R.F. Note 81

March 15, 1982
Toshi Miyanaga

2 MHZ MIXER - PHASE DETECTOR AND PHASE DETECTING ERROR

Contents:

1. INTRODUCTION

The history of the development of 2 MHZ MIXER-PHASE DETECTOR can be traced by refering to the RF Notes listed in Appendix 1.

When I took charge of these modules from another enginner (March '81), the scheme was fixed, all parts for the production of over 10 modules were purchased, and the work order for the fabrication was in the electronics shop.

While I was working with the final prototype module in order to learn about the functions of each circuit, the fabrication was completed for 13 modules of QUAD 2 MHZ MIXERS and 8 modules of QUAD PHASE DETECTORS.

After simple tests with the criterion being that a proper output signal is obtained, 9 MIXER's and 6 PHASE DETECTOR's modules were installed in the RF console.

Since then, many problems such as improper operation of RF OK signals or phase detection errors have been found with those circuits. Complicated modifications and adjustments were completed for the threshold level of RF-OK signals and for the offset of PHASE DETECTOR outputs.

Because of these modifications, the arrangement of the parts mounted on the PHASE DETECTOR boards have become excessively complicated, mixed up, and over-crowded.

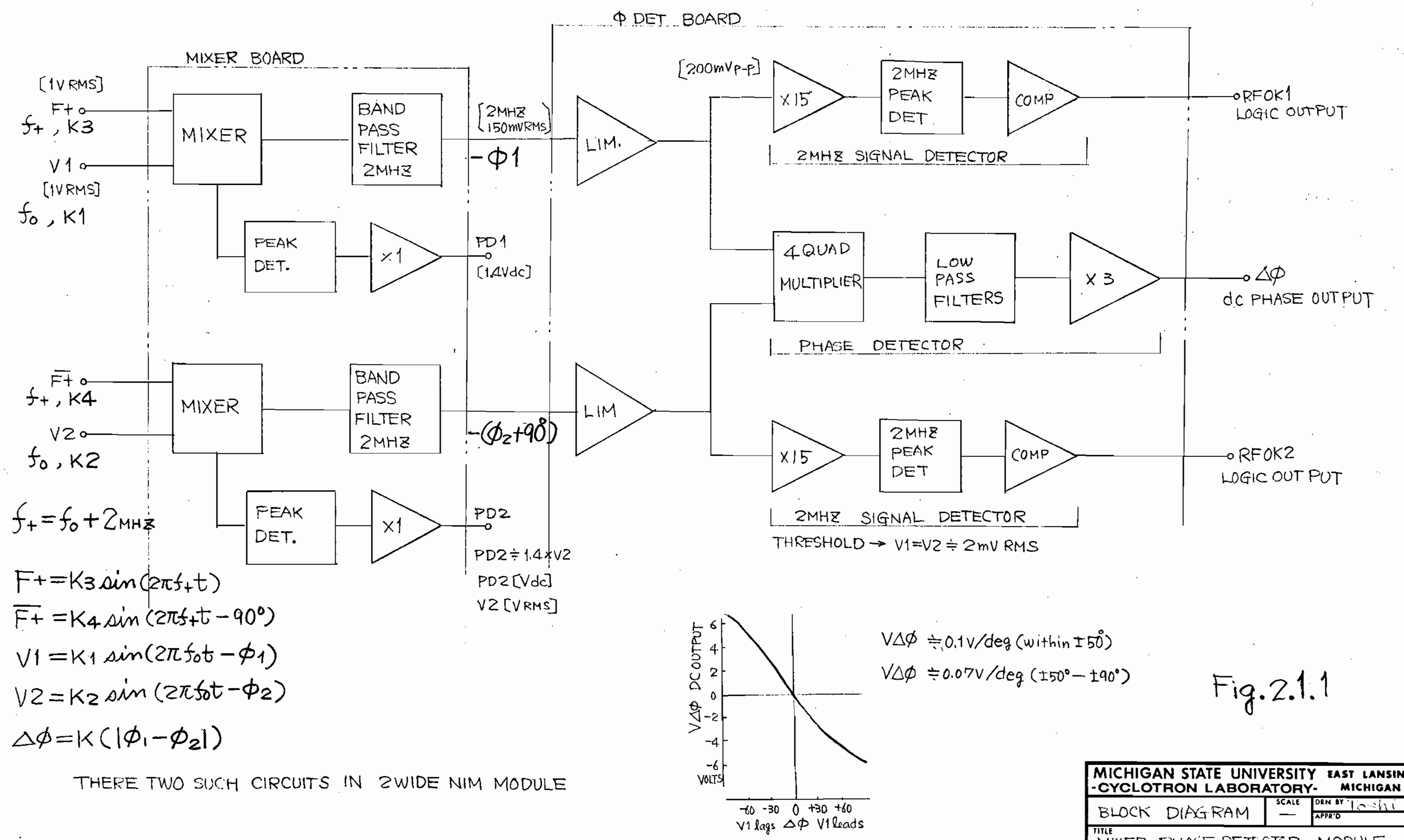
Finally, as a solution to the problem, I proposed the new MIXER/PHASE DETECTOR module that was designed such that adjustment of the offset and of the threshold level of RF-OK signal would be simple and easy. Furthermore the new design would allow a reduction of the number of the cable connections on the face of the RF control console.

In sections 3 and 4, the specifications, the performance that was obtained during the modifications, and the adjustments are presented. These results will be the inspection criteria of the new MIXER/PHASE DETECTOR module.

Finally, the problem of the phase detecting error is described in section 5 along with some ideas for its correction.

2. SCHEME OF PHASE DETECTION

The 2MHZ MIXERs (MIXER) and the PHASE DETECTORS (ϕ-DETECTOR) were fabricated in single width NIM modules with each module containing 4 circuits. They are used for phase detection in the various tuning servos of the RF system.



$f_+ = f_0 + 2\text{MHz}$

$F+ = K_3 \sin(2\pi f_+ t)$

$\overline{F+} = K_4 \sin(2\pi f_+ t - 90°)$

$V1 = K_1 \sin(2\pi f_0 t - \phi_1)$

$V2 = K_2 \sin(2\pi f_0 t - \phi_2)$

$\Delta\phi = K(|\phi_1 - \phi_2|)$

THERE TWO SUCH CIRCUITS IN 2WIDE NIM MODULE

Fig. 2.1.1

MICHIGAN STATE UNIVERSITY -CYCLOTRON LABORATORY- EAST LANSING, MICHIGAN			
BLOCK DIAGRAM	SCALE —	DRN BY Toshi	APPR'D
TITLE MIXER-PHASE DETECTOR MODULE			
DATE 9-16-81	SHEET 1 of 1	DRAWING NO.	REV.

BRUNING 40-22 45265

The input signals to MIXERs come from the DEE voltage, the anode or the grid RF voltages of the transmitter and so on. These signals are mixed with F+(Fo+2 MHZ) or $\overline{F+}$(90^o shifted from F+ signal) from the buffer amplifiers in the frequency synthesizer; the 2 MHZ signals that contain the phase information are then fed to the ϕ-DETECTORS.

The signals to the mixers from the various points in the RF system undergo amplitude variations up to 1000 to 1. For example, the range is approximately 10 mV to 8 V RMS at the DEE voltage. This variation allows for the DEE to be tuned from the multipactoring level up to 100 kV. Limiting amplifiers following the MIXER handle this wide range without introduction of phase errors.

The output of the MIXER has frequency components of f+ + fo, f+ - fo, and higher order terms. The filtered output signal, however, is only f+ - fo = 2 MHZ and contains the phase information referred to F+ or $\overline{F+}$ signal. Also, the MIXER modules supply DC outputs proportional to the peak RF signals. These signals are used as the monitors of the RF signals from the various points of the RF system. They go to the meter panel of on the face of the RF console through the status signal junction panel.

Thus from the MIXERs, a pair of 2 MHZ signals that would be 90^o out of phase if the input signals were in phase are connected to the ϕ-DETECTOR inputs. The limiting amplifiers change these signals to square waves of 0.2V p-p with constant amplitude over a very wide amplitude range of 2 MHZ signals.

The phase detected output ($\Delta\phi$) which is generated by the IC 4 Quad multiplier goes to the appropriate servo circuit for tuning. The 2 MHZ signal detecting logic outputs (RF-OK signals) also go the same servo circuit so that the function of the servo can be halted when the RF signals are off.

Figure 2.1.1 shows the block diagram of this scheme with the signal levels and the simplified equations to express the signal relationship.

3. PERFORMANCE OF 2 MHZ MIXER

3.1 Nature of Output at 2 MHZ

Figure 3.1.1 and 3.1.2 show the input-output relationship of a 2 MHZ MIXER. The output is filtered by the 2 MHZ Band Pass Filter (Bandwidth is 1 MHZ). The saturated curves with higher input amplitude show the so called "output compression regions"; here, the frequency conversion losses are high. However, the linear region can be expanded by increasing the level of F+($\overline{F+}$) signal.

The peak detector outputs are plotted in Fig. 3.1.3. This output is buffered by a unity gain operational amplifier. In the original modules, the output pin was connected directly To the output connector and, as a result, some of the OP-amp IC's were burned out by the oscillation that was caused by the capacitance of the loading cable. A feed back capacitor of 10 pf and the series resistor of 51Ω at the output was needed to eliminate the oscillation.

3.2 Crosstalk and Isolation.

Generally, the isolation is a measure of the circuit balance within the mixer and the crosstalk in the wiring.

There was a significant crosstalk problem at the input between the BNC connector and the soldering post on the MIXER PC board. A twisted pair was employed; the measured isolation (F+ → 2 MHZ output) was about -40 dB. The isolation value of -40 dB means that 10 mV RMS of F+($\overline{F+}$) signal at the 2 MHZ output line was obtained when 1 V RMS F+($\overline{F+}$) reference signal was used. This value of 10 mV is enough to turn on the RF-OK signal of the ϕ-DETECTOR circuit, since the threshold for that logic signal is set at less than 1 mV sensitivity for operation of the phase servos.

To reduce this crosstalk, the input connection was replaced with RG-178/U coaxial cable instead of a twisted pair and the ground lugs of the panel mounted BNC connector were replaced with 2 leg ones; these legs were bent closely and symmetrically to the center conductor.

The adjustments of the balancing resistors between the diodes were made at the 1 V RMS level while the isolation of F+($\overline{F+}$) to the V_{in} port was being measured.

The resulting isolation achieved went up to -80 dB (F+ → 2 MHZ output) and -65 dB (F+ → V_{in}).

3.3 2MHZ Band-Pass Filter

The scheme and the characteristics were described in RF Note #35. Some of the pairs of filters used 10% accuracy components had a phase difference in excess of 10°. The offset adjustment of the ϕ-DETECTOR circuit can conceal these phase errors; however, by the selection of components with 1% accuracy, a close phase difference within 1° can be realized. Some of the modules existing in the RF console were adjusted to within a 2° difference temporarily by an additional capacitor (130 pf) in one of the pair of filter circuits.

The filters rebuilt or adjusted within 1° difference will be mounted in the New MIXER/ϕ-DETECTOR.

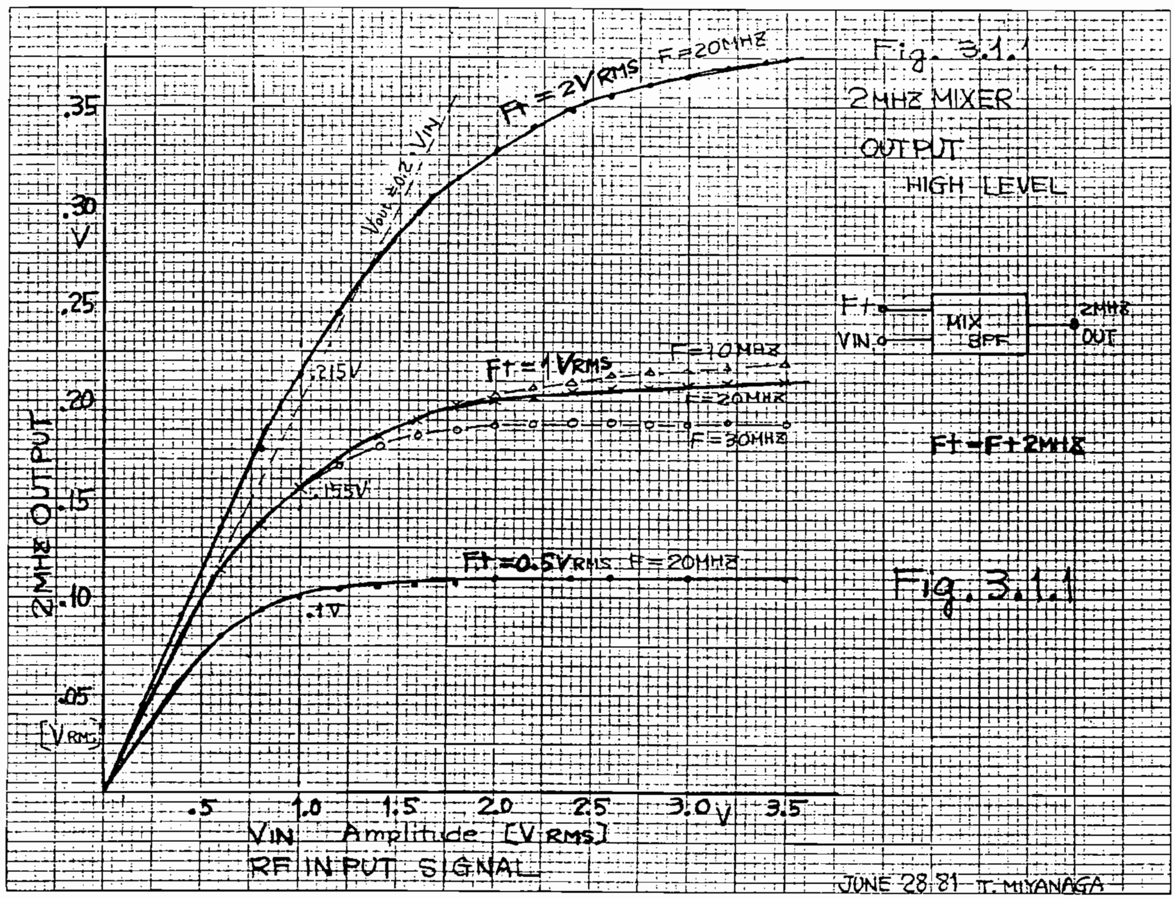


Fig. 3.1.1
2MHz MIXER
OUTPUT
HIGH LEVEL
Ft = 2VRMS F=20MHz
Vout = 0.2 VIN
Ft = 1VRMS
F=10MHz
F=20MHz
F=30MHz
Ft = 0.5VRMS F=20MHz
.215V
.155V
.1V
Ft
VIN
MIX
BPF
2MHz OUT
Ft - F ± 2MHz
2MHz OUTPUT [VRMS]
.35
.30
.25
.20
.15
.10
.05
.5
1.0
1.5
2.0
2.5
3.0
3.5
VIN Amplitude [VRMS]
RF INPUT SIGNAL
JUNE 28 '81 T. MIYANAGA

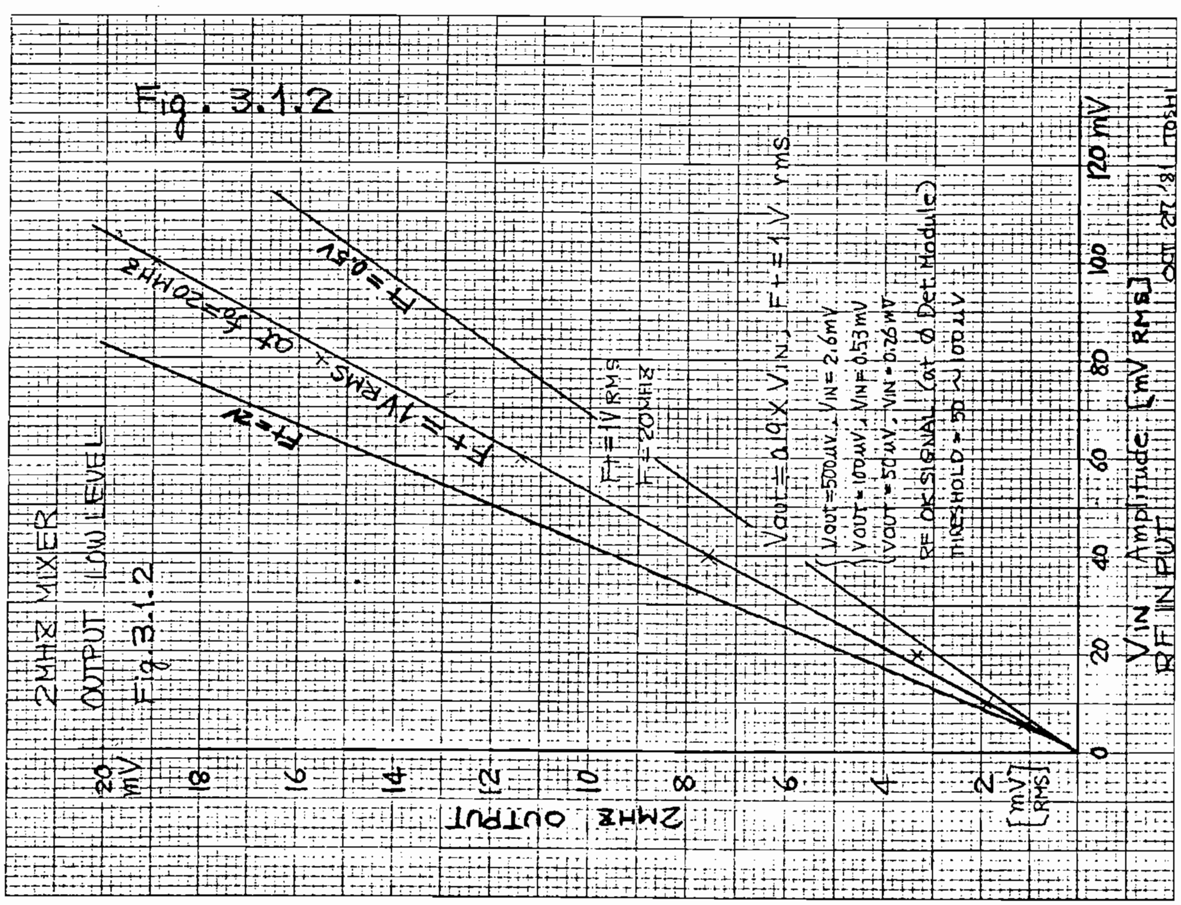


Fig. 3.1.2
2MHz MIXER
OUTPUT LOW LEVEL
Fig. 3.1.2
Ft = 0.5V
Ft = 1VRMS, F = 20MHz
Ft = 2V
Ft = 1VRMS
F = 20MHz
Vout = 0.10 X VIN, Ft = 1V rms
Vout = 500μV, VIN = 2.6mV
Vout = 100μV, VIN = 0.53mV
Vout = 50μV, VIN = 0.26mV
RF OK SIGNAL (at Det Module)
THRESHOLD = 50 ~ 100μV
2MHz OUTPUT [mV RMS]
20 mV
18
16
14
12
10
8
6
4
2
0
20
40
60
80
100
120 mV
VIN Amplitude [mV RMS]
RF INPUT
OCT 27 '81 TOSHI

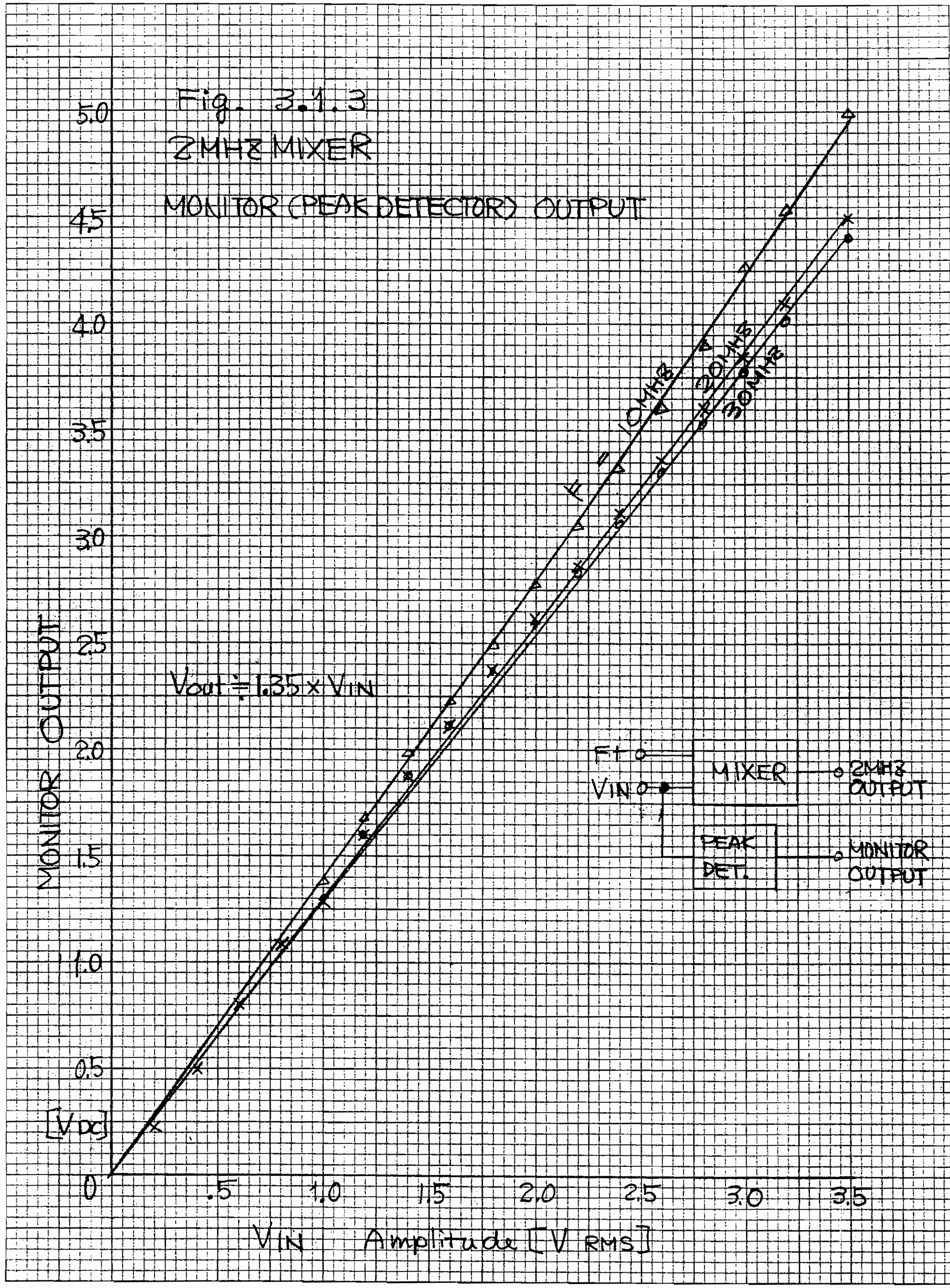


Fig. 3.1.3
2MHz MIXER
MONITOR (PEAK DETECTOR) OUTPUT
Vout ≒ 1.35 × VIN
F = 10MHz
20MHz
30MHz
Ft
VIN
MIXER
2MHz OUTPUT
PEAK DET.
MONITOR OUTPUT
MONITOR OUTPUT [VDC]
VIN Amplitude [V RMS]
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0

JAN 18 '82

2MHZ MIXER INPUT IMPEDANCE

Balance adjustment at 1V RMS

>RUN

08:51 JAN 18 VVMIMP... F+ = 0.5Vrms

V1	V2	02	Z	P	A	+ j B
9.10E-03	5.00E-03	-2.15°	60.9	-4.77°	60.6	-5.06
1.80E-02	1.00E-02	-2.60	62.3	-5.84	62.0	-6.34
9.00E-02	5.00E-02	-2.00	62.4	-4.50	62.2	-4.89
.180	.100	-2.20	62.4	-4.94	62.1	-5.38
.930	.500	-.600	58.1	-1.30	58.1	-1.32
1.97	1.00	-1.40	51.5	-2.84	51.5	-2.55
4.10	2.00	0.00°	47.6	-1.78E-14°	47.6	-1.48E-14

09:25 JAN 18 VVMIMP... F+ = 1Vrms

V1	V2	02	Z	P	A	+ j B
9.80E-03	5.00E-03	.100°	52.1	.204°	52.1	.186
1.95E-02	1.00E-02	-.200	52.6	-.411	52.6	-.377
9.98E-02	5.00E-02	.400	50.2	.802	50.2	.702
.198	.100	.200	51.0	.404	51.0	.360
1.00	.500	1.20	50.0	2.40	49.9	2.09
2.01	1.00	-.300	49.5	-.597	49.5	-.516
4.10	2.00	-.500°	47.6	-.976°	47.6	-.811

09:28 JAN 18 VVMIMP... F+ = 1.5Vrms

V1	V2	02	Z	P	A	+ j B
9.90E-03	5.00E-03	.800°	51.0	1.62°	51.0	1.44
2.02E-02	1.00E-02	.400	49.0	.792	49.0	.678
.101	5.00E-02	1.00	49.0	1.98	49.0	1.69
.200	.100	.900	50.0	1.80	50.0	1.57
1.03	.500	1.70	47.1	3.30	47.1	2.72
2.08	1.00	.600	46.3	1.16	46.3	.934
4.10	2.00	1.10°	47.6	2.15	47.6	1.78

09:31 JAN 18 VVMIMP... F+ = 2Vrms

V1	V2	02	Z	P	A	+ j B
2.00E-02	1.00E-02	.700°	50.0	1.40°	50.0	1.22
.102	5.00E-02	1.30	48.1	2.55	48.0	2.14
.204	.100	1.20	48.1	2.35	48.0	1.97
1.04	.500	2.20	46.2	4.23	46.1	3.41
2.08	1.00	1.10	46.3	2.12	46.2	1.71
4.20	2.00	1.60°	45.4	3.05°	45.4	2.42

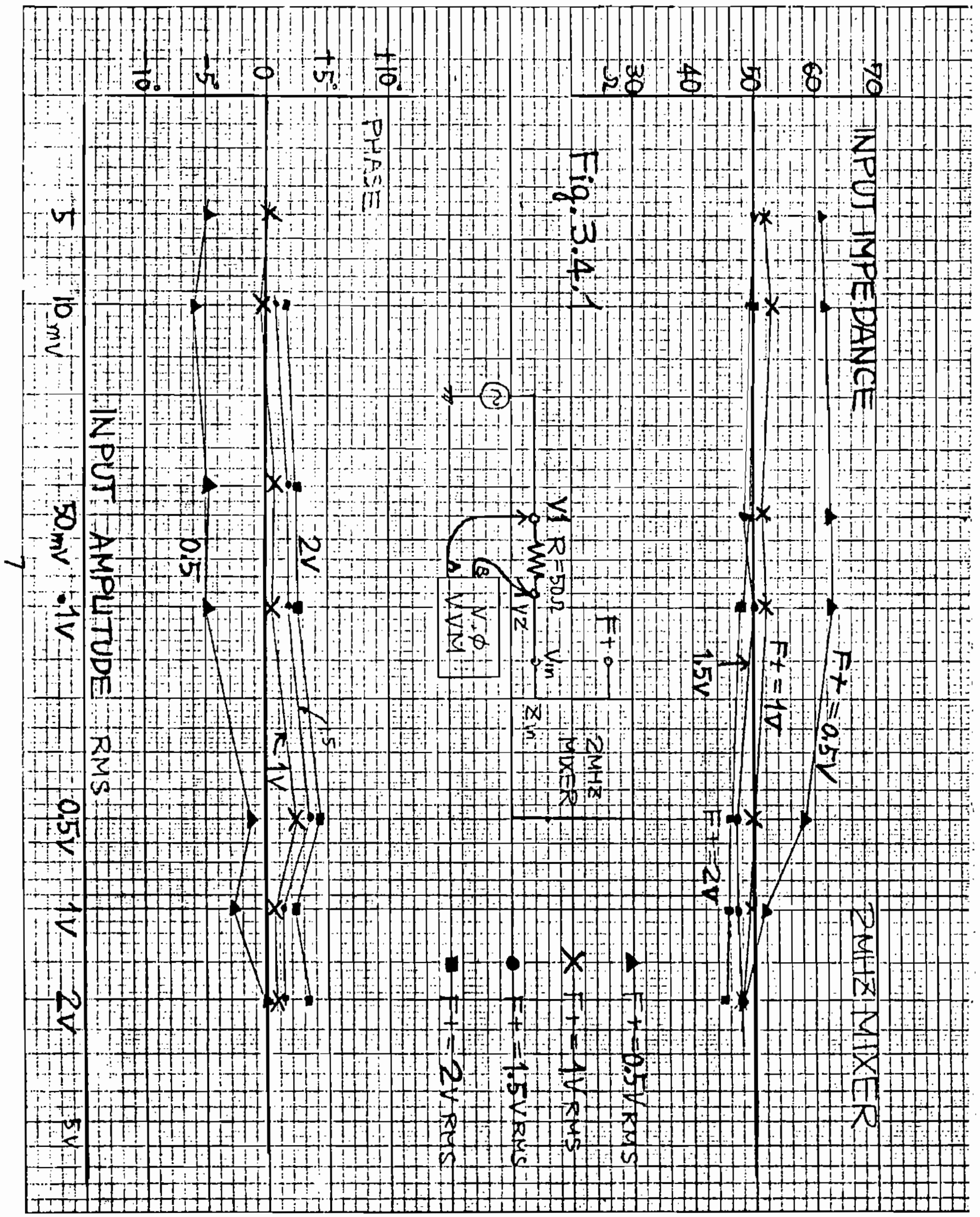


Fig. 3.4.1

3.4 Input Impedance

The input impedance of the MIXER varies by a large factor with the amplitude of the F+($\overline{F+}$) signal, but only slightly with the amplitude of the input signal. The conventional impedance meter that uses a fixed signal level for the RF source is useless for this measurement.

The measurements were performed with a vector voltmeter that could read the voltage across a known value of resistance connected in series with the input. The input impedance at the various amplitude levels was calculated vectorally from the measured voltages across the series resistor.

The measuring scheme and results are presented in Fig. 3.4.1.

4. PERFORMANCE OF PHASE DETECTOR

The circuit that was described in RF Note #35 is being used except for some modificaton of the signal detection scheme used for the RF-OK signal. The performance for most of the circuit was presented in that RF Note. Here, the typical characteristics that were measured with newly fabricated module are presented.

4.1 Phase Detector Output

The output response of the ϕ-Detector over the range of $\pm 180^{\circ}$ is plotted in Fig. 4.1.1. The portions of the curve that are near the zero-crossing point and that may be considered linear can be expressed as;

$$V_{out} = 0.1 \times (\Delta\phi \pm 90^{\circ}).$$

The zero-crossing points of the curve indicate the in-phase (0°) and the out-of-phase (180°) detecting points for V_1 and V_2 to the MIXERs because of the 90° phase difference between F+ and $\overline{F+}$. If the polarity required for the servo system associated with a Phase Detector, for example, corresponds to 180° rather than 0° operation, the polarity of the phase detecting curve can be reversed by switching the F+ and $\overline{F+}$ signals.

4.2 Limiting Amplifier and RF-OK Signal Detection

Figure 4.2.1 shows the peak-detector characteristic of the limiting amplifier with FET buffer and diodes; the output level is nearly constant above 500 μV for 2 MHZ input, although the shape of the square wave output from the limiting amplifier changes slightly as the input amplitude is varied.

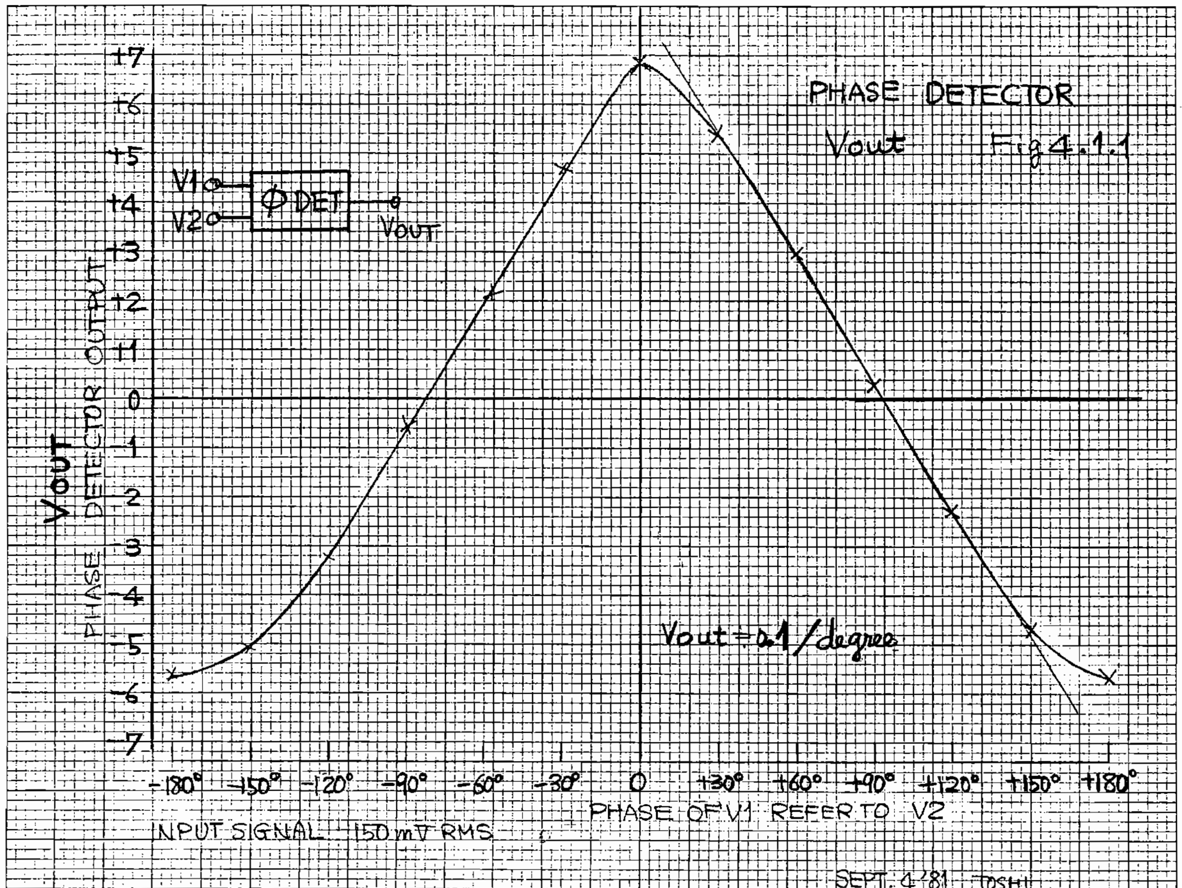
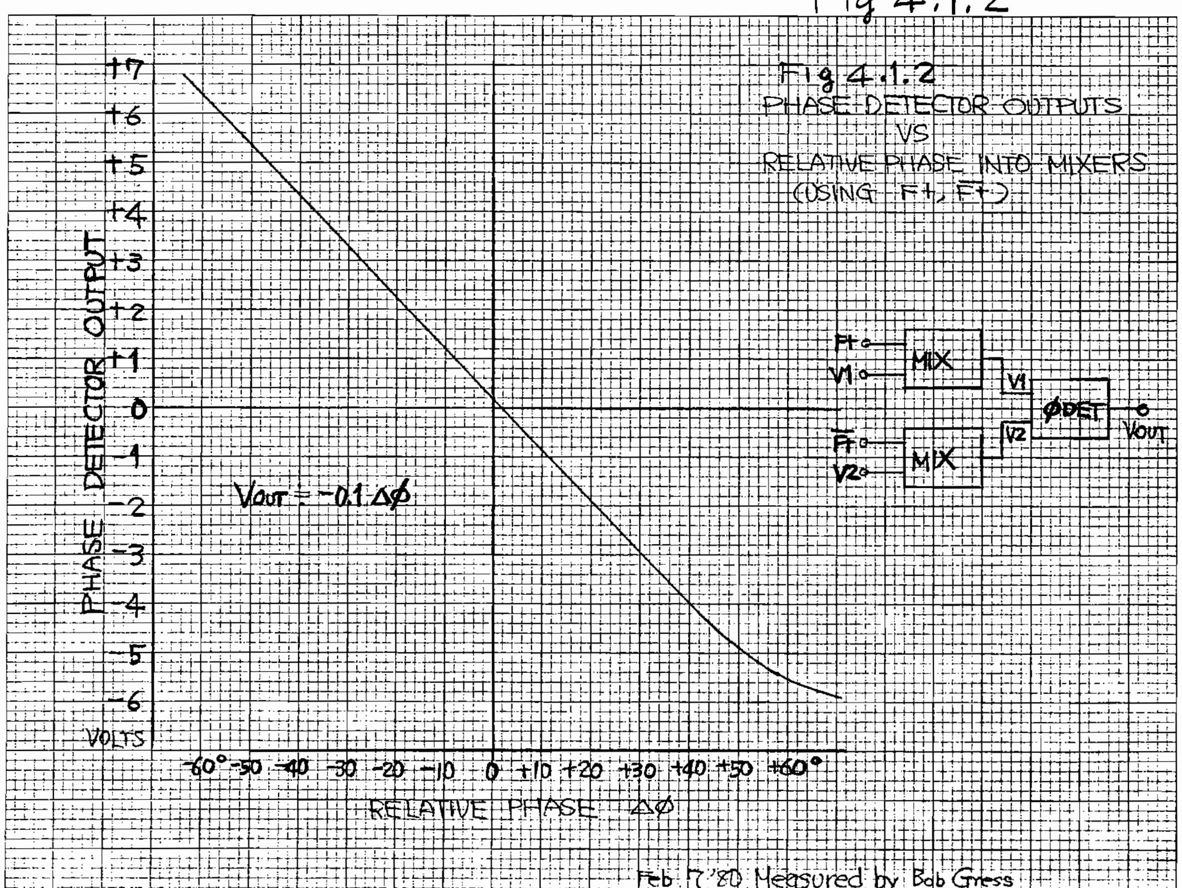


Fig. 4.1.1

Fig 4.1.2



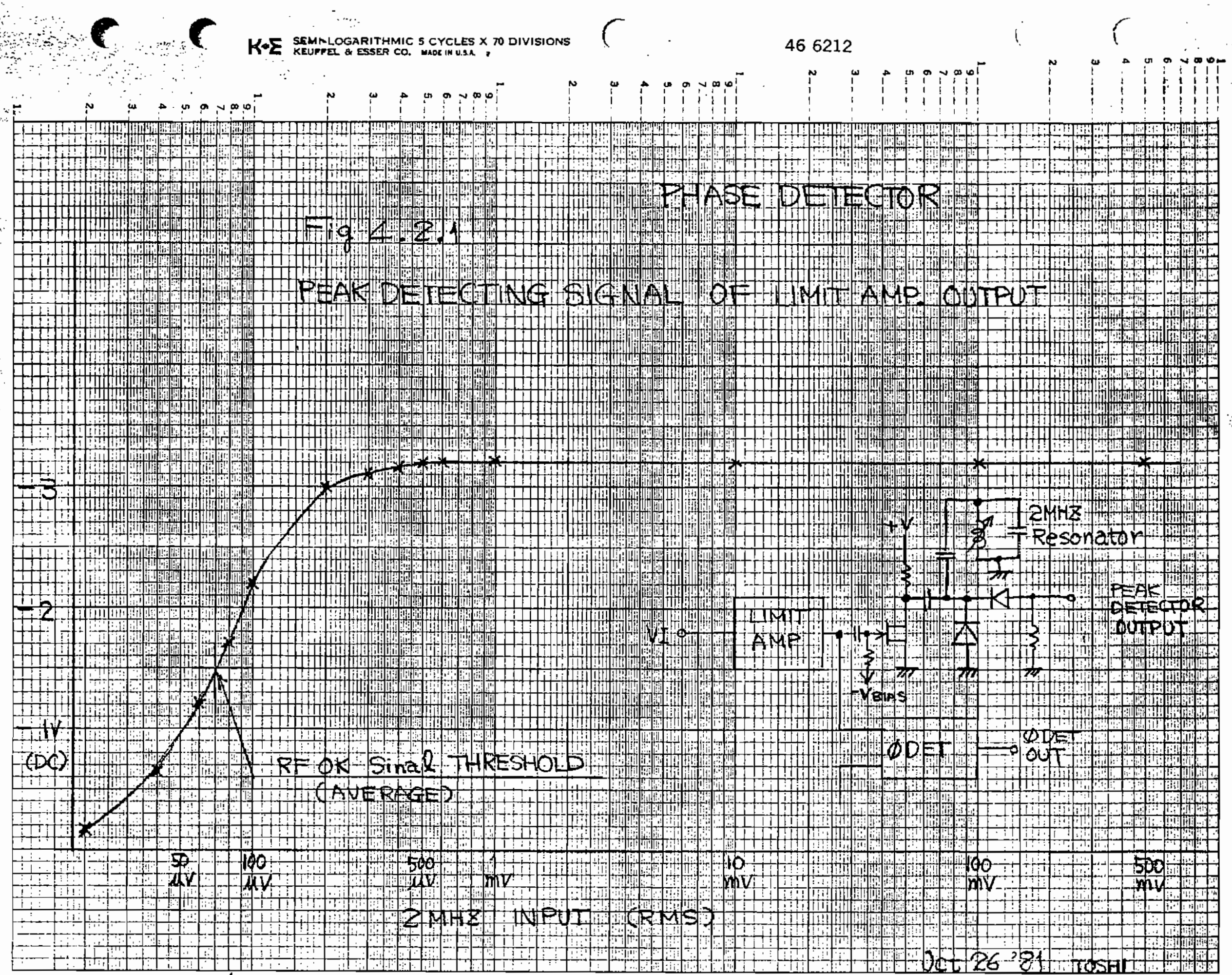
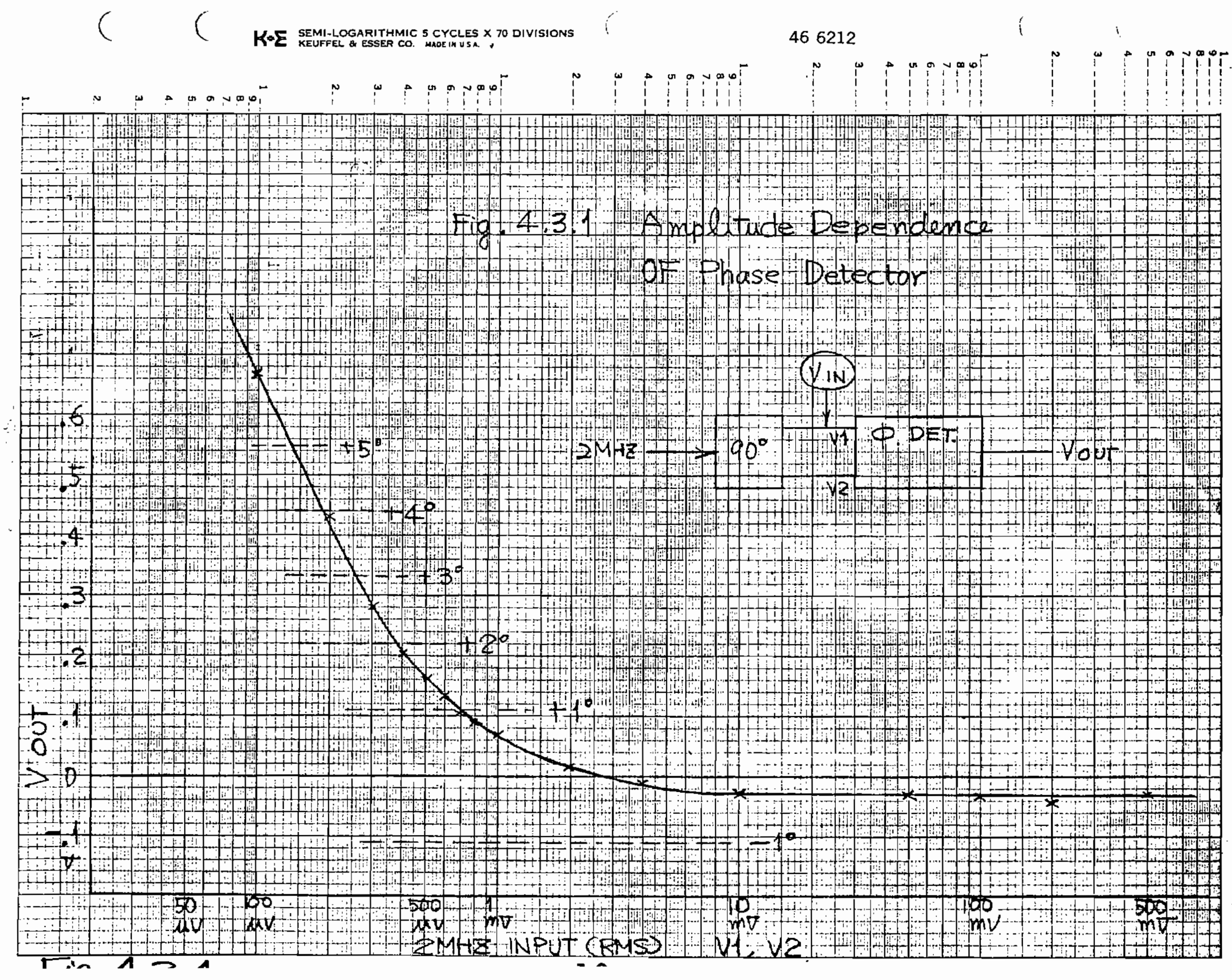

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6212
PHASE DETECTOR
Fig 4.2.1
PEAK DETECTING SIGNAL OF LIMIT AMP. OUTPUT
-3
-2
-1V
(DC)
RF OK Sinal THRESHOLD
(AVERAGE)
+V
2MHz
Resonator
PEAK
DETECTOR
OUTPUT
V1
LIMIT
AMP
-VBIAS
ØDET
ØDET
OUT
50 μV
100 μV
500 μV
1 mV
10 mV
100 mV
500 mV
2MHz INPUT (RMS)
Oct 26 '81 TOSHI

Fig 4.2.1


K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6212
Fig. 4.3.1 Amplitude Dependence
OF Phase Detector
VIN
2MHz
90°
V1
V2
Φ. DET.
Vout
+5°
+4°
+3°
+2°
+1°
-1°
.6
.5
.4
.3
.2
.1
0
-.1
V
V OUT
50 μV
100 μV
500 μV
1 mV
10 mV
100 mV
500 mV
2MHz INPUT (RMS) V1, V2

This peak detector signal is used in the RF-OK logic circuit to turn on the servo circuit when its input amplitude, the phase error signal, goes over the threshold level. The threshold level is set around 100 μV (-67 dBm) for 2 MHZ input making it extremely sensitive. Even though there is a 2 MHZ Band-Pass Filter at the output of the MIXER and overall cross-talk inside the MIXER is less than -70 dB, enough amplitude to turn on the RF-OK signal can be obtained, if 1 V RMS (+13 dBm) F+ signal is fed to the MIXER. This value leads to a 300 μV (-57 dBm) signal input to the limiting amplifier which has a high gain up to higher frequency of the F+ signal.

This behaviour was the first problem found when the MIXER/ϕ-DET's were set up at the RF console. The threshold level could be set to a higher level, for example to 400 μV, then the discrimination margin was only 100 μV against the very wide operation range from 1 mV to 1 V input level. This small margin could not deal with the noise level of the limiting amplifier (S/N ratio 60 db at 1 V input) or even the temperature dependence of the peak detector circuit included with FET buffer. Consequently it was the experience that the RF-OK signal did not turn on even if high enough amplitude of RF signal came in to the MIXER.

In order to solve this problem, some other schemes of the signal detection had been attempted but intricate modification to existing modules had been avoided. A parallel resonant circuit was added between the FET buffer and the peak detecting diodes as shown in Fig. 4.2.1. The selectivity of this scheme helped to avoid the misoperation of the RF-OK signal detector successfully, although a resonant circuit was used at the square wave signal detector.

4.3 Amplitude Dependence of Phase Detection

The amplitude dependence of the ϕ-Detector is plotted in Fig. 4.3.1. At 2 MHZ, the phase detector error was within one degree in the range of 1 mV to 1 V RMS input, and within 0.2 degree in the range of 10 mV to 1 V rms input. The error at low level is caused mainly by the characteristics of the limiting amplifier.

5. PHASE DETECTING ERROR

Repeatedly since test operation of the complete RF system began, phase detecting errors have been found. Each time an error was observed, correction was attempted by adjustment of the offset of the Phase Detector circuit. It takes about 2 hours to adjust all 15 phase detectors, in large part, because all of the trimmer pots are mounted deep inside in the module case. Many BNC connectors mounted on the small area of the module panel in a highly dense manner have to be removed in order to pull out the modules from the NIM-BIN. Further, the circuits have to be adjusted while they are hanging in a very unsatisfactory condition on these same cables among the great mass of other cable connections. Hence, it was necessary in the new MIXER/PHASE DETECTOR to make convenient the offset adjustment and the threshold level adjustment of RF-OK logic signal without having to pull the modules.

5.1 Drift of MIXER/ϕ-DETECTOR

The curves of Fig. 5.1.1 show that the drift of the ϕ-DETECTORs combined with MIXERs have excellent characteristics over a 15 hour drift of less than 0.1 degree. It was mentioned above that an analog multiplier has a relatively large drift with temperature. However, the drift is not a problem. The new MIXER/ϕ-DETECTOR module will use the same IC. To reduce drift, some improvements were incorporated such as a configuration with carefully selected low temperature effect capacitors in the filters and the resonator at 2 MHZ. In addition, the variable range of the trim pots were narrowed suitably for the offset or gain and bias adjustments.

5.2 Input Impedance of Various Circuits

One problem that caused phase detection errors was found to be the mismatching of the input impedance of modules in the RF control system to the 50Ω transmission lines.

The RF monitor signals of the DEE voltages are divided by splitters enroute to the MIXER and to the 3ϕ Digital Phase Meter. As described previously, MIXERs present an input impedance of $50\pm3\Omega$, $\pm3^{o}$ over a very wide amplitude range. The input impedance of the 3 ϕMeter had a large amplitude dependence as shown below.

Amplitude of Input Signal	50 mV RMS	0.1 V	0.5 V	1V
Impedance	88.4Ω	85.7	16.4Ω	12.3Ω
Phase	-9.98^{o}	-7.60^{o}	$+31^{o}$	$+46.7^{o}$

As a result, the 3ϕ Meter indicated an error of about 10^{o} and gave a bad error of over 7^{o} to the MIXER/ϕ-DETECTORs.

The input impedance of 3ϕ Meter was improved to $50\pm1\Omega$, $\pm0.1^{o}$ over a wide amplitude range. This improvement was accomplished by an increase in the amplitude of the local oscillator signal to the commercial mixer (DBM SRA-1) and by adding an additional resistive attenuator at the input.

PHASE DETECTOR 15 hours DRIFT   Dec 17 '81

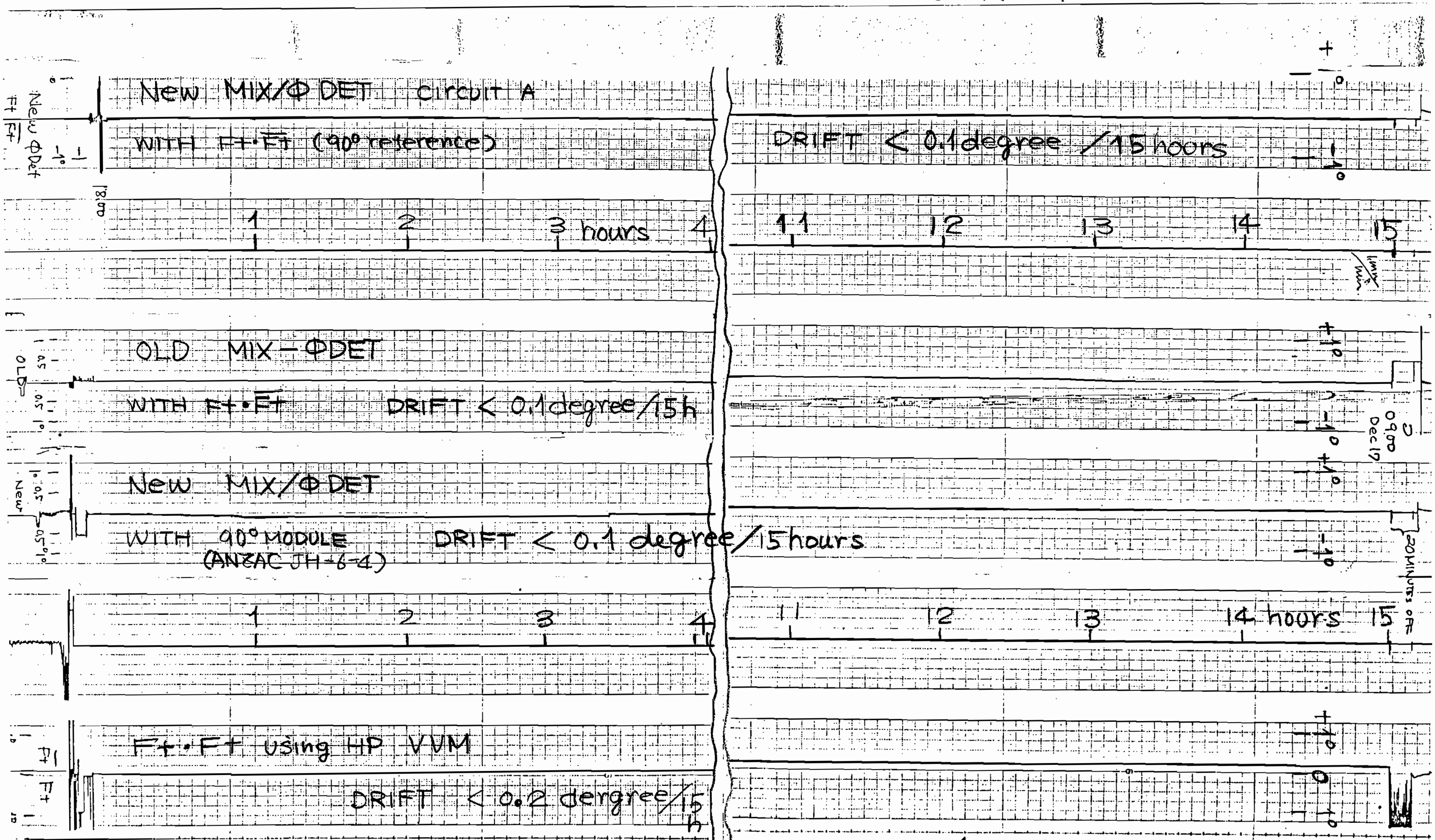


Fig. 5.1.1

Also, the forward power detecting signals of the Directional Couplers are shared between the Peak Detector modules and the MIXER. The input impedance of the Peak Detector was measured to be close enough to 50Ω.

5.3 Overall Amplitude Dependence

The phase detector with the limiting amplifiers has an amplitude dependence as described in section 4.3 and Fig. 4.3.1.

Figure 5.3.1 and 5.3.2 show the amplitude dependence of the ϕ-DETECTOR with the MIXER measured in the configuration shown by the block diagram. F+ and $\overline{F+}$ signals were fixed in amplitude at 1 V RMS; the amplitude scale of the graph is the reading of the voltmeter at the A input.

The results that were measured when the amplitude at the A and B inputs were equal are plotted as curve 1 of Fig. 5.3.2. The errors in the amplitude of less than 10 mV are assumed to be caused by the original amplitude dependence fo the limiting amplifier and the cross-talk noise of MIXER at low level.

The B inputs were attenuated 3dB for curve 2 and 10dB for curve 3 in Fig. 5.3.2. The phase detection errors were obvious at high input amplitude (around 0.8V). The amplitude dependence of the MIXER outputs measured by the vector voltmeter agreed with the curves in Fig. 5.3.2.

The amplitude fo the MIXER output displayed a saturated region for various amplitudes of F+ (or $\overline{F+}$) signal as shown in Fig. 3.1.1. When the amplitude dependence was measured using the configuration shown in Fig. 5.3.2, in which, the input to a pair of MIXERs was changed equally and simultaneously through the output saturation region (output compression region), the phase errors were cancelled as is shown in curve 1. In the other cases, in which only one of a pair reached the compression region, the phase errors remained.

Curves for the amplitude dependence of the phase error with various amplitudes of F+ (or $\overline{F+}$) are shown in Fig. 5.3.3. The curve for F+ = 0.5 V shows it is completely out of the question. For the higher amplitudes of F+ (or $\overline{F+}$) signal, the phase errors were considerably reduced.

Hence, for small phase errors, the amplitude of F+ (and $\overline{F+}$) signal must be high enough to switch the mixer diodes and to keep the amplitude of the RF signal in the linear region of the MIXER output vs input curve. The proposed amplitude of F+ and $\overline{F+}$ were 5 V RMS as described on RF Note #28; however, the maximum output of the existing system is 1.2 V RMS working into 50Ω impedance.

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6010

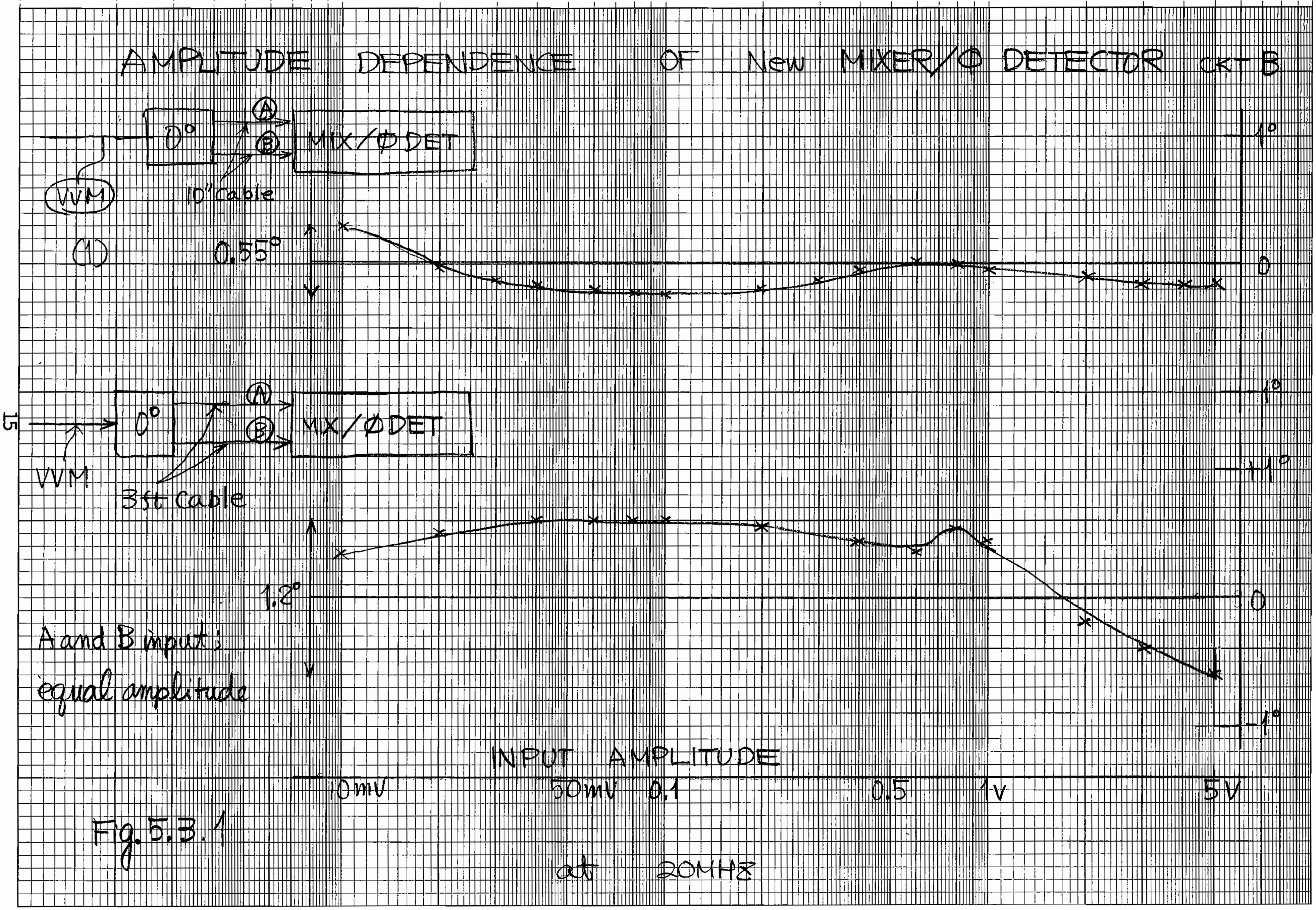


Fig. 5.3.1

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 6010

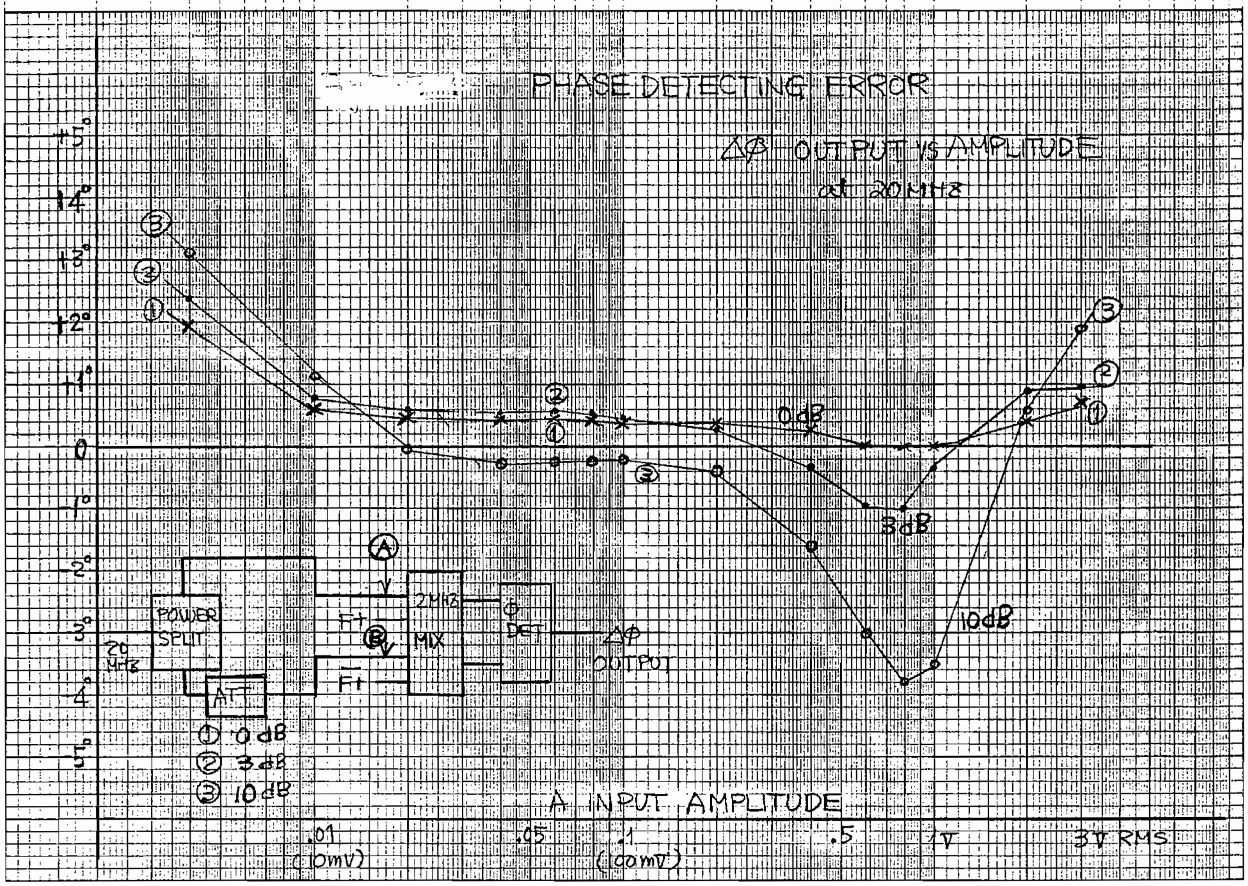


Fig 5.3.2

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 6010

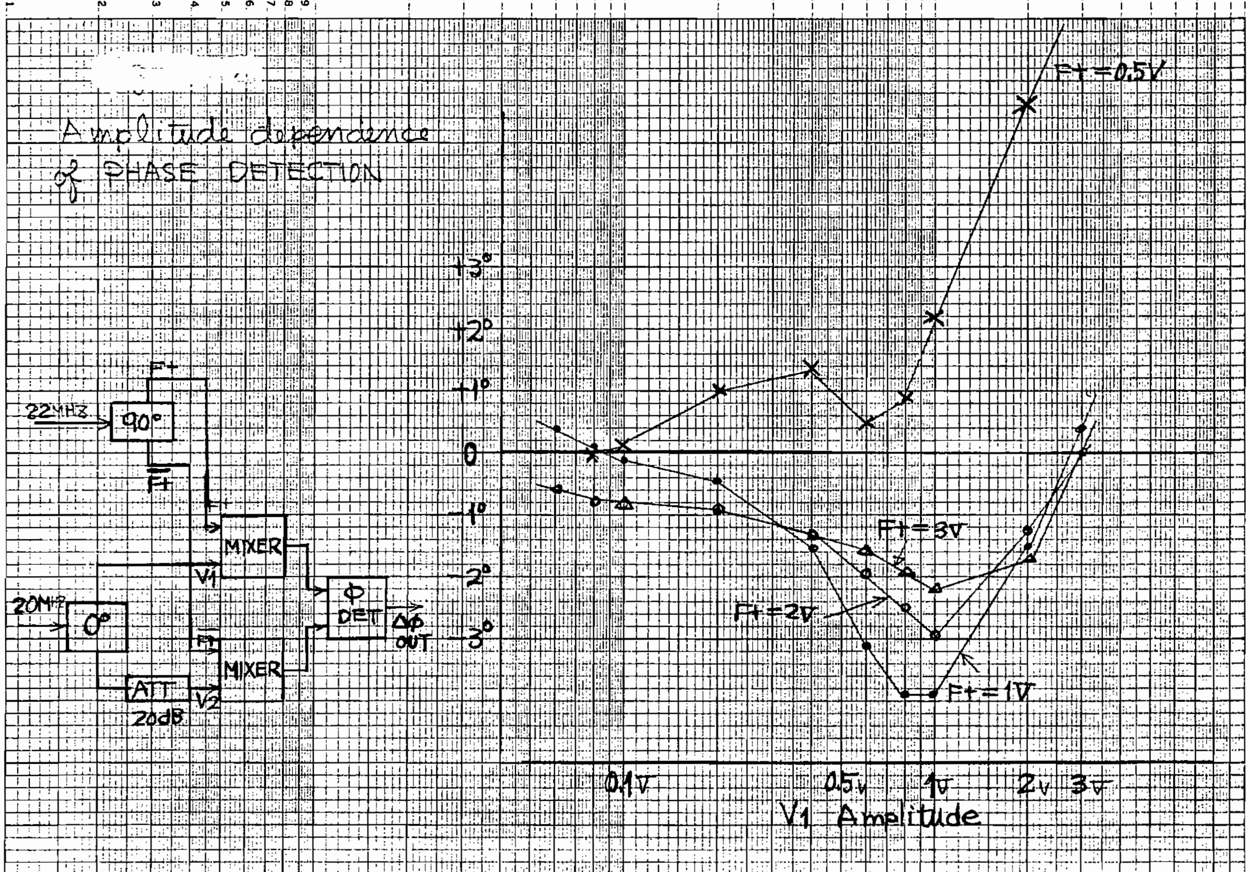


Fig 5.3.3

At the front end of MIXER, the RF transformers whose maximum power rating is 250 mW (3.5 V RMS, 50Ω), are used in the existing module. These transformers will be replaced by ones with 500 mW rating for the new MIXER/PHASE DETECTOR, in order to prevent any trouble caused by a high voltage from the RF monitors.

Although more detailed analysis of a mixer circuit may be required, the easiest means of reducing the phase error are to increase the amplitudes of F+ and $\overline{F+}$ signals or to decrease the RF signal amplitude monitoring various points of the RF system, or to reduce the amplitude difference of the pair of RF input signals when the circuit is completely tuned.

5.4 Frequency Dependence

The frequency dependence of the prototype new MIXER/ϕ-DETECTOR was measured with a 90^o phase reference signal from a 90^o splitter. The results were less than ±0.5 degree over the range 8 to 32 MHZ when all four inputs to MIXER were constant amplitude at 1 V RMS as shown in Fig. 5.4.1.

The phase difference between F+ and $\overline{F+}$ as a function of the operating frequency is shown in Fig. 5.4.1. The results were measured by the vector voltmeter, after careful adjustments have done in the buffer amplifier for F+ and F+. This behaviour has a direct effect on the phase detection accuracy.

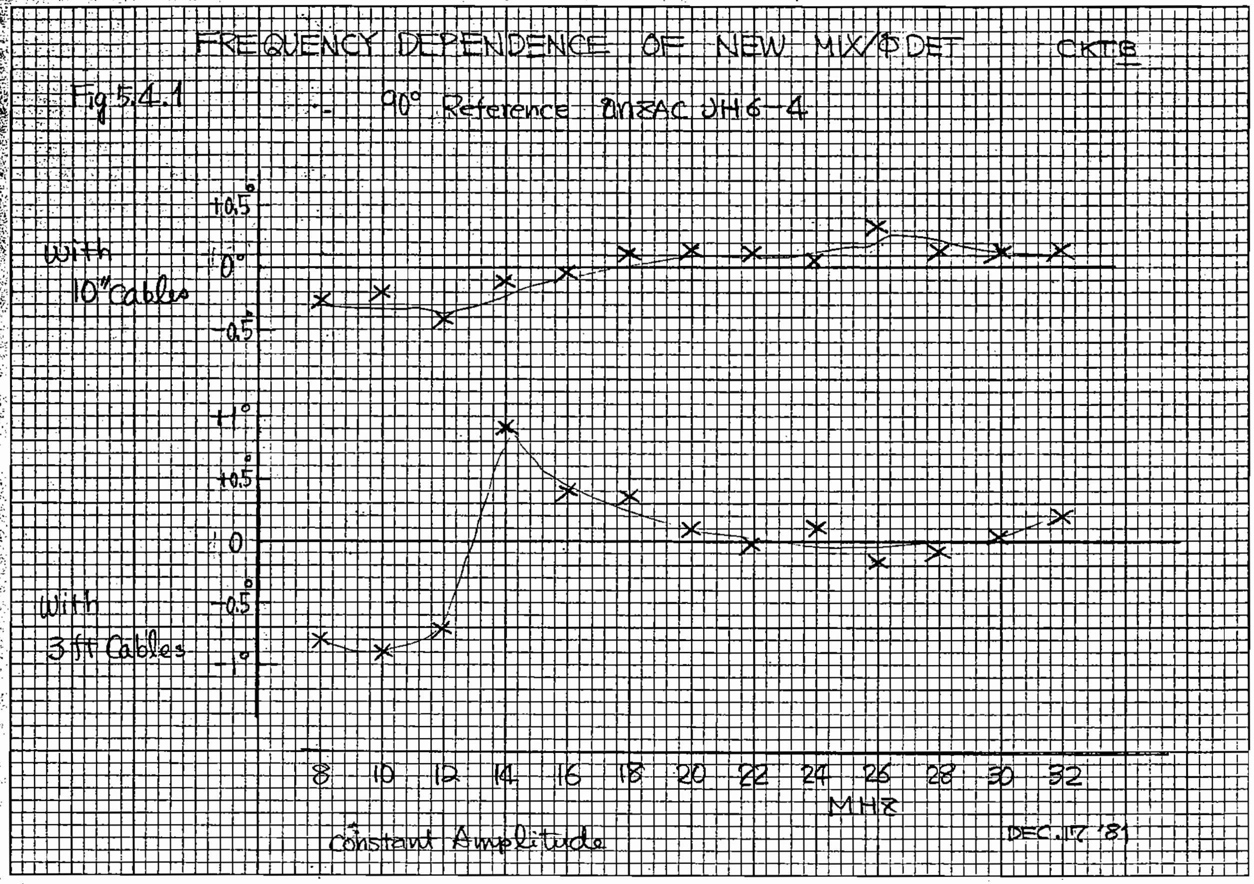
6. ADJUSTMENT PROCEDURE

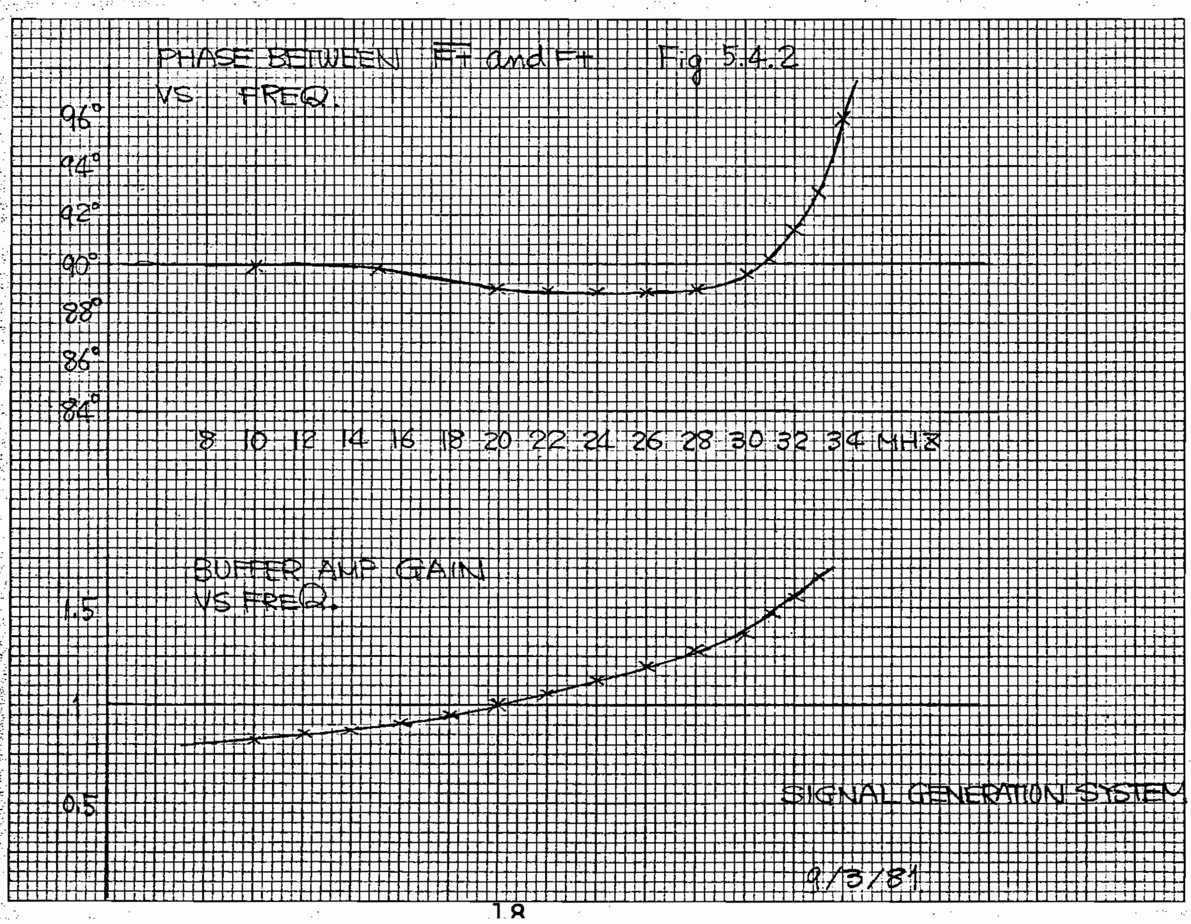
6.1 Adjustments on the Front Panel

Adjustments of threshold level for RF-OK signals and offset adjustment for phase detection are available by trim pots mounted on the front panel.

Proceed as follows;

1. Adjust RF-OK trim pot (R163, 183, 263, 283) to set the threshold level at 2 mV RMS f_o. The 2 mV RF signal can be obtained from the Dee Voltage Regulator output or from a Signal Generator (HP 8654A).
2. Connect a pair of in-phase signals using a power splitter (MCL ZFSC2-1) from the spare output of F1($\overline{F1}$,F2,$\overline{F2}$,F3 or $\overline{F3}$) buffer amplifier at the signal Generation System (Synthesizer System).
3. Adjust ZERO trim pot (R196, R296) to get OV dc at Δϕ output (TP13, TP23).


FREQUENCY DEPENDENCE OF NEW MIX/Φ DET CKT B
Fig 5.4.1
90° Reference anzac JH6-4
+0.5°
0°
-0.5°
With 10" Cables
+1°
+0.5
0
-0.5
-1°
With 3 ft Cables
8 10 12 14 16 18 20 22 24 26 28 30 32
MHz
constant Amplitude
DEC. 17 '81


PHASE BETWEEN F̄+ and F+ Fig 5.4.2
VS FREQ.
96°
94°
92°
90°
88°
86°
84°
8 10 12 14 16 18 20 22 24 26 28 30 32 34 MHz
BUFFER AMP GAIN
VS FREQ.
1.5
1
0.5
SIGNAL GENERATION SYSTEM
9/3/81

6.2 Balance Adjustment of MIXER Circuit

1. Refer to Fig. 6.2.1. The inputs to the F+ and should be 1 V RMS signals at 32 MHZ.
2. Measure the voltage presented at the V1(V2) input. A 50Ω terminator is required.
3. Adjust one-turn pots (R117, 118, 127, 128, 217, 218, 227, 228) on the MIXER board to minimize the voltage presented at V1(V2) input (less than 1 mV RMS).

6.3 FET Buffer of Peak Detector

1. Refer to Fig. 6.3.1, adjust bias trimmer (R157, 177, 257, 277) on the ϕ-Det board to get maximum dc voltage at the peak detector (point A).
2. Adjust coils (L151, 171, 251, 271) to maximize the peak detector voltage.
3. Repeat Step 1 and 2 until the maximum voltage at the point is obtained.

6.4 Offset and Gain Adjustment of Phase Detector

1. Set up the equipment as shown in Fig. 6.4.1.
2. With a pair of in-phase signals, try to adjust ZERO trim pot (R198, 298) on the front panel for the output signal $\Delta\phi$ = OV.
3. Change to quadrature (ANZAC JH-6-4) input signals adjust GAIN trim pot (R197, 297) on the ϕ-Det. board to get the $\Delta\phi$ output voltage = 7V.
4. Repeat step 2 and 3 alternately adjusting GAIN and ZERO to obtain V_o = +7V for 90^o signals and V_o = OV for 0^o signals.

A great deal of measurement was done for the investigation of the Phase Detection Errors. All of the modifications to correct these errors are accumulated in the new 2 MHZ MIXER/PHASE DETECTOR module.

Further, the new MIXER/ϕ-DETECTOR modules feature easy offset or threshold fine adjustment without the neccessity of turning off the RF system.

These units are soon to be installed in the RF console.

Fig 6.2.1

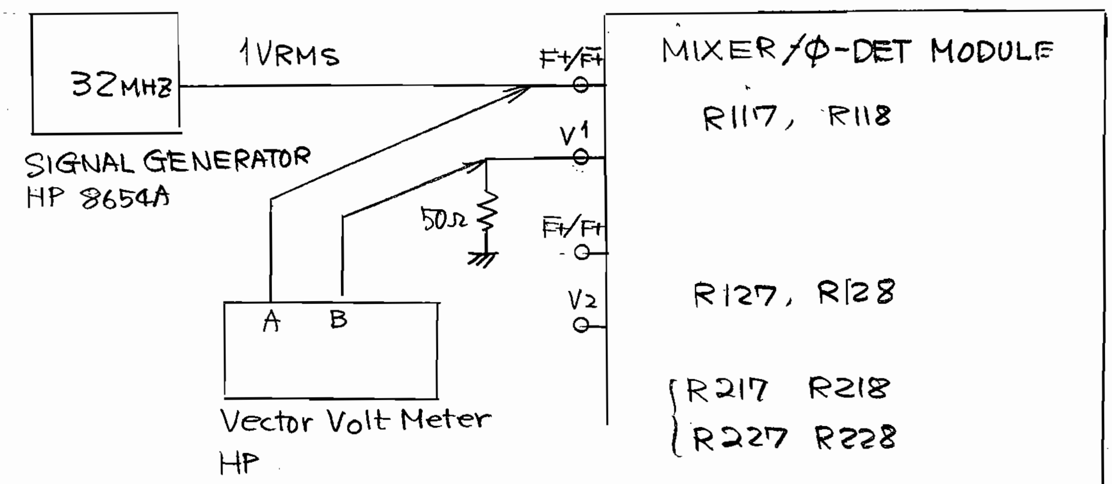


Fig 6.3.1

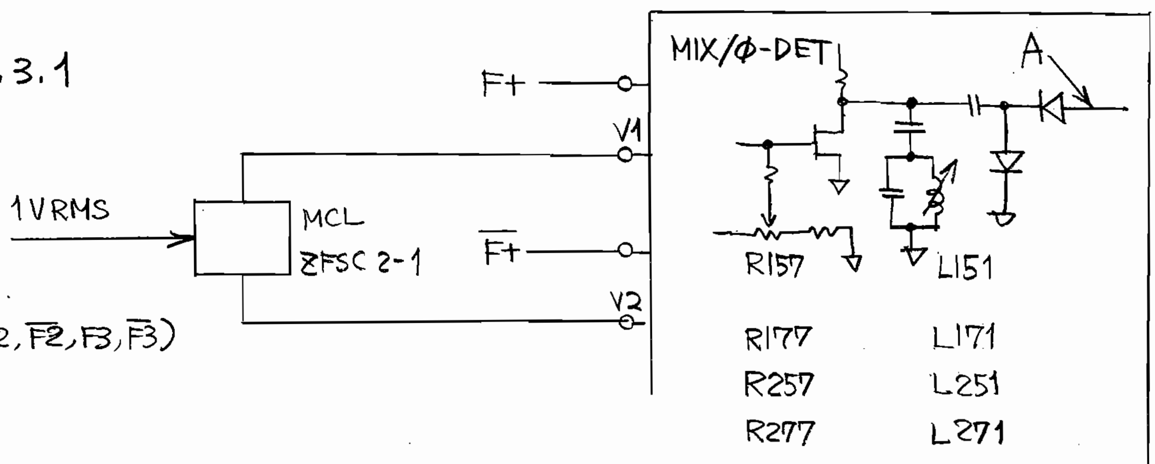
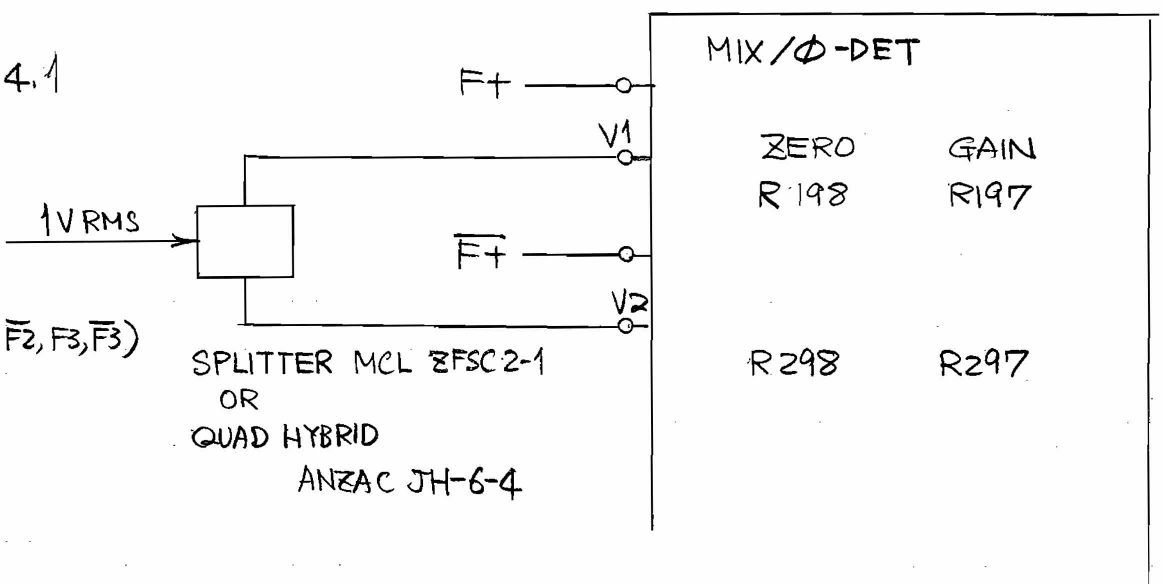


Fig 6.4.1



Appendix 1

List of RF Notes described on MIXER/PHASE DET.

#10 June '77 J. Riedel
Conceptual plan, F+/F+ signal, amplitude range block diagram.

#19 Nov. '77 J. Riedel
Analysis of Riedel's version Ring Modulator

#28 June '78 J. Riedel
The amplitude of F+/F+ signals are 5V rms. The RF transforms for MIXER look like 8 pin DIP's and are inexpensive.
2 MHZ BAND PASS FILTER.
MC1355 is employed for the limting amplifier.

#35 Aug. '78 D. Birkett
The schematic diagram of the Phase Detector.
XR-2208 4 quadrant multiplier for Phase Detecting.
Characteristics of limiting amplifiers.

#44 Apr. '79 R. Gress
Production Status of 2 MHZ MIXER/Phase Detector Modules.

Appendix 2

MIXER-PHASE DETECTOR MODULE DRAWINGS LIST

MIX/ϕ-DET MODULE ASSEMBLY	5-RVJ-1A-1-B
" " F.P. R.P. MILLWORK	5-RVJ-1A-2-B
" " BLOCK DIAGRAM	5-RVJ-1B-1-B
" " INTER CONNECTION DIAGRAM	5-RVJ-1B-2-B
MIXER BOARD ASSEMBLY	5-RVJ-1D-1-D
" " SCHEMATIC	5-RVJ-1D-2-C
" " FABRICATION	5-RVJ-1D-5-C
" " ART WORK	5-RVJ-1D-3-C
2MHZ BPF SUBASSEMBLY	5-RVJ-1C-1-B
" " PCB ASSEMBLY	5-RVJ-1E-2-A
" " SCHEMATIC	5-RVJ-1E-3-A
" " PCB FABRICATION	5-RVJ-1E-5-A
" " INDUCTOR FABRICATION	5-RVJ-1E-7-A
" " ENCLOSURE FAB.	5-RVJ-1E-8-A
" " SEPTUM FAB.	5-RVJ-1C-9-A
ϕ-DET BOARD ASSEMBLY	5-RVJ-1C-1-D
" " SCHEMATIC	5-RVJ-1C-2-D
" " PCB FABRICATION	5-RVJ-1C-3-C
" " PCB ARTWORK	5-RVJ-1C-4-D

Appendix 3

TYPICAL CHARACTERISTICS OF MIXER/ϕ-DETECTOR

Frequency Range: 8-32 MHZ, (F+/$\overline{F+}$ 10-34 MHZ)

Maximum Input: +27 dBm (5V RMS) at 20 MHZ

Input Impedance: $54\pm6\Omega$, $-5^\circ-0^\circ$ at F+ = 0.5 V RMS, 20 MHZ
$50\pm2\Omega$, $\pm1^\circ$ at F+ = 1V RMS, 20 MHZ

Frequency Dependence: Within 1°, 8-32 MHZ, Constant Amplitude

Amplitude Dependence:

Difference of a pair of inputs	F+=1VRMS	F+=2V	F+=3V	Input Amplitude Range
0 dB (1:1)	1°	-	-	10mV - 3VRMS
3 dB (1:0.7)	2°	-	-	10mV - 3V
10 dB (1:0.3)	5°	-	-	20mV - 3V
20 dB (1:0.1)	5°	3°	2°	50mV - 3V

Peak Detector Output (Monitor): V_{out} DC = 1.35 x Vin RMS at 20 MHZ

ϕDet. Output: 7 volts at 0°, 0 volt at 90°

ϕDet. conversion gain: ±0.1 V/degree near zero-crossing points

RF-OK threshold level: Vth $\doteq$ 2 mV RMS at 20 MHZ

RF-OK signal: ON = 10V, OFF = 0V max 10mA

MIXER OUTPUT:

1 Vout (RMS, 2HMZ) = 0.15 x Vin (RMS, at 20 MHZ), F+=0.5VRMS
2 " = 0.2 " F+=1VRMS
3 " = 0.24 " F+=2VRMS

Band Pass Filter: Fo = 2 MHZ, Band Width = 1 MHZ
Phase difference between a pair of filters wthin 2° at 2 HMZ

MIXER Isolation:

F+($\overline{F+}$) → Vinput: 50 db at 20 MHZ
F+($\overline{F+}$) → 2 HMZ output: 70 db at 20 MHZ
Between a pair of filters: 60 db at 2 MHZ

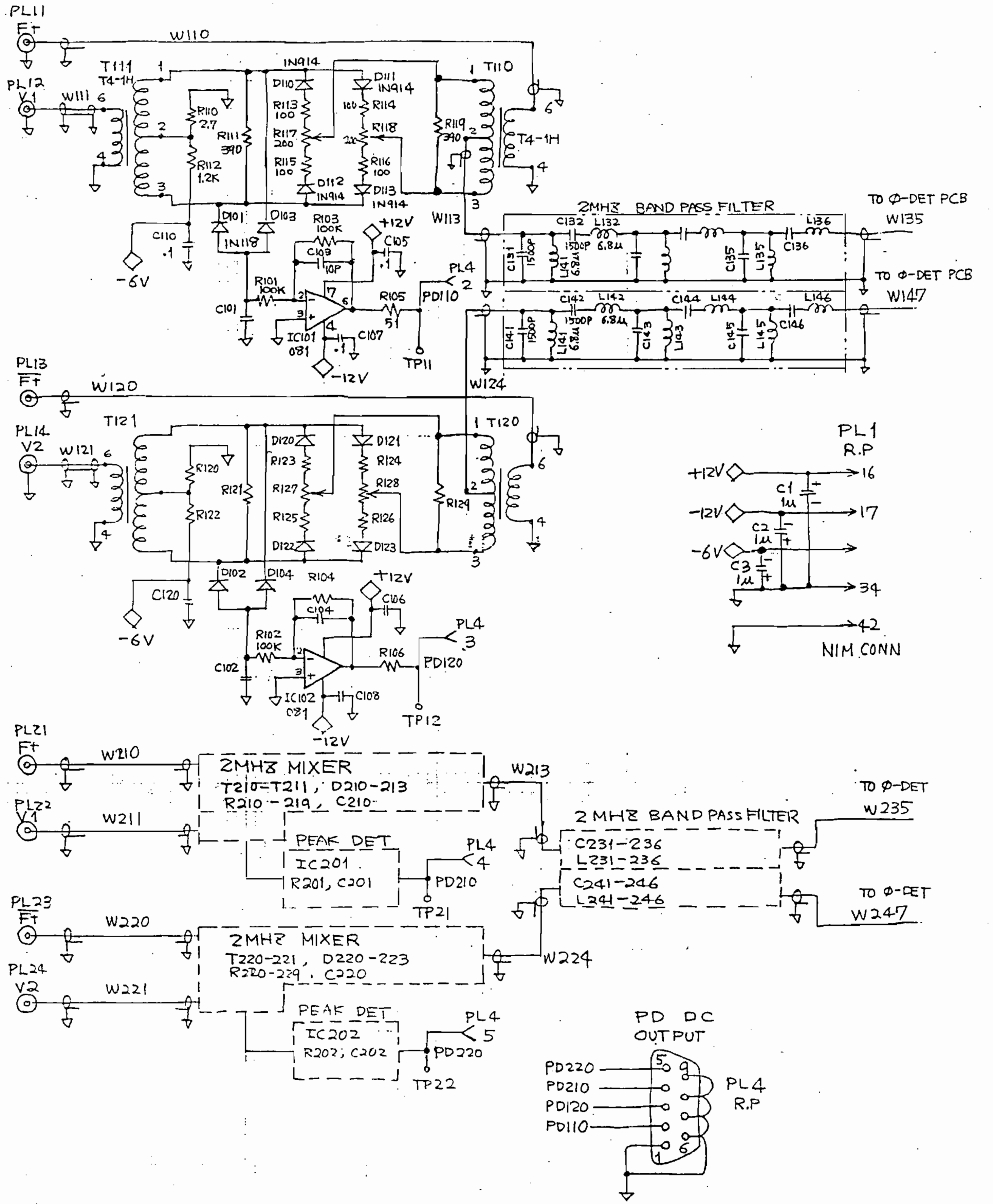
Limiting Amplifier Output: 200 mV square wave

RF-OK Threshold level: 2mV at 20 MHZ input, 100 μV at 2 HMZ signal, 2 V dc at the peak detector

RF-OK Comparator input: ON → 3V dc, OFF → 1Vdc

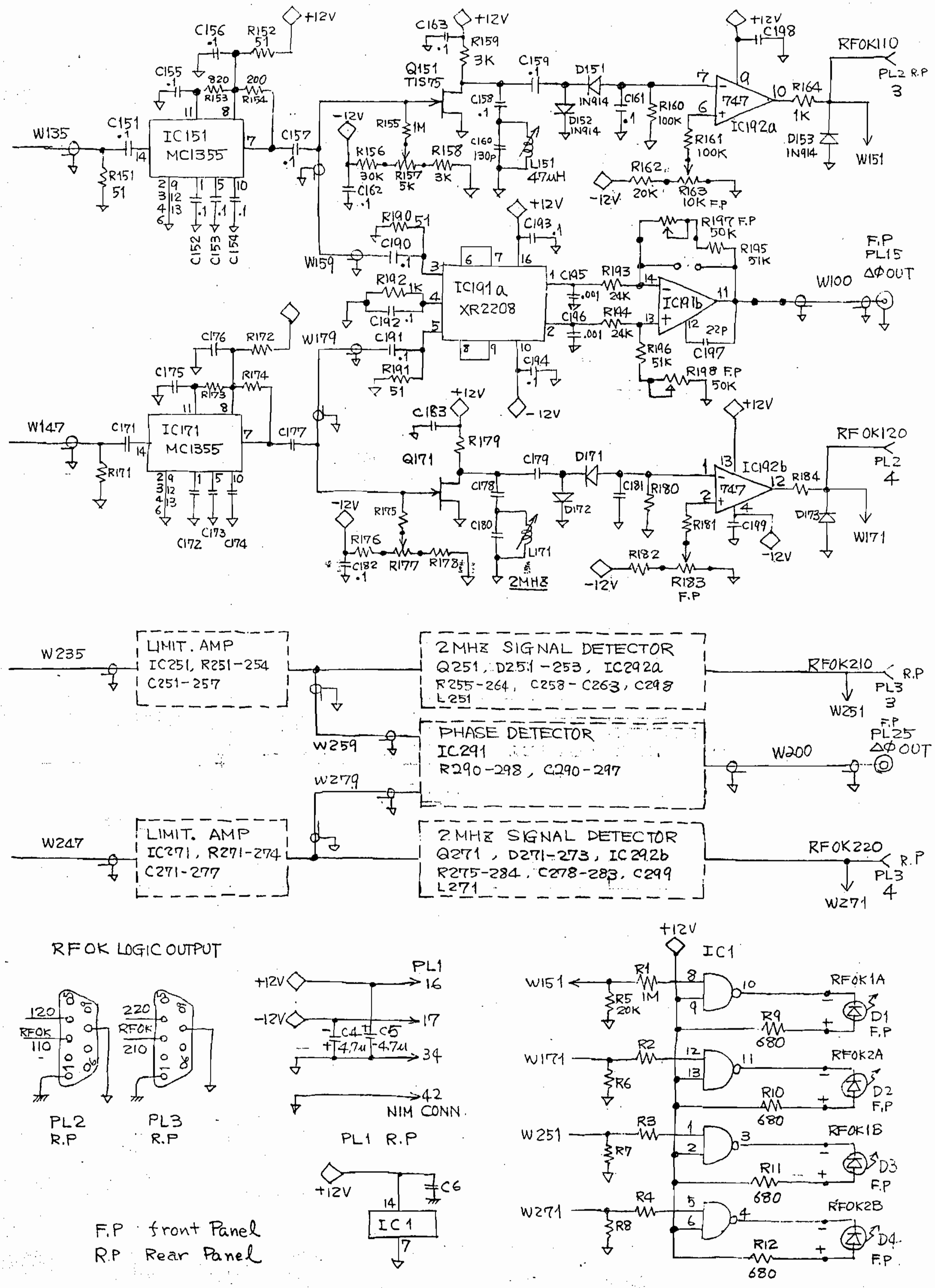
φ-Detector Drift: less than 0.5^{o} for 15 hours.

Power Requirements: + 12 V @ 130 mA, + 12 V @ 130 mA, -6 V @ 10 mA



SEP. 18 '81 T.MIYANAGA MIX/Φ-DET. MODULE

SCHEMATIC
2MHZ MIXER BOARD



SEP. 18'81 T. MIYANAGA

MIX/Φ-DET. Module Φ-DET. BOARD SCHEMATC