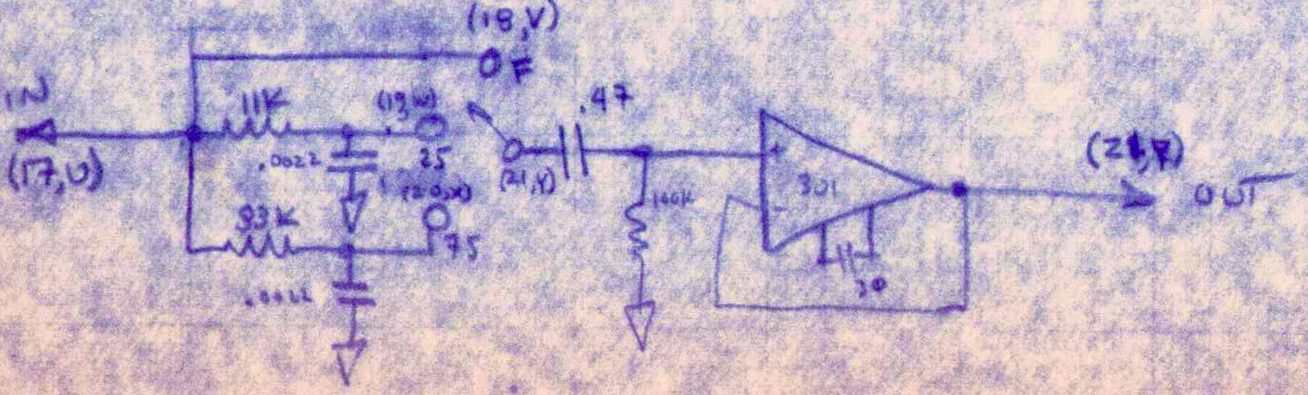
AUTOMATIC POLARITY (WITH ZERO CROSS SWITCHING)

RA GRAY JAN 25, 1975 REV. JAN 29 - LULL DETECT.
REV. JAN 30.
REV FEB 4
REV FEB 5.

PRELIMINARY







MULTIMETER

SWITCHABLE EMPHASIS -

DIAGRAM

3/16/75

It would seem we temporarily 'borrowed the output circuitry