R.F. BOOK

RF NOTE #30

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The purpose of this note is to document the data obtained from tests of the amplifiers developed for the special synthesizer. Much time was spent in evaluation and optimization, and presented here are the significant results distilled from this activity.

7-70 MHz GAIN AMPS

These amps are needed to drive the buffer amps (described later) to provide the multitude of outputs we require. Ideally, they should have: a voltage gain of at least 10, constant across the 7-70 MHz bandwidth; negligible distortion; approximately a 50 ohm input impedance, and low power consumption. As developed, these amps meet all of these desired qualities except the last. It was decided at the outset that constant gain bandwidth, distortion, and input impedance would have priority over gain and power requirements.

Thus the amplifiers had to be broadband over a decade of frequency (essentially a video amp), and preferably a single stage to minimize size. Therefore distributed amp techniques were ruled out. Also, since our desired output voltage was on the order of 5 V rms (.5Ω into 50Ω), a power device was indicated. Add to this the fact that it would be convenient and economical to use the same device for the 135-210 MHz amplifiers (described later). Taking all of this into account, the design was based on a vertical channel power MOSFET (VMOS) built by Siliconix. This device has been used successfully up to 260 MHz by others, and has also been used to power the three phase dee and stem model. Although the input capacity of 30 pf is somewhat large for VHF work, the VMP4 VMOSFET is a very linear device, and its 25 W flange-mount stripline package is easy to work with.

The final circuit is shown in Fig. 1. It is basically a common source amp with feedback for gain tailoring over the band. A word about each part of the circuit is in order. The strange looking input circuit is the result of efforts to make the input impedance essentially 50 ohms across the band without dropping much voltage ahead of the device. A standard choke bias circuit was tried on the gate but many problems with low frequency resonances in band were encountered. So, this scheme was scrapped in favor of the resistor bias method. Considering the feedback circuit, there are three options which are of interest. Each of the amplitude response curves for the three variations is illustrated in Fig. 2.

Because the amplifier tended to roll off slightly before 70 MHz, a .22 nH series peaking coil was used to boost this frequency. The circuit was optimized to work into a 200 ohm load. There were two reasons for this, (1) the gain of the amp can be higher; and (2) if necessary, cascading is possible using a 4:1 broadband transformer.

Gate biasing was deliberately set low to minimize idling current; with 3 volts bias, drain current is 250 mA. This bias point is nearly at the low knee of the input transfer curve so input voltages above .5 V_{rms} begin to distort noticeably. Since the crystal oscillators will be the lowest output signal source in the synthesizer (.5 V_{rms}), a design input voltage somewhat below this of .35 V_{rms} was chosen. The response curves were obtained using this value of input voltage set at 30 MHz (midband).

Distortion across the band was negligible. Operating temperature was 60°C.

7-70 MHz Buffer amps ("Damnfast" vs. VMOS homebrew)

The multitude of signal outputs leaving the synthesizer must be suitably buffered. The desired properties for such buffers are: (1) ability to feed a reasonable fanout of similar buffers for signal splitting; (2) capability of driving a 50-ohm cable; (3) gain of one essentially constant across the band; (4) reproducible with reasonable uniformity; (5) low distortion; and (6) single stage for minimal size. Two possible methods for realizing these performance objectives were evaluated and will be discussed separately.

"Damnfast" amps

These are 5 watt FET input I.C.s specified for use up to 100 MHz. They may be plugged into a suitably designed p.c. board socket and mounted directly to the copper foil for heat sinking. Clearly they are easy to use. Performance-wise, these amps exhibited rather severe roll-off above 30 MHz when fed directly from a 50 Ω source. However, the addition of a 70 MHz series peaking coil cured this. The input impedance is equivalently a 3900 ohm resistor in shunt with 12 pF. The test circuit is shown in Fig.3. A response curve for the buffer tested independently is Fig. 4. Distortion was negligible across the band and a fanout load of up to 7 (557 ohms in shunt with 84 pF) should be feasible with adequate output signal.

The test circuit for the gain amp/damnfast buffer combination is shown in Fig. 5. The overall response is graphed in Fig. 6. When tested with a 50 ohm load, the output of the pair fell off drastically above 40 MHz in spite of the 70 MHz peaking coil. A 200 ohm load was used on the gain amp output. Best high frequency response was obtained with direct feed to the buffer and adjustment of the gain amp feedback resistor. During the tests, two buffers failed, probably due to oscillation induced heating. Case temperature was 65°C. While this is well within the operating specifications, evidently these buffers need a higher integrity heatsink than mere p.c. board foil. One buffer died after less than two minutes with 5 V_{rms} applied. Oscillations are suppressed by a series 47 ohm resistor to give the buffers a positive input resistance.

VMOS homebrew amps

As Fig. 7 shows, these amps are basically source followers with a choke replacing the source resistor. The measured input impedance is equivalent to 800 ohms in shunt with 12 pF. Because of a tendency to oscillate, this circuit was not tested individually, but rather in conjunction with a gain amp. Fig. 8 shows the response of the combination circuit driving a load equivalent to a fanout of four. Because of the high response at 70 MHz, the feedback circuit of the gain amp was modified by removing the 5 pF shunt capacitor. Two curves are shown, (1) with the gain amp input circuit intact, and (2) with the .68 μH/51 ohm series combination to ground removed. Some distortion is evident around 44-48 MHz. Hopefully this can be corrected.

Comparing the two

The question now is: which is the better way to go? Actually both amps do a pretty good job of meeting the original performance objectives. However, it may be well to examine circuit reproducibility.

From a cost standpoint, the "Damnfast" scheme would require a component cost of about $40 per buffer. Also printed circuit boards would have to be etched (commercially), and eight-pin sockets would have to be constructed for each buffer stage (probably in-house). The ICs could then be mounted to the boards and modularized. For the VMOS buffer amps, components would cost about $20 per amp and point to point wiring would be used. Construction would then include mounting the transistors, installing seven additional components and interconnection.

IC amps do have the important advantage of commercial uniformity although the VMOS amps do not seem particularly sensitive to either component tolerance or placement. However, since a large number of buffers (as high as 288) will be needed, the prepackaged IC is the preferred method.

135-210 MHz GAIN AMPS

As expected, it turned out much simpler to develop these amps than it did the 7-70 MHz version. The main reason is that the latter must operate over a decade of frequency, whereas here the range is less than one octave. Little attention was paid to input impedance for a couple of reasons. First, the network analyzer only works up to 110 MHz, and second the impedance when fed by a 50Ω source should be quite constant over the restricted bandwidth. The 135-210 MHz filter, of course, will have a 50Ω output impedance. All the rest of the design objectives which applied to the 7-70 MHz amps also apply here, except that in this case a gain of 5 will probably be adequate. Fig. 9 shows the schematic and Fig. 10, the response curves. Actually, only a single amp of this type should be required in the present synthesizer scheme.

135-210 MHz Buffer Amps

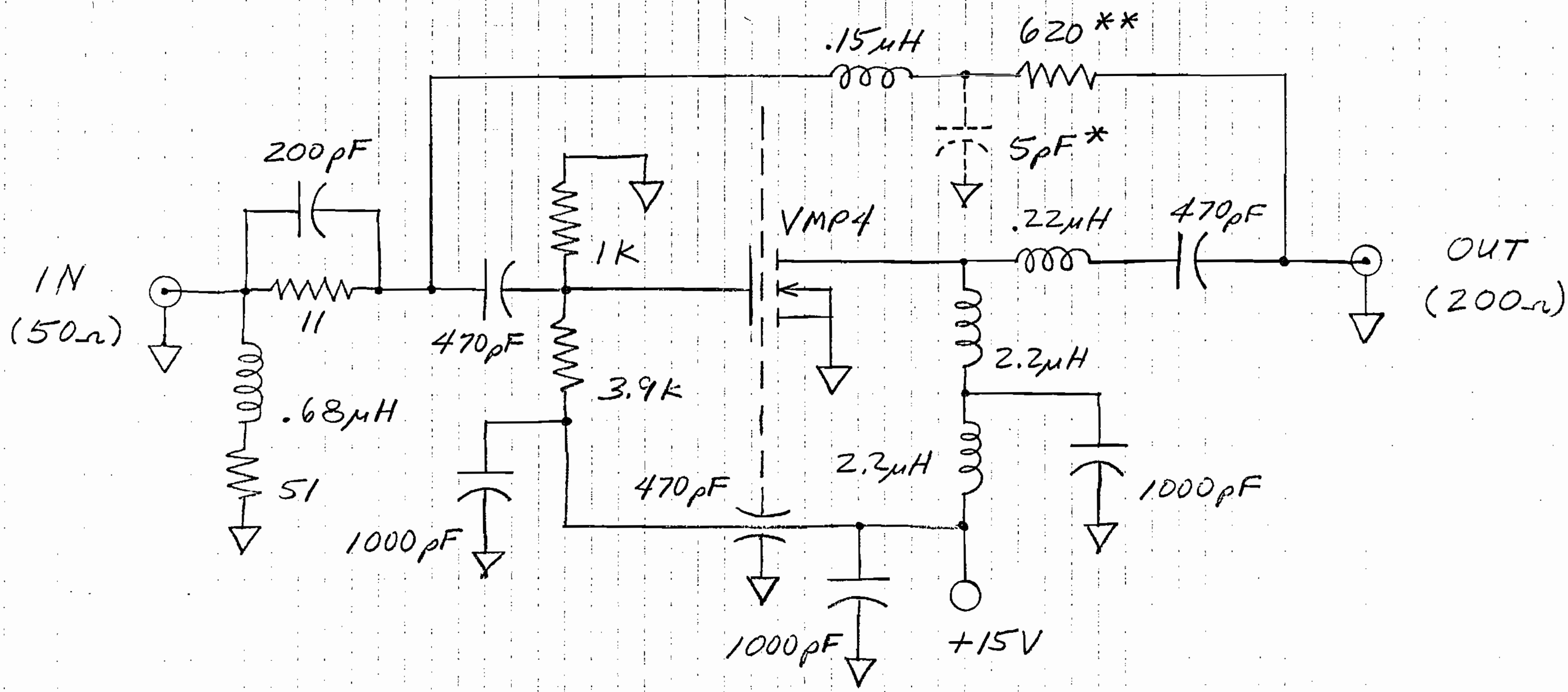
Fig. 11 is the circuit diagram for the buffers which are essentially the same as those for 7-70 MHz with the exception of component scaling. Response curves are shown in Fig. 12 and the gain amp + buffer overall curves are Fig. 13. Nine such buffers will be required.

Packaging

Figs. 14 through 16 are block diagrams of the proposed circuit boards for the various signals. The present plan is to incorporate a dozen IC buffer amps, all suitably heat-sinked, on a NIM module board. If all goes according to plan, there should be one single width NIM module for the F1, $\overline{F1}$ signals, (likewise for the F2, $\overline{F2}$ and F3, $\overline{F3}$ signals), and a double width module for each of the F+ and $\overline{F+}$ signals. Note that except for these latter two, all signals and their respective quadrature counterparts will be on the same board in the same module. The F1, $\overline{F1}$ board will require the addition of an amplitude regulator for the reference signals.

In a similar fashion, the 7-70 MHz gain amps will be mounted with one buffer each in a separate double width module.

Figure 17 is the latest diagram of the synthesizer.



* CKT 2A & 2B ONLY

** CKT 1 : 620Ω
2A : 820Ω
2B : 910Ω

FIG 1

7-70 MHz GAIN AMP

min. volt. gain = 10 (9-70 MHz)

CKT 2A volt. gain = 14.6 @ 30 MHz

Z_{IN} { $|Z_{IN}|$ range : 32 to 50Ω
φ range : −18° to +18°

(same for all CKTS)

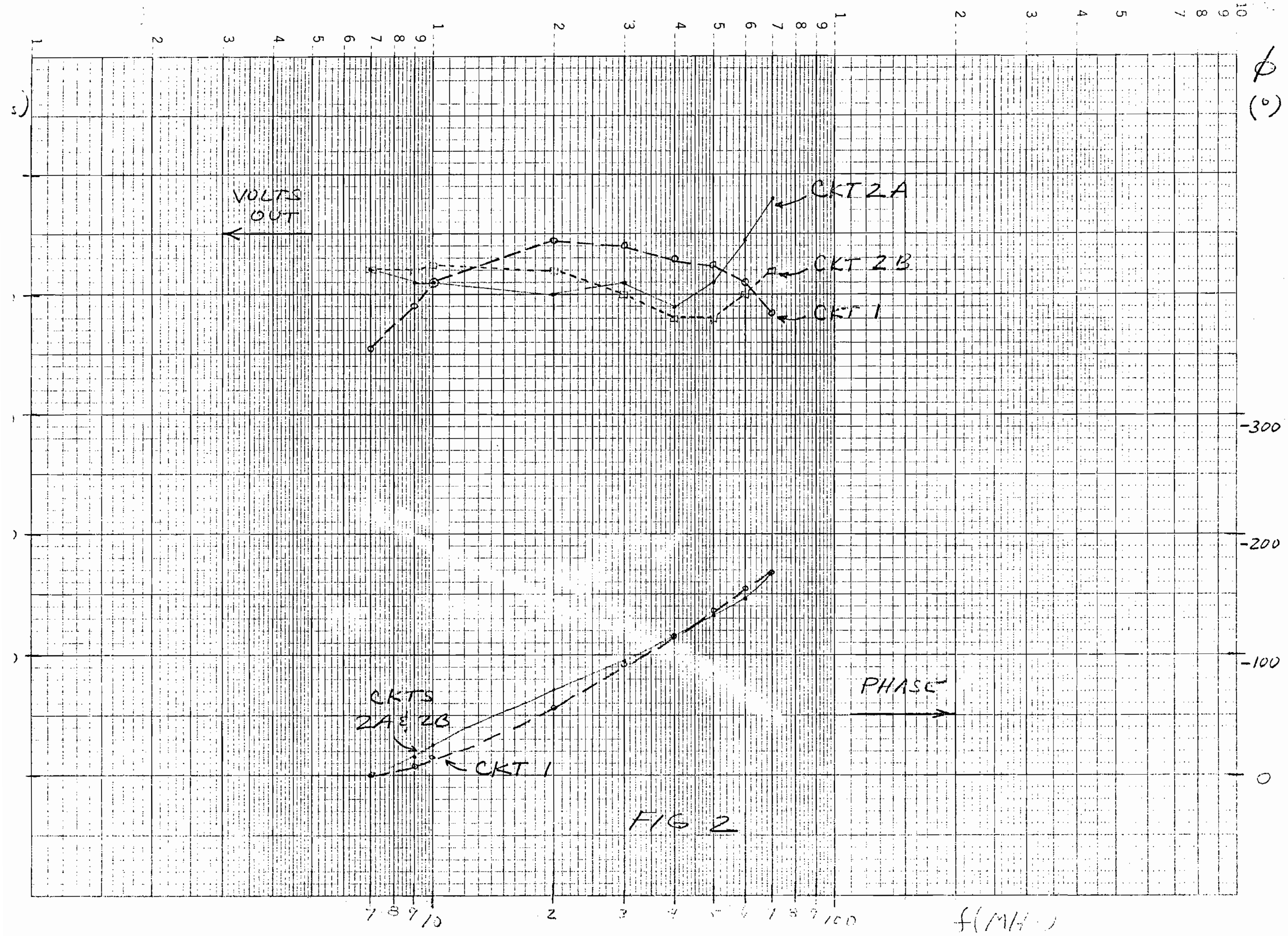
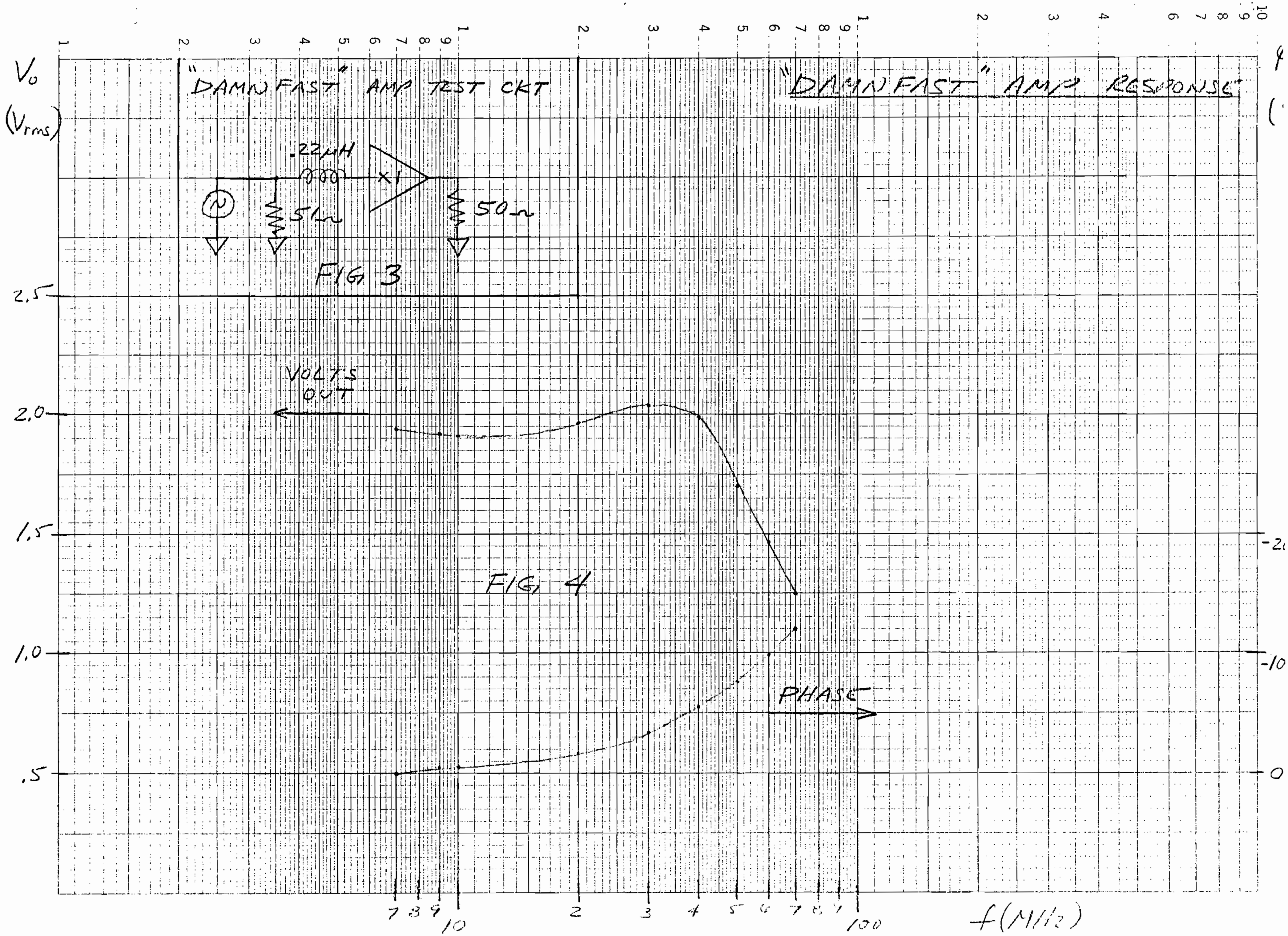
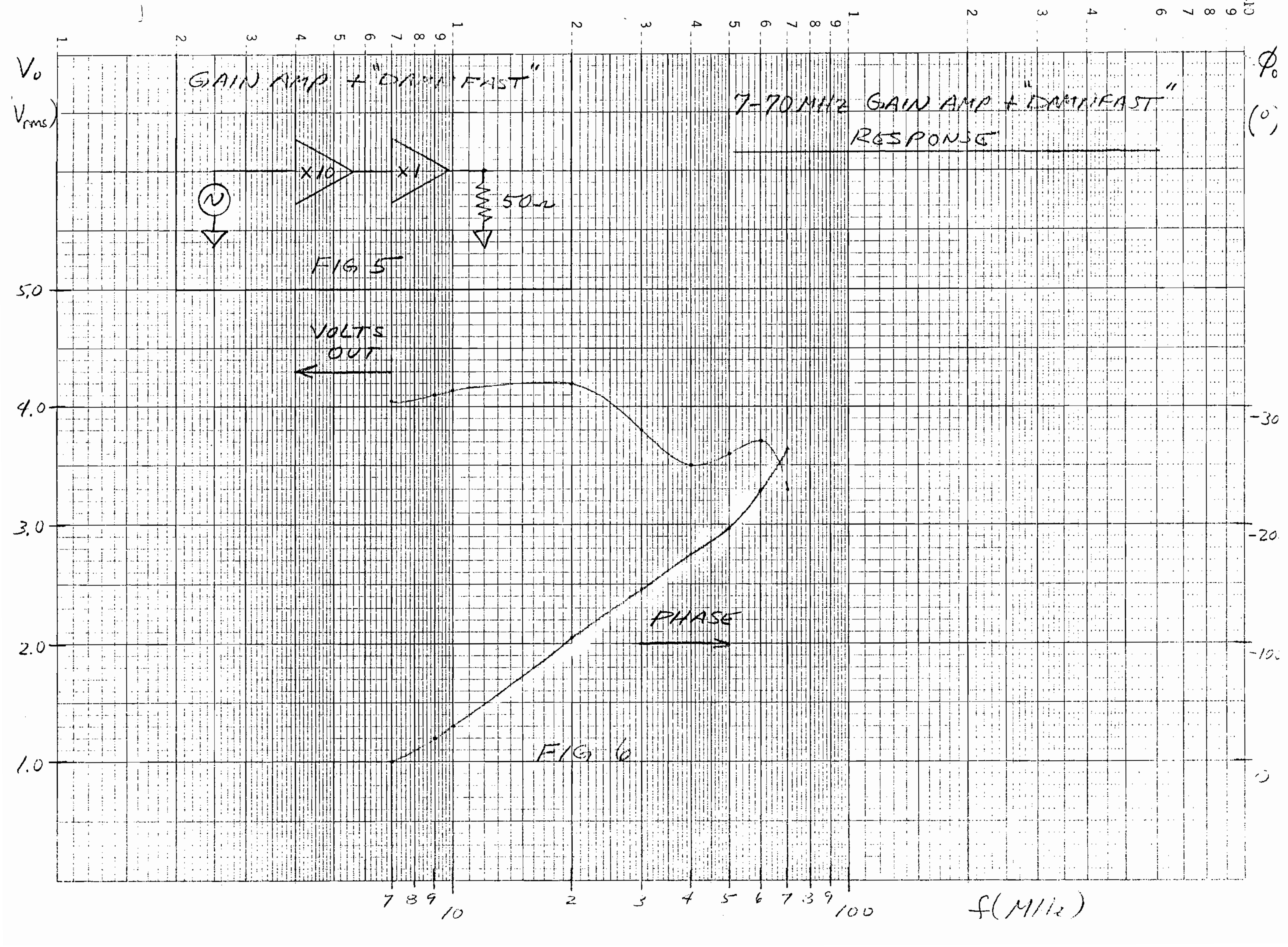
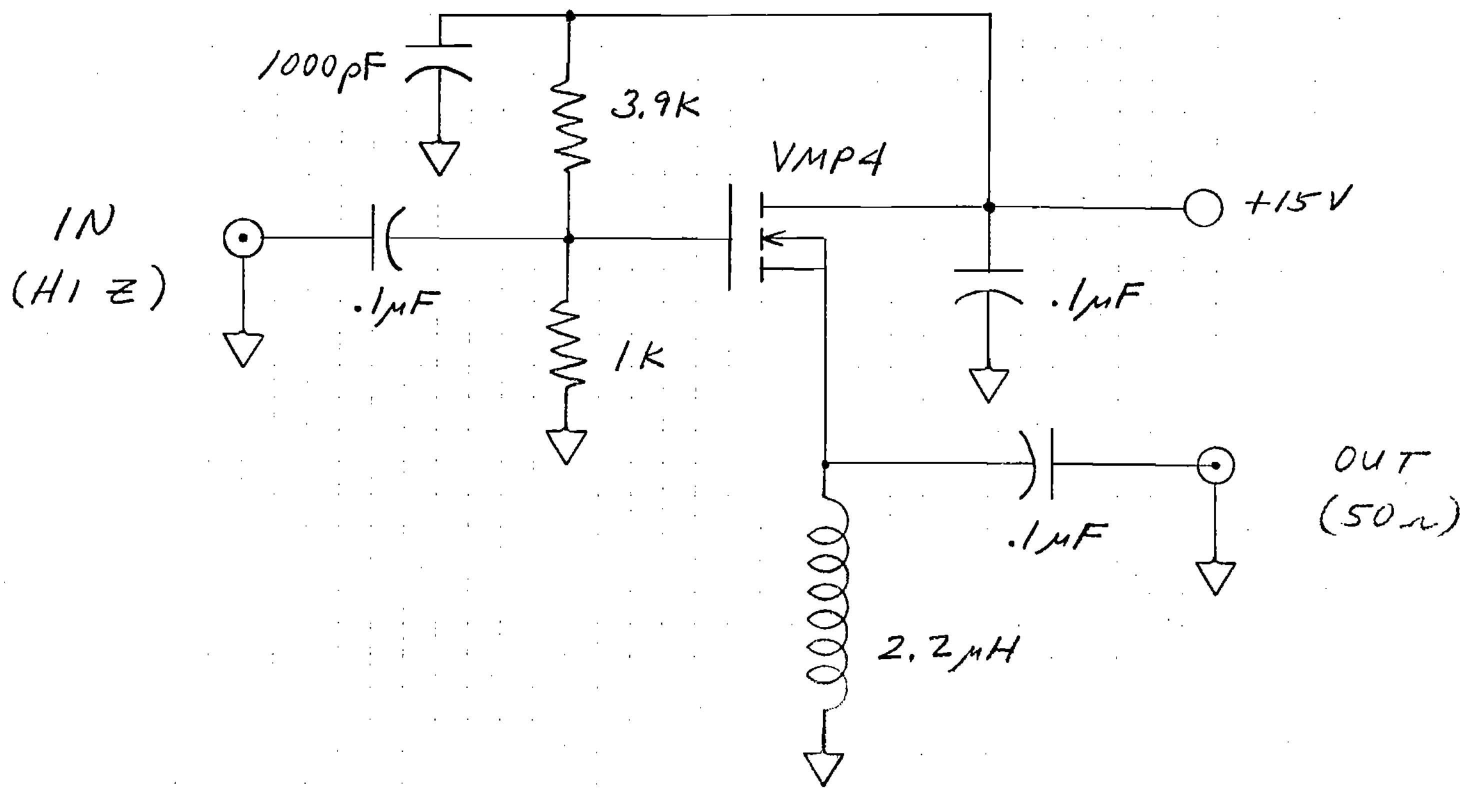

φ (°)
VOLTS OUT
CKT 2A
CKT 2B
CKT 1
-300
-200
-100
0
PHASE
CKTS 2A & 2B
CKT 1
7 8 9 10 2 3 4 5 6 7 8 9 100
f (MHz)

FIG 2


"DAMN FAST" AMP TEST CKT
.22μH
X1
5Ω
50Ω
FIG 3
"DAMN FAST" AMP RESPONSE
V_o (V_{rms})
2.5
2.0
1.5
1.0
.5
VOLTS OUT
FIG 4
PHASE
-20
-10
0
7 8 9 10
2
3
4
5
6
7
8
9
100
f (MHz)


GAIN AMP + "DAMNFAST"
X10
X1
50Ω
FIG 5
7-70MHz GAIN AMP + "DAMNFAST" RESPONSE
VOLTS OUT
PHASE
FIG 6
V_o (V_{rms})
ϕ_o (°)
f(MHz)
5.0
4.0
3.0
2.0
1.0
-30
-20
-10
0
7
8
9
10
2
3
4
5
6
100



7-70MHz VMOSFET BUFFER AMP

FIG 7

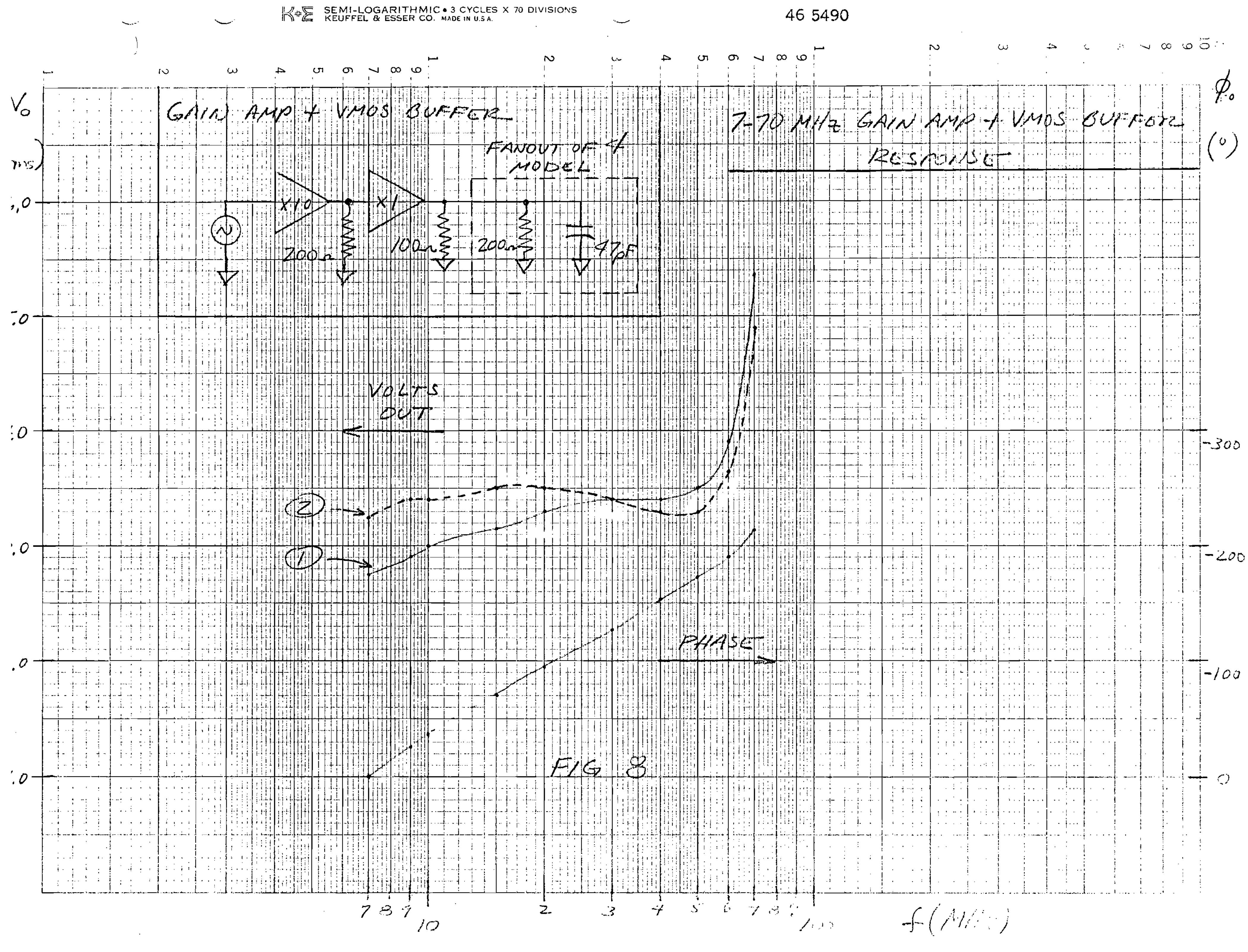
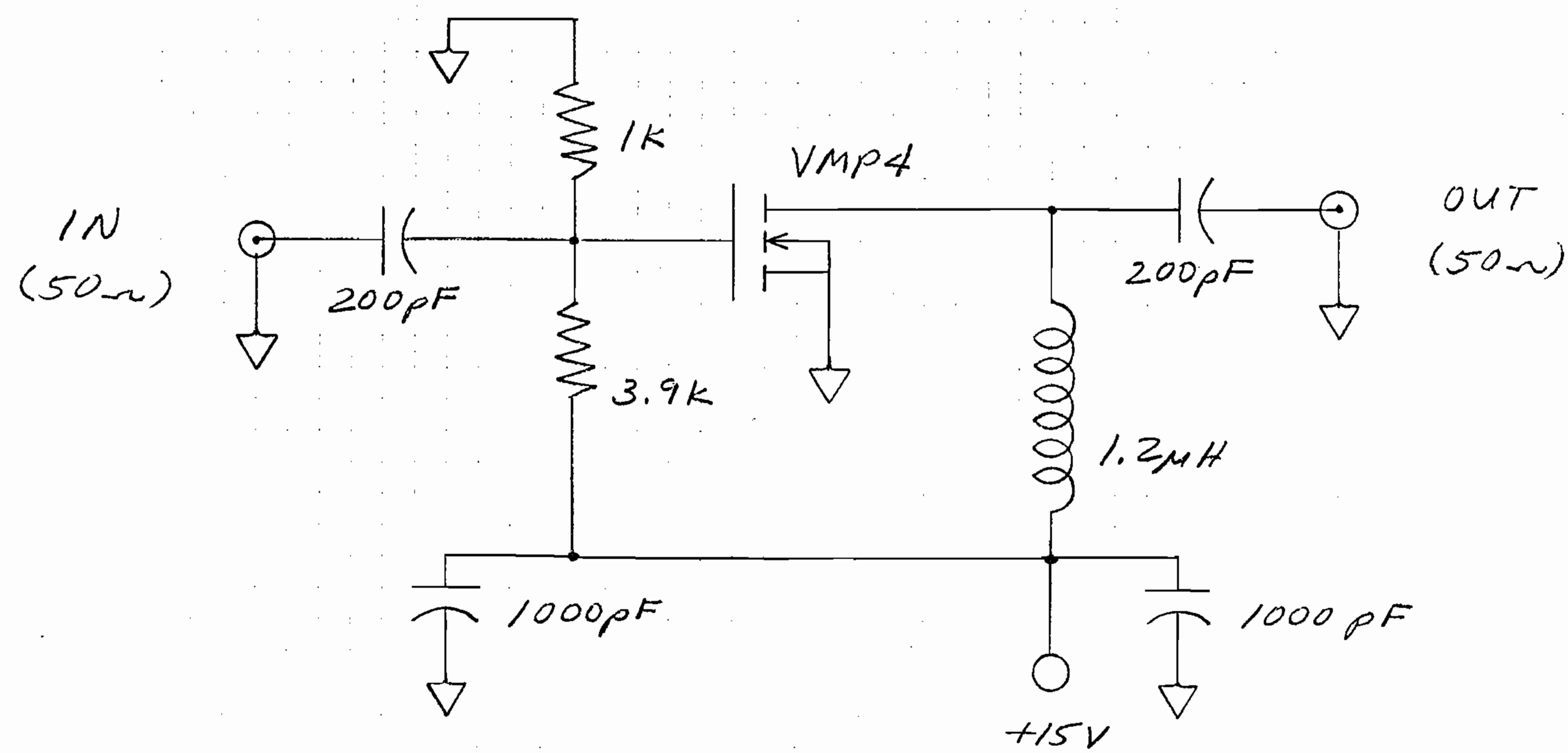

7-70 MHz GAIN AMP + VMOS BUFFER RESPONSE
GAIN AMP + VMOS BUFFER
FANOUT OF 4 MODEL
X10
X1
200Ω
100Ω
200Ω
47pF
VOLTS OUT
PHASE
V₀ (rms)
φ₀ (°)
f (MHz)
-300
-200
-100
0

FIG 8



135-210 MHz GAIN AMP

FIG 9

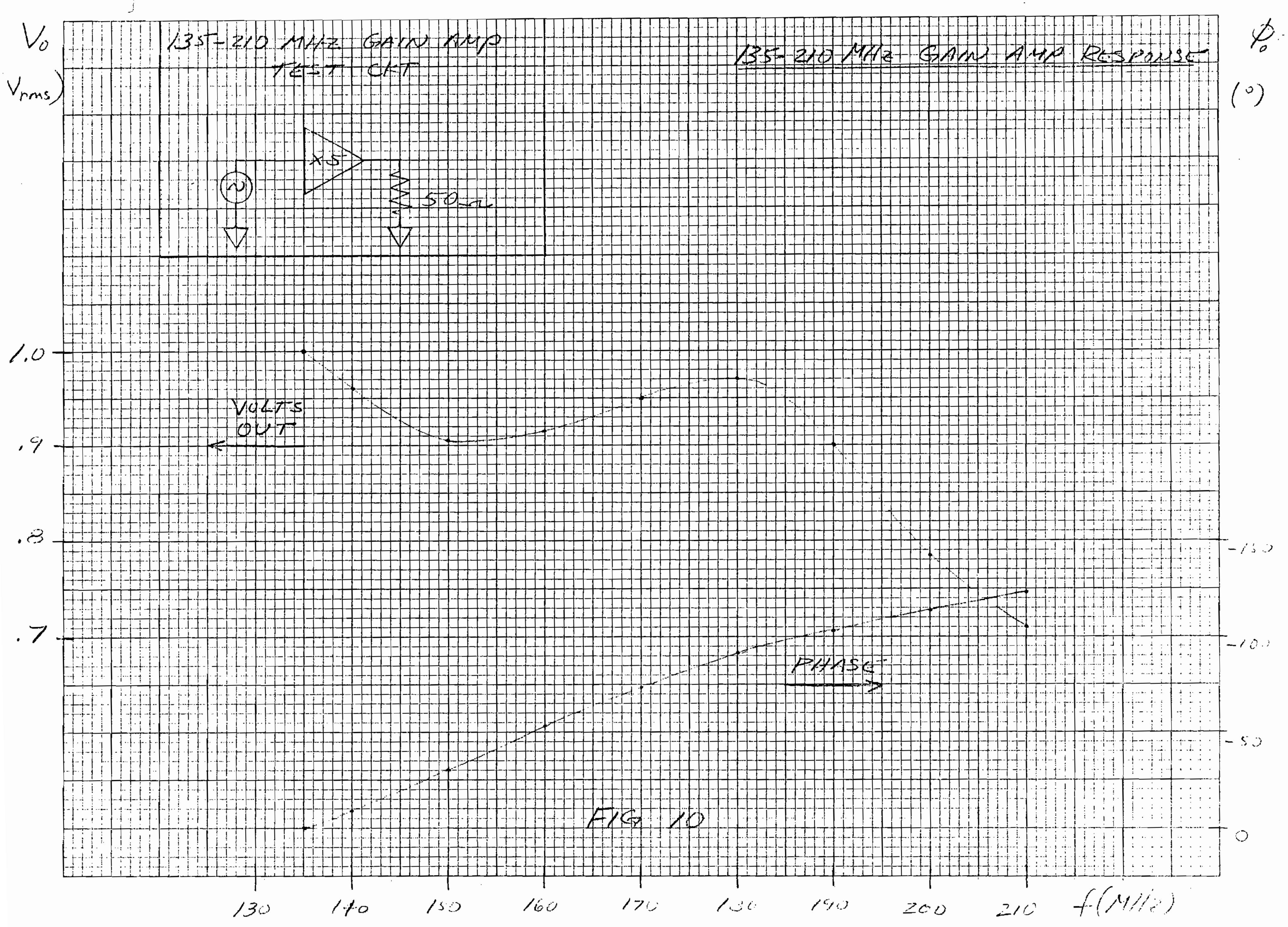
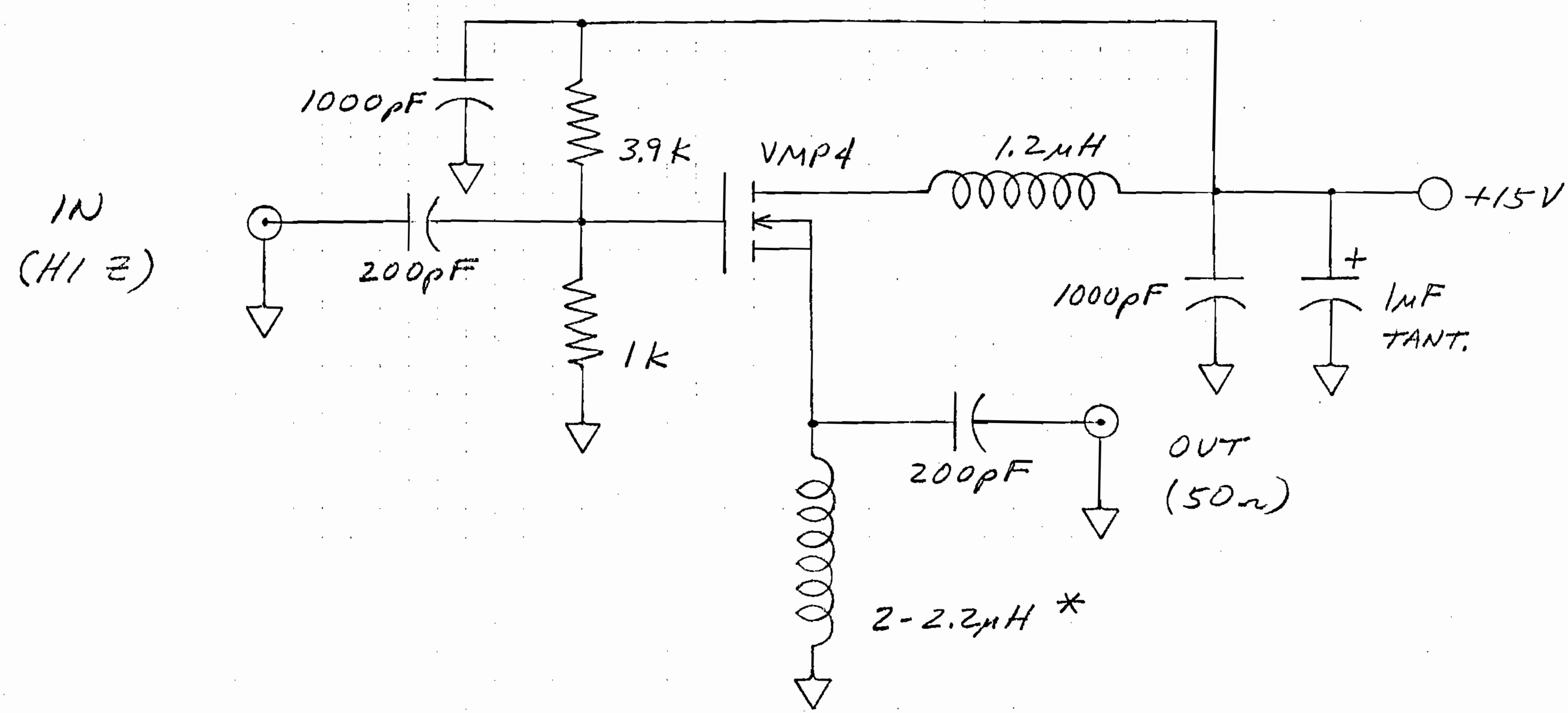

135-210 MHz GAIN AMP
TEST CKT
X5
50Ω
135-210 MHz GAIN AMP RESPONSE
V0
Vrms)
1.0
.9
.8
.7
VOLTS
OUT
PHASE
φ0
(°)
-150
-100
-50
0
130
140
150
160
170
180
190
200
210
f(MHz)

FIG 10



* ONE 2.2µH choke from each source Lead to ground.

135-210 MHz BUFFER AMP

FIG 11

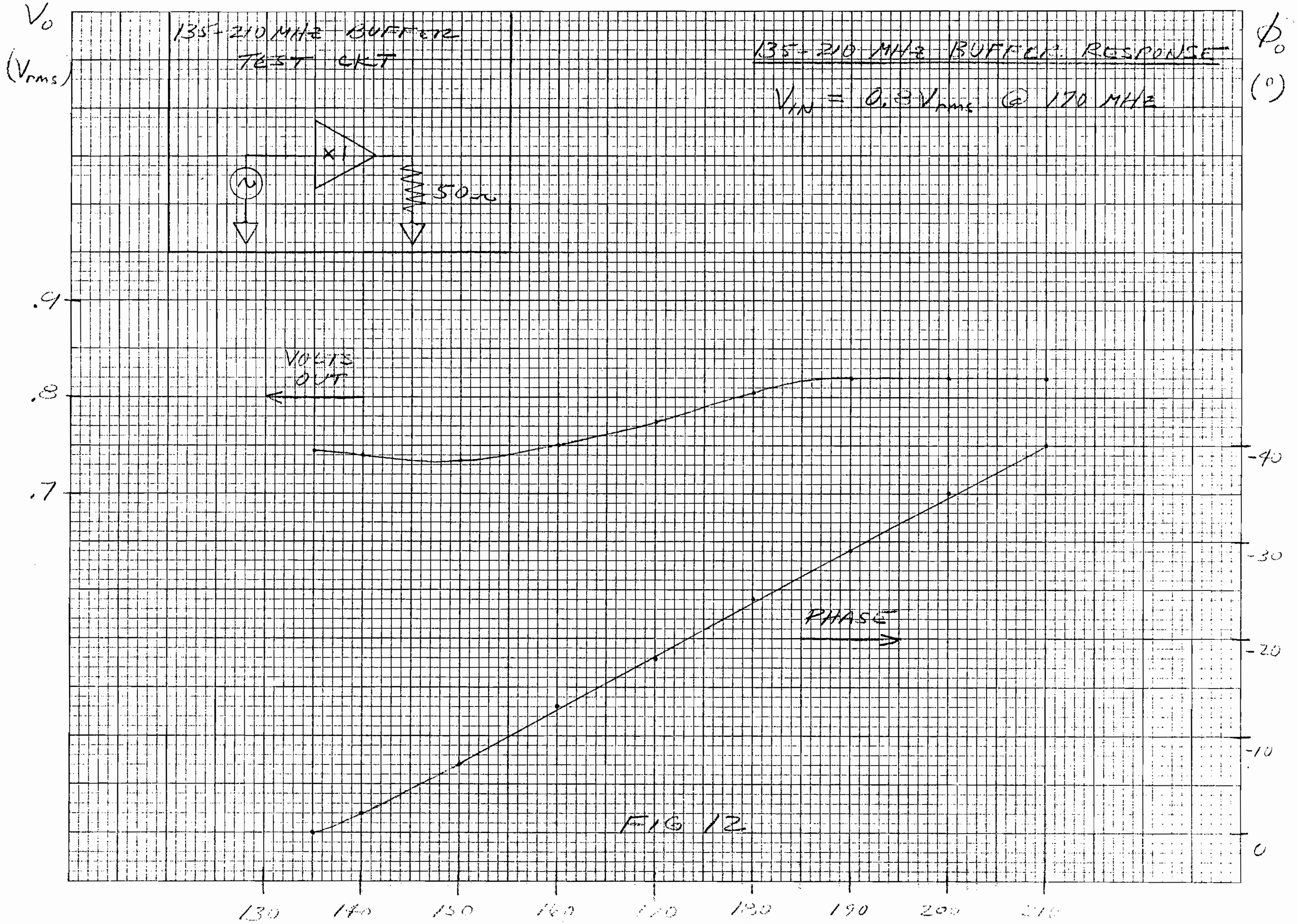

V_o
(V_{rms})
135-210 MHz BUFFER
TEST CKT
x1
50Ω
135-210 MHz BUFFER RESPONSE
V_{IN} = 0.8 V_{rms} @ 170 MHz
ϕ_o
(°)
.9
.8
.7
VOLTS
OUT
PHASE
-40
-30
-20
-10
0
130
140
150
160
180
190
200

FIG 12

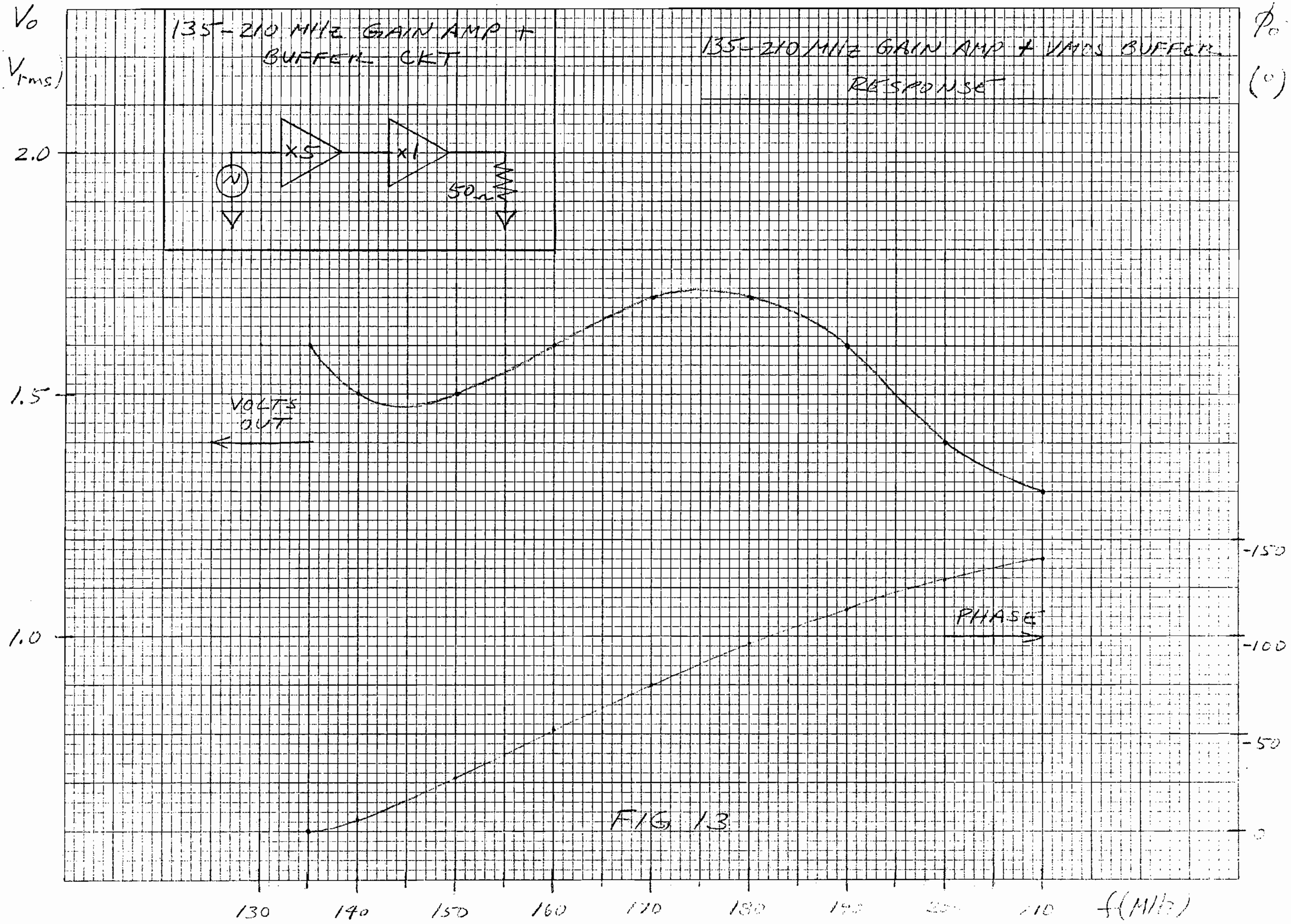

135-210 MHz GAIN AMP + BUFFER CKT
135-210 MHz GAIN AMP + VMOS BUFFER RESPONSE
Vo
Vrms)
2.0
1.5
1.0
×5
×1
50Ω
VOLTS OUT
PHASE
Φo
(°)
-150
-100
-50
0
130
140
150
160
170
180
210
f(MHz)

FIG. 13

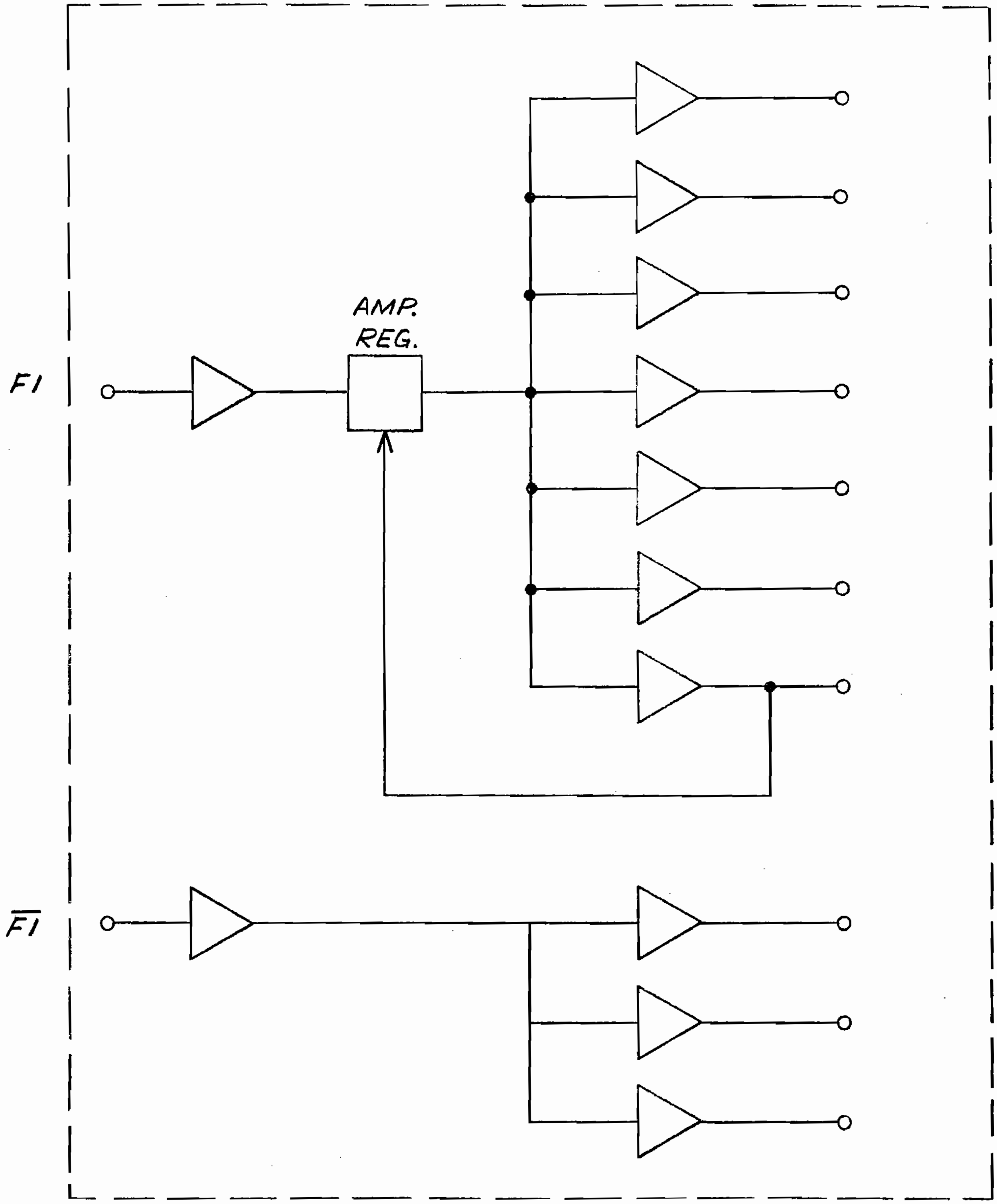


FIG. 14

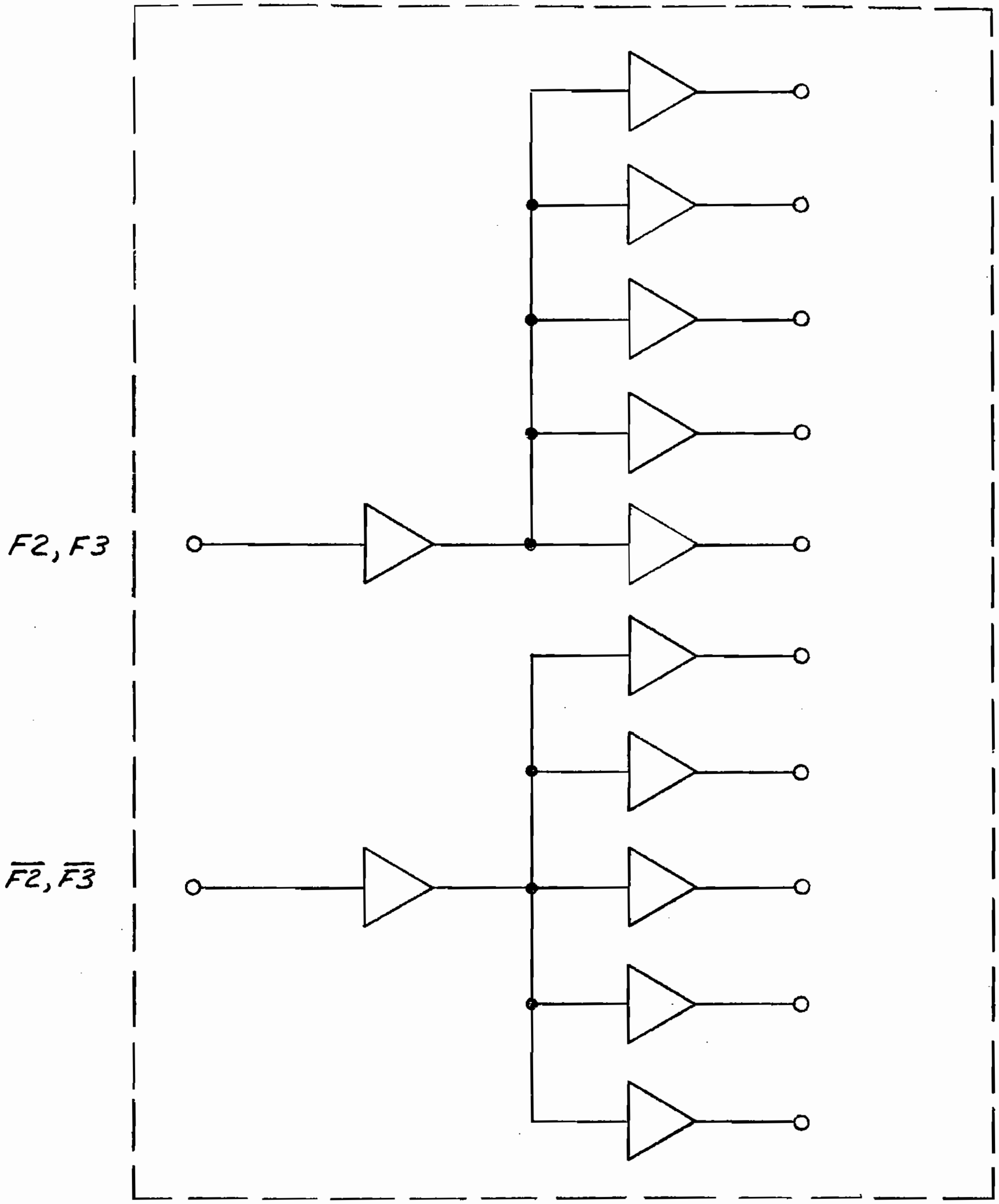
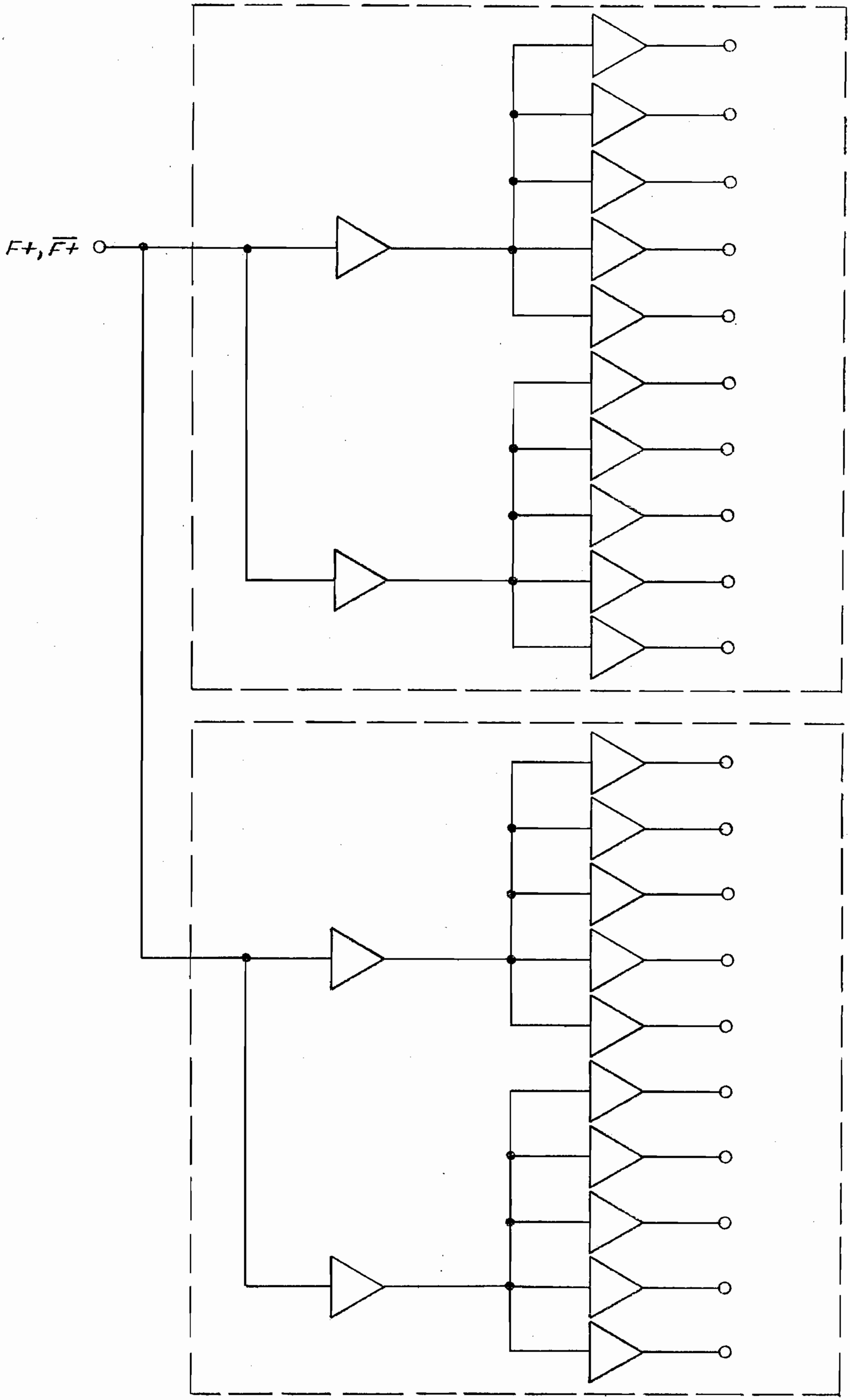


FIG. 15


$F+, \overline{F+}$

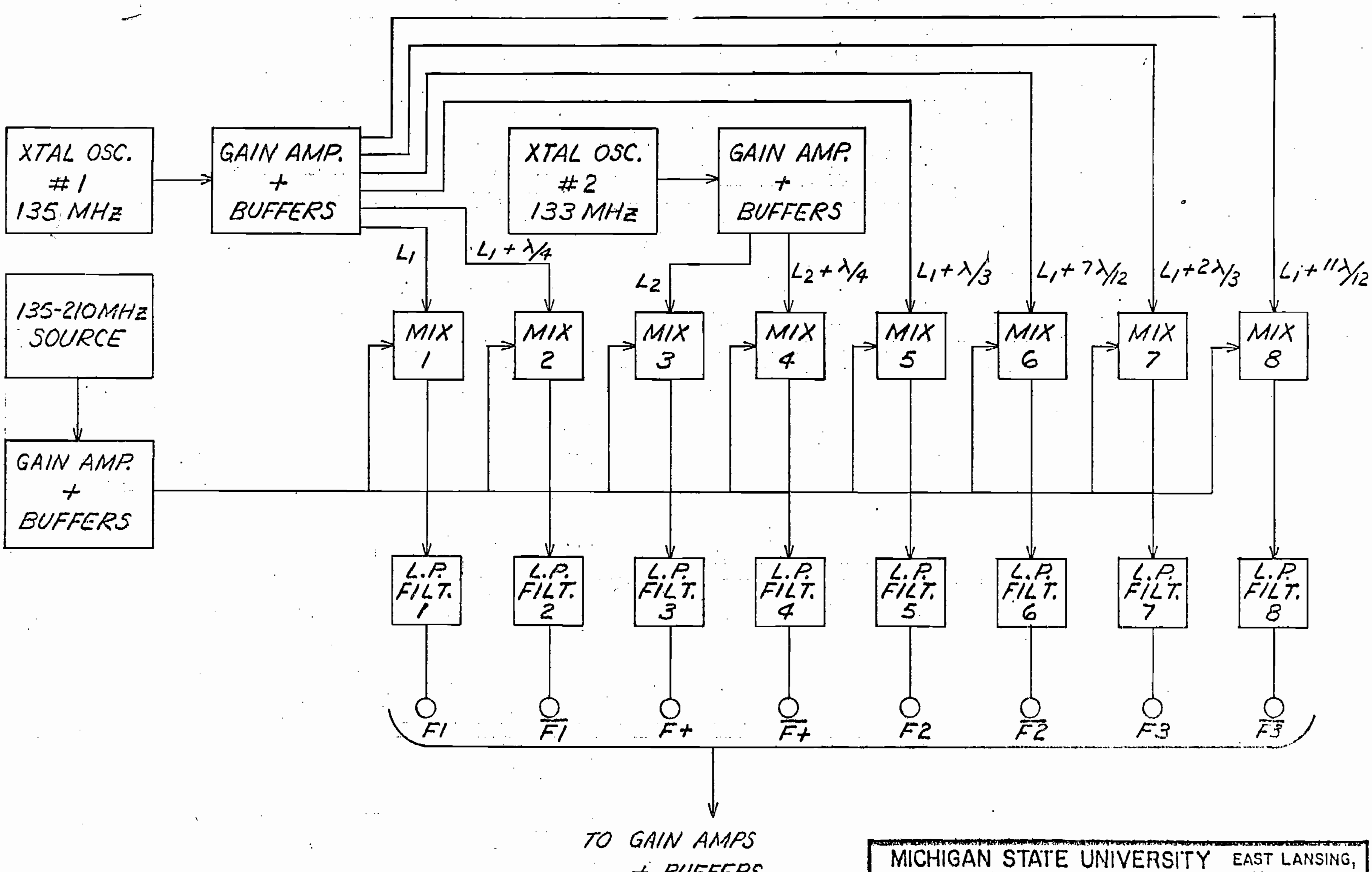


FIG. 17

MICHIGAN STATE UNIVERSITY CYCLOTRON LABORATORY			EAST LANSING, MICHIGAN
	SCALE —	DRN BY WS	REV'D
FREQUENCY SYNTHESIZER			
DATE 7-19-78	APPR'D BY	DRAWING NO. 5-REK-1K-1-A	REV 1