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KD-107
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A&A Report No. 285

AN ANALYSIS AND APPRAISAL OF THE [redacted] CERAMIC RESONATOR AND CRYSTAL FILTER IF AMPLIFIERS, (KD-107)

25X1

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ABSTRACT

A Class "A" evaluation was conducted on a Ceramic Resonator IF Amplifier and a Crystal Filter IF Amplifier, [redacted] 25X1
[redacted] 25X1

The results of the evaluation indicate that the manufacturer has not met the target specifications outlined in "Proposal for the Construction of Miniaturized IF Amplifier Packages" in the following areas:

(1) Overall selectivity (both).

(2) Overall power gain (both).

(3) Size of Crystal Filter IF Amplifier.

(4) Output frequency of the Crystal Filter IF Amplifier.

The amplifiers meet the specification regarding:

(1) Battery drain (both).

(2) Size of Ceramic Resonator IF Amplifier.

I. INTRODUCTION

This report presents the results of a Class "A" evaluation which was conducted on two miniature transistorized IF amplifiers constructed by [redacted] 25X1

The two amplifiers are engineering models. One employs ceramic resonator transformers for coupling and selectivity. The other amplifier uses a small crystal filter for selectivity.

The ceramic resonator amplifier accepts an input frequency of 2.28 mc. A crystal controlled local oscillator and a mixer are included in the unit. The output frequency is 456 kc.

The crystal filter IF amplifier is a band-pass amplifier operating at a frequency of 2.28 mc. No conversion is provided.

The amplifiers require an external 12 volt dc power source.

2. SUMMARY OF TEST DATA

Amplifier Characteristics	Contractor's Target Specification	Contractor's Final Test Data	R&D Laboratory Measurements
Battery Drain			
Ceramic Resonator	Not Specified	12 volts/2 ma.	12 volts/2.1 ma.
Crystal Filter		12 volts/1.4 ma.	12 volts/1.4 ma.
Input Frequency			
Ceramic Resonator	2.2 MC	2.28 MC	2.28 MC
Crystal Filter	2.2 MC	2.28 MC	2.28 MC
Output Frequency			
Ceramic Resonator	455 KC	455 KC	456 KC
Crystal Filter	455 KC	2.28 MC	2.28 MC
Input Impedance			
Ceramic Resonator	Not Specified	400 Ohms	329 Ohms
Crystal Filter		1200 Ohms	1038 Ohms
Over-all Gain			
Ceramic Resonator	100 db	89 db	59.3 - 84.8 db
Crystal Filter	100 db	72 db	54.9 - 57.1 db
Selectivity			
Ceramic Resonator	3 db points = 5.4 KC	Varies with Input Signal	3 db points = 6.484 KC
Crystal Filter	3 db points = 5.4 KC	3 db points = 5.4 KC	See Curve, Figure 2

Amplifier Characteristics	Contractor's Target Specification	Contractor's Final Test Data	R&D Laboratory Measurements
Image Rejection Ceramic Resonator	Not Specified	Over 60 db	46.46 db
IF Rejection Ceramic Resonator	Not Specified	Not Specified	49.54 db
Spurious Response Ceramic Resonator Crystal Filter	Not Specified	Four were measured	See Page 12
Temperature Range Ceramic Resonator	-40°C to +40°C	Center frequency varied +1.5 KC at -40°C. Gain variation is -5.5 db at -40°C to +1.3 db at +40°C.	Center frequency varied 51 cps at -40°C. Gain variation is -7.62 db at -40°C to +1.2 db at +40°C.
Crystal Filter		Gain variation is -5.5 db at -40°C to 1.3 db at +40°C.	Gain variation is -15.56 db at -40°C to +0.74 db at +40°C.

3. DETAILS OF TEST DATA

3.1. Mechanical

3.1.1. Size and Weight

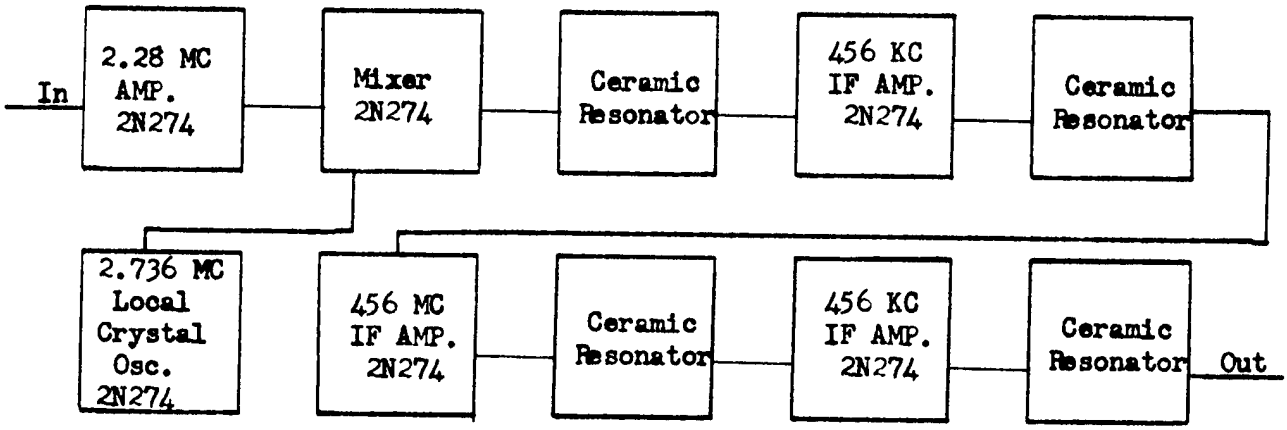
Amplifier	Size	Weight
Ceramic Resonator	2 1/8 x 1 21/32 x 21/32	2.5 ozs.
Crystal Filter	2 11/32 x 1 31/32 x 1	5.0 ozs.

3.1.2. Mechanical Inspection

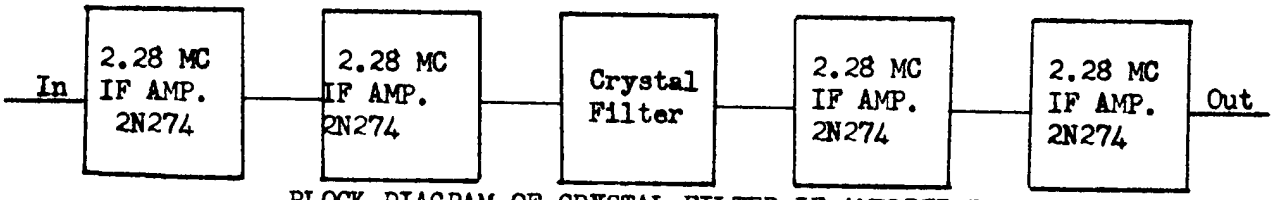
The ceramic resonator and crystal filter amplifiers are housed in fragile thin wall copper cases. The cover on each amplifier case is secured with solder. The cases are painted grey and all electrical input and output terminals are marked. There are no operating controls. A 12 volt dc source is required for operation of the amplifiers. This is not supplied with the present units.

3.2. Electrical

3.2.1. Electrical Inspection



BLOCK DIAGRAM OF CERAMIC RESONATOR IF AMPLIFIER



BLOCK DIAGRAM OF CRYSTAL FILTER IF AMPLIFIER

3.2.1.1. Amplifiers Descriptions

Ceramic Resonator IF Amplifier

The amplifier consists of a 2.28 MC amplifier, a crystal controlled local oscillator and a three stage IF amplifier. The input signal of 2.28 MC is amplified in the first transistor stage and is converted in the mixer to 456 KC. The mixer output is fed directly into the input ceramic resonator of the three stage amplifier. Four ceramic resonator transformers are used in the amplifier for interstage coupling and to achieve the desired selectivity and band-pass characteristics.

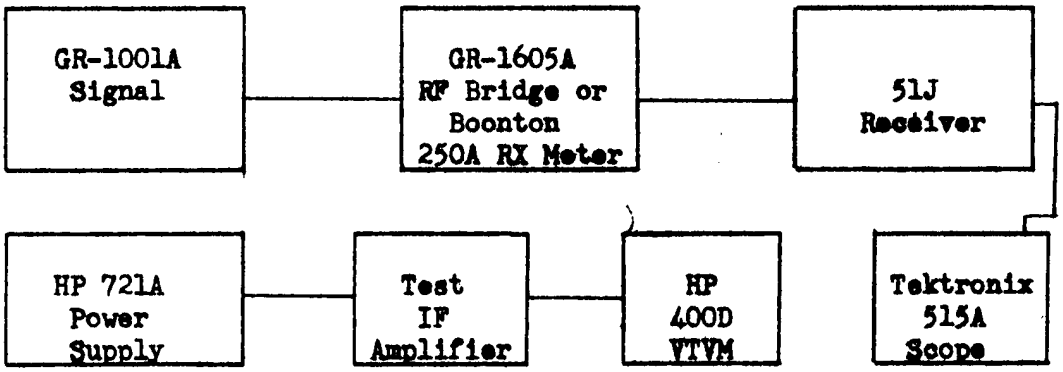
Crystal Filter IF Amplifier

The four stage amplifier operates at a center frequency of 2.28 MC and is of the conventional transistor type. The outstanding feature of the amplifier is the miniature crystal filter which is inserted between the second and third stages of the amplifier.

3.3. Electrical Tests

3.3.1. Input Impedance

Test Setup:



Test Method:

1. The standard bridge method was used to measure the input impedance of the crystal filter amplifier.

2. The input impedance of the ceramic resonator amplifier was measured with a Boonton RX Meter.

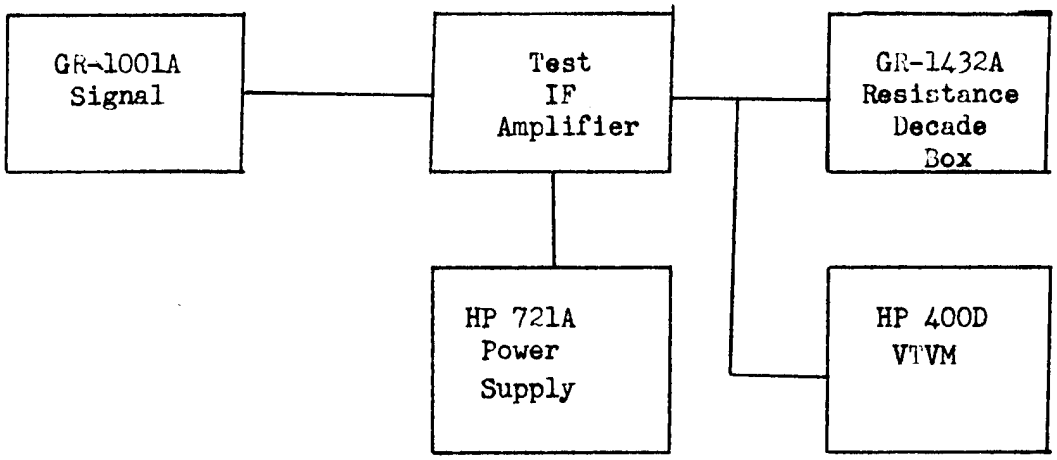
Test Results:

Input Impedance

AMPLIFIER	Active Components (Ohms)			
	XC	XL	R	Z
Ceramic Resonator	---	149	293	329
Crystal Filter	942	---	214	1038

3.3.2. Output Impedances

Test Setup:



Test Method:

1. The test amplifier was set up for normal operation on a test frequency of 2.28 MC.

2. A resistance decade box was connected to the amplifier output terminals and was set at various load positions from 1000 to 8000 ohms.

3. The output voltage readings were recorded.

4. The resistance value which produced maximum IF amplifier output power was calculated from the formula:

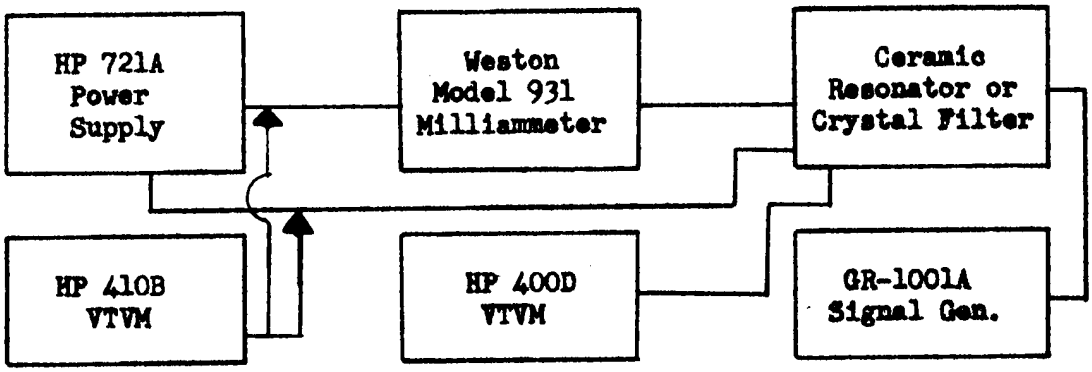
$$\text{POWER} = \frac{E^2 \text{ (volts)}}{R \text{ (ohms)}}$$

Test Results:

AMPLIFIER	MAXIMUM OUTPUT POWER VALUE OF RESISTANCE (OHMS)
Ceramic Resonator	4000
Crystal Filter	3000

3.3.3. Battery Drain

Test Setup:



Test Method:

1. The test IF amplifier was set up for normal operation.

2. The output voltage of the DC power supply was set at 12 volts and the DC current required to operate the amplifier was measured.

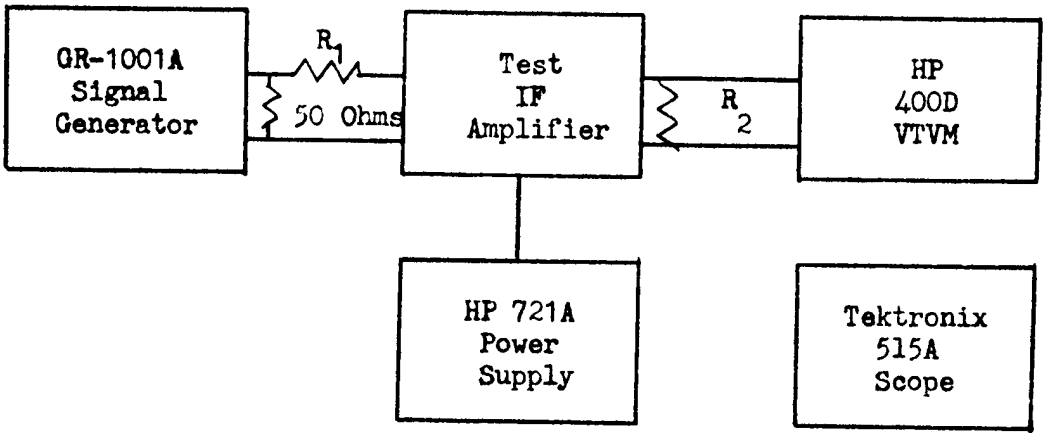
Test Results:

AMPLIFIER	VOLTS	CURRENT (MA.)	MILLIWATTS
Ceramic Resonator	12	2.1	25.2
Crystal Filter	12	1.4	16.2

It was observed that when the power supply voltage was raised to approximately 13 volts, the crystal filter amplifier self oscillated. This condition did not occur with the ceramic resonator IF amplifier.

3.3.4. Over-all Gain

Test Setup:



R_1 = 275 Ohms for Ceramic Resonator

R_1 = 1000 Ohms for Crystal Filter

R_2 = 4000 Ohms for Ceramic Resonator

R_2 = 3000 Ohms for Crystal Filter

Test Method:

1. The test IF amplifier was set up for normal operation.
2. The signal generator was tuned to the IF test frequency. A meter was used to monitor the IF output voltage.
3. The IF output voltage level was recorded when the signal generator output was varied from 0 to 2000 microvolts.
4. The over-all power gain of each IF amplifier was calculated from the formula:

$$\text{Over-all gain (db)} = 10 \log \frac{\frac{E_2{}^2}{R_2}}{\frac{E_1{}^2}{R_1}}$$

When E_1 = Signal Generator Output Voltage

E_2 = IF Amplifier Output Voltage

R_1 = IF Amplifier Input Resistance Load Impedance

R_2 = IF Amplifier Output Resistance Load Impedance

Test Results:

Over-all Gain

Amplifier	RF Input (Microvolts)	IF Output (Millivolts)	Signal Plus Noise/Noise Ratio (db)	Over-all Gain (db)
Ceramic Resonator	0	54	---	---
	0.5	57	0.44	90.23
	1	61	1.06	84.84
	2	77	3.08	80.81
	3	100	5.34	79.56
	4	128	7.50	79.20
	5	155	9.18	78.94
	10	272	14.06	77.80
	15	350	16.24	76.46
	20	400	17.40	75.12
	50	520	19.66	69.39
	100	590	20.74	64.53
	200	650	21.62	59.33
	*400	685	22.06	53.75
	500	695	22.20	51.94
	1000	710	22.38	46.13
	1500	725	22.54	42.77
	2000	730	22.62	46.13

*RF Inputs greater than 400 microvolts caused overloading.

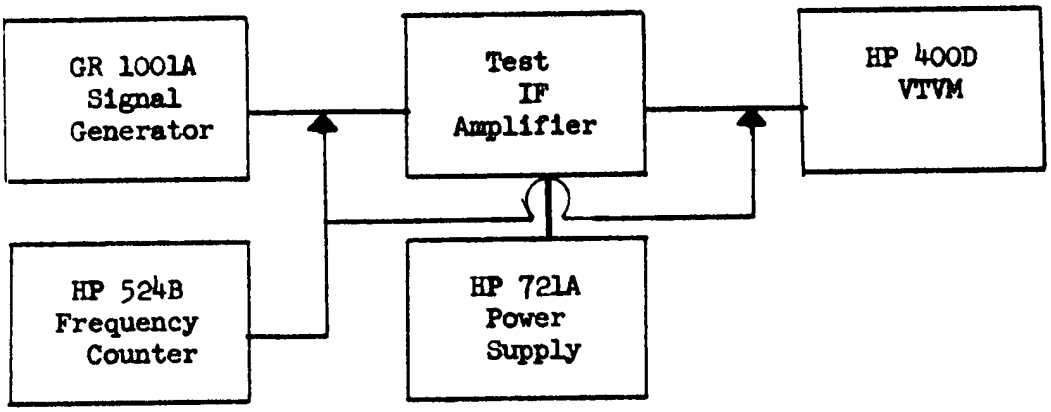
Over-all Gain (Con't.)

Amplifier	RF Input (Microvolts)	IF Output (Millivolts)	Signal Plus Noise/Noise Ratio (db)	Over-all Gain (db)
Crystal Filter	0	0.30	---	---
	0.5	0.52	4.78	45.78
	1	0.95	10.00	54.98
	2	2.04	16.66	55.60
	3	3.3	20.82	56.27
	4	4.4	23.34	56.26
	5	5.5	25.04	56.27
	10	10.8	31.14	55.91
	15	16.8	34.96	56.40
	20	23.0	37.68	56.66
	50	59.8	46.00	56.99
	100	110	51.28	56.07
	200	260	58.74	57.71
	400	460	63.72	56.65
	500	560	65.40	56.41
	1000	858	69.12	54.10
	*1500	1000	70.46	51.91
	2000	1100	71.26	50.24

*Amplifier overloads with RF Inputs greater than 1500 Microvolts.

3.3.5. **Image and IF Rejection and Spurious Responses**

Test Setup:



Test Method:

1. The test IF amplifier was set up for normal operation.

2. The signal generator, with the output level set at 10 microvolts, was tuned to the IF frequency which produced maximum response at the output terminals of the test IF amplifier. The IF output level was metered and the output at maximum meter response was used as the 0 db reference.

3. The signal generator, in approximate 1 db steps, was tuned below/above the IF frequency of maximum response. At each step the signal generator output level was adjusted to reproduce the meter reading of step 2. The signal generator output level in microvolts was recorded.

4. The test method described was used to measure the IF frequency response of the Ceramic Resonator Amplifier and of the Crystal Filter Amplifier. The response curves are shown as Figures 1 and 2, pages 18 and 19.

5. The test procedure, also, was used to measure the IF and Image Rejection of the Ceramic Resonator Amplifier. In addition the spurious frequency responses of both IF amplifiers were measured within the frequency range of 50 KC to 50 MC.

Test Results

IF Rejection (456 KC)

Amplifier	Signal Generator Output (Microvolts)	IF Rejection (Decibels)
Ceramic Resonator Crystal Filter	3000	49.54
	No frequency conversion	

Image Rejection (3.192 MC)

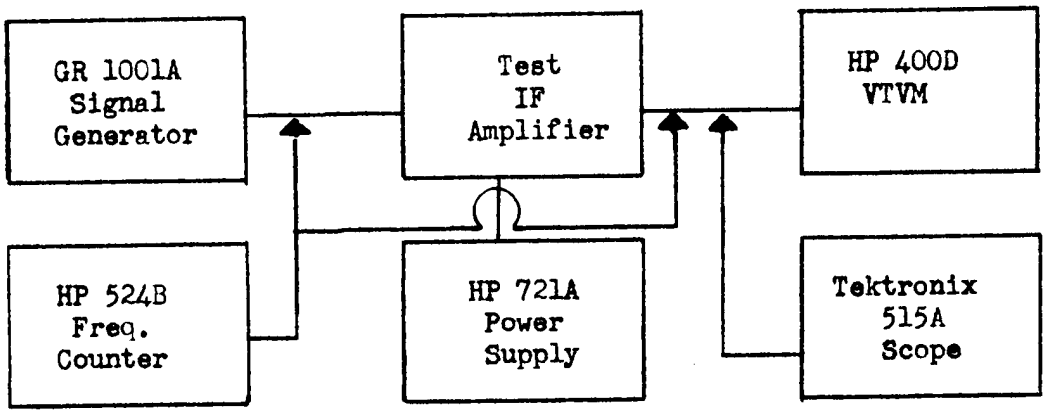
Amplifier	Signal Generator Output (Microvolts)	Image Rejection (Decibels)
Ceramic Resonator Crystal Filter	2100	46.46
	No frequency conversion	

Spurious Frequency Response

Amplifier	Signal Generator Output Freq. (KC)	(Microvolts)	Spurious Response Below 0 db reference (Decibels)
Ceramic Resonator	569.9	1000	40
	759.9	60	15.56
	1139	160	24.08
	2411	8800	58.88
	2508	2100	46.46
	5016	5750	55.20
Crystal Filter	284.8	3400	50.64
	285.2	4800	53.62
	325.5	3600	51.20
	326	2500	47.96
	455.7	2200	46.84
	456.4	1600	44.08
	569.7	650	35.26
	570.6	490	33.80
	759.6	350	30.88
	760.7	250	29.84
	1139	360	31.12
	1141	440	32.88

3.3.6. **Selectivity**

Test Setup:



Test Method:

1. The test IF amplifier was set up for normal operation.

2. The signal generator was coupled to the input of the amplifier. The generator was tuned to the frequency (approximately 2.28 MC) which produced maximum IF output. The generator output level was set at 10 microvolts.

3. The output of the IF amplifier was metered and the output level of Step 2 was used as the 0 db reference level.

4. The generator output voltage was raised in specific steps from 0 to 60 db. At each step the generator was tuned to the frequencies, above and below the reference frequency of Step 2.

5. The generator frequencies and the IF amplifier output frequencies were measured with a HP 524B frequency counter.

6. The described test method was used to:

    1. Determine the input and output frequencies of the ceramic resonator amplifier and of the crystal filter amplifier.

    2. Measure the selectivity curves of each amplifier.

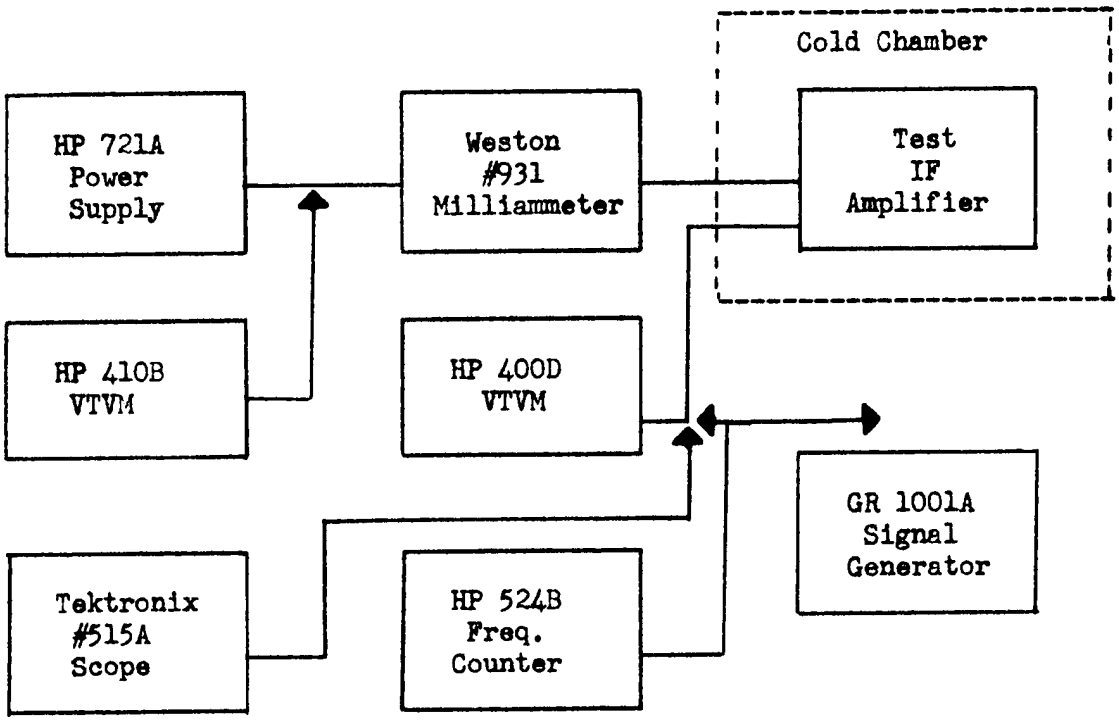
Test Results:

	Ceramic Resonator	Crystal Filter
Input Frequency	2.8 MC	2.8 MC
Output Frequency	456 KC	2.8 MC

Selectivity curves are shown on Figures 1 and 2, Pages 18 and 19.

3.3.7. Electrical Performance Versus Temperature

Test Setup:



Test Method:

1. The test IF amplifier was set up in the cold chamber with the appropriate input and output load resistors connected to the amplifier.

2. The signal generator output frequency was set at 2.28 MC and the generator output level was set at 20 microvolts.

3. The environmental chamber was operated; in 10° steps, in the temperature range of - 40°C to +40°C.

4. At each step the amplifier was allowed to stabilize for 30 minutes. The major electrical parameters of the amplifier were then measured and recorded.

5. The change of amplifier output at the various temperature levels versus the amplifier output at 22°C (77°F) was calculated in decibels.

Test Results:

Ceramic Resonator IF Amplifier Characteristics

Versus Temperature

(Input Frequency 2.280 000 MC)

Temp. °C	IF OUTPUT Freq. (KC)	IF OUTPUT (Volts)	IF OUTPUT Relative Level (db)	Waveform	DC INPUT (Volts)	DC INPUT (MA.)
40	455.990	0.149	+1.20	Sine wave	12	2.2
30	456.020	0.147	+1.06	Sine wave	12	2.1
22	456.049	0.13	0	Sine wave	12	2.1
10	456.081	0.105	-1.86	Sine wave	12	2.0
0	456.088	0.087	-3.48	Sine wave	12	1.95
-10	456.124	0.081	-4.10	Sine wave	12	1.91
-20	*456.073	0.065	-6.02	Sine wave	12	1.82
-30	*456.347	0.062	-6.44	Sine wave	12	1.75
-40	*351.627	0.054	-7.62	Sine wave	12	1.7

*Due to instrumentation cable attenuation and low IF amplifier output, the level of the IF output voltage is too low at temperatures below -20°C for accurate frequency counter measurements.

Crystal Filter IF Amplifier Characteristics

Versus

Temperature (Input Frequency 2.280 000 MC)

Temp. °C	Freq. (MC)	Volts	Relative Level (db)	Waveform	Volts	(MA)
40	2.280 000	0.0049	0.74		12	1.43
30	2.280 000	0.0047	0.36		12	1.40
22	2.280 000	0.0045	0		12	1.40
10	2.280 000	0.0042	-0.62		12	1.37
0	2.280 000	0.0040	-1.00		12	1.35
10	2.280 000	0.0018	-7.96		12	1.30
-20	2.280 000	0.0014	-10.14		12	1.30
-30	2.280 000	0.00089	-14.08	Distorted Sine wave	12	1.25
-40	2.280 000	0.00075	-15.56		12	1.25

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

The results of the tests conducted on the Ceramic Resonator and Crystal Filter IF Amplifiers indicate that the manufacturer has not achieved the design goals described on Page 2 of the manufacturer's "Proposal for the Construction of Miniaturized IF Amplifiers."

The amplifiers fail to meet the target specifications in the following areas:

1. Over-all Selectivity. (Both)
2. Over-all Power Gain. (Both)
3. Size of Crystal Filter Amplifier.
4. Output Frequency of Crystal Filter Amplifier.

The amplifiers meet the specifications in the following area:

1. Battery drain. (Both)

The performance of the amplifiers approximates the manufacturer's final test data regarding:

1. Size of Crystal Filter IF Amplifier.
2. Output Frequency of the Crystal Filter IF Amplifier.
3. Input Impedances. (Both)
4. Output Impedances. (Both)

4.2. Recommendations

The amplifiers should be returned to the manufacturer for improvement in the following areas:

1. Over-all gain.
2. Over-all Selectivity.
3. Spurious Frequency Response.

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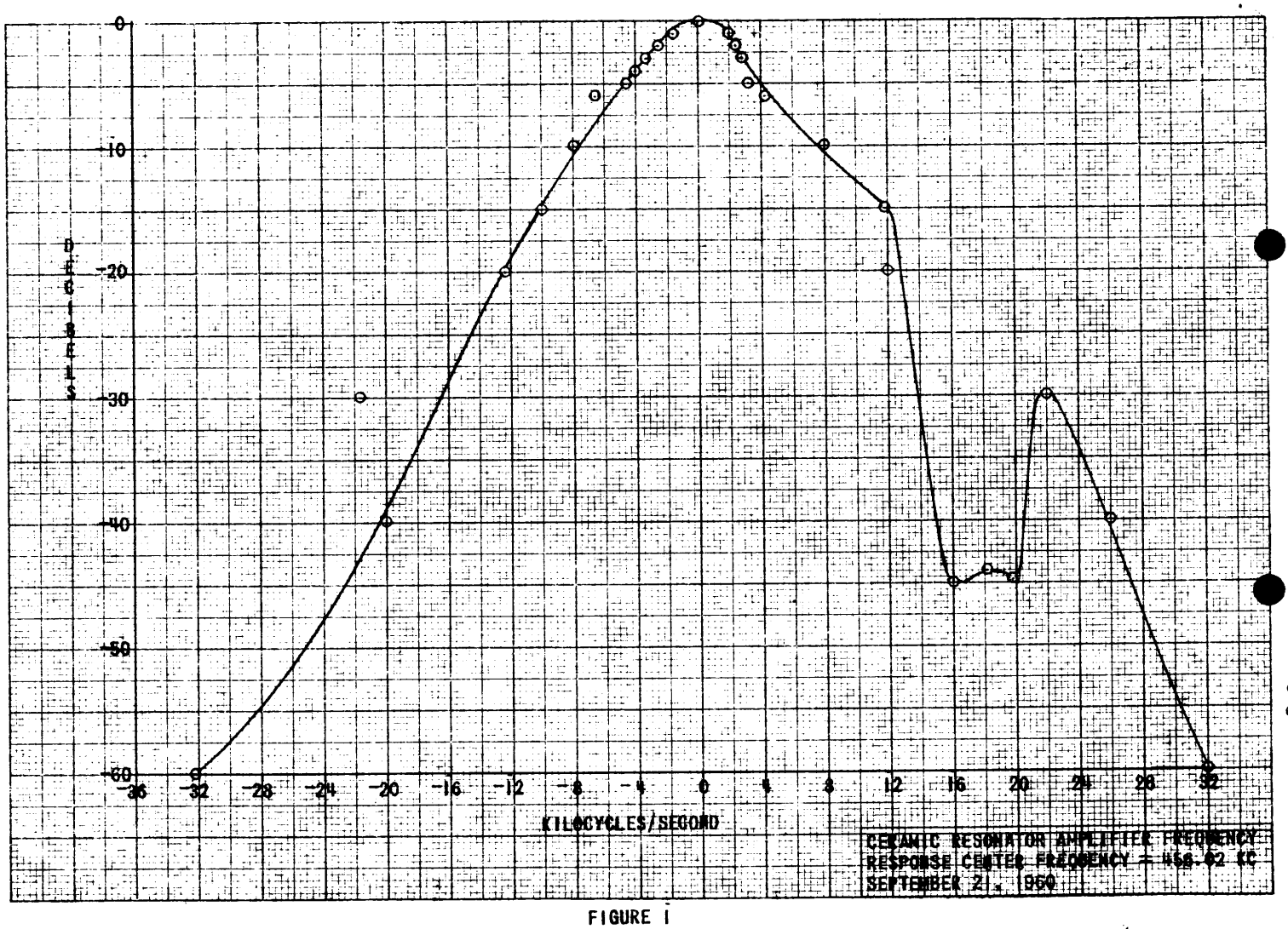


FIGURE 1

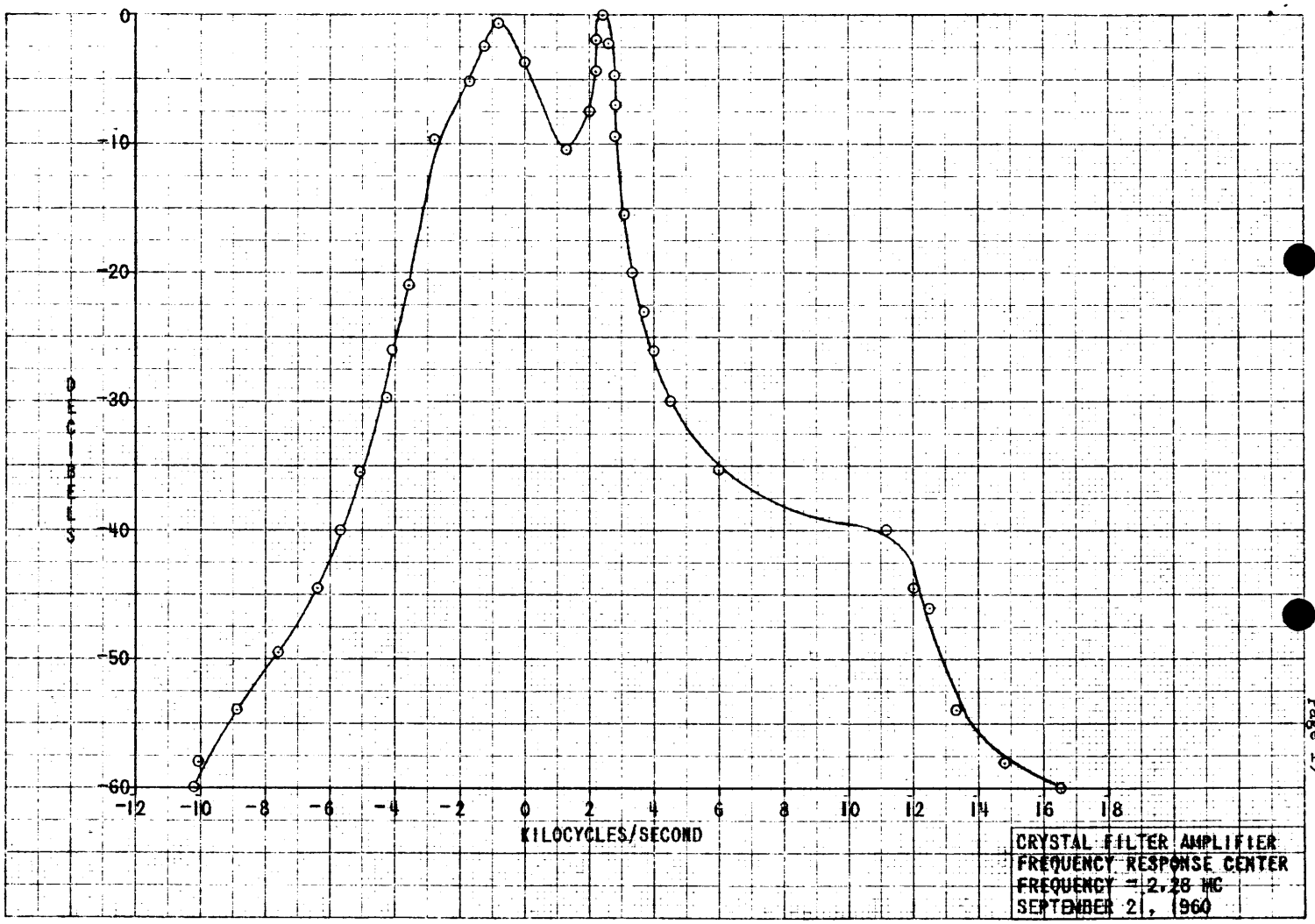
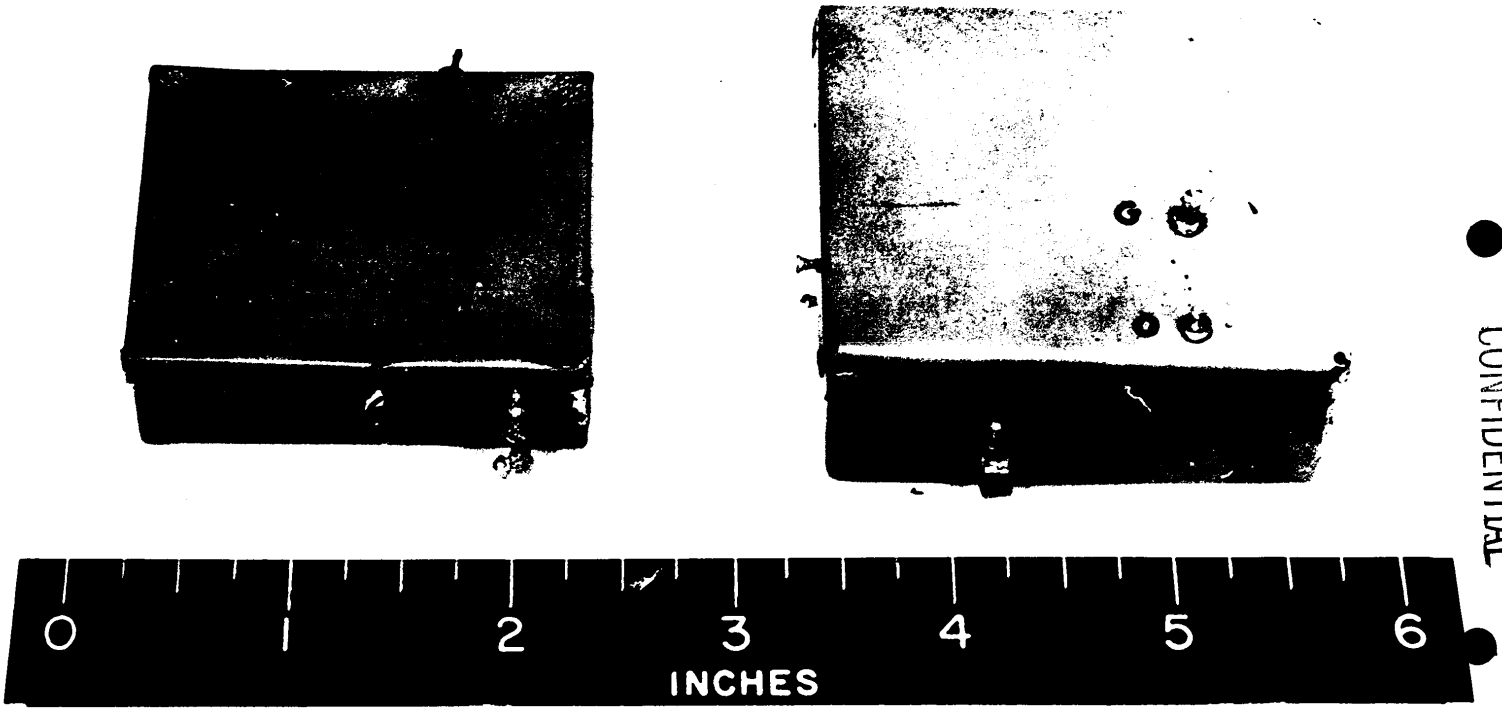
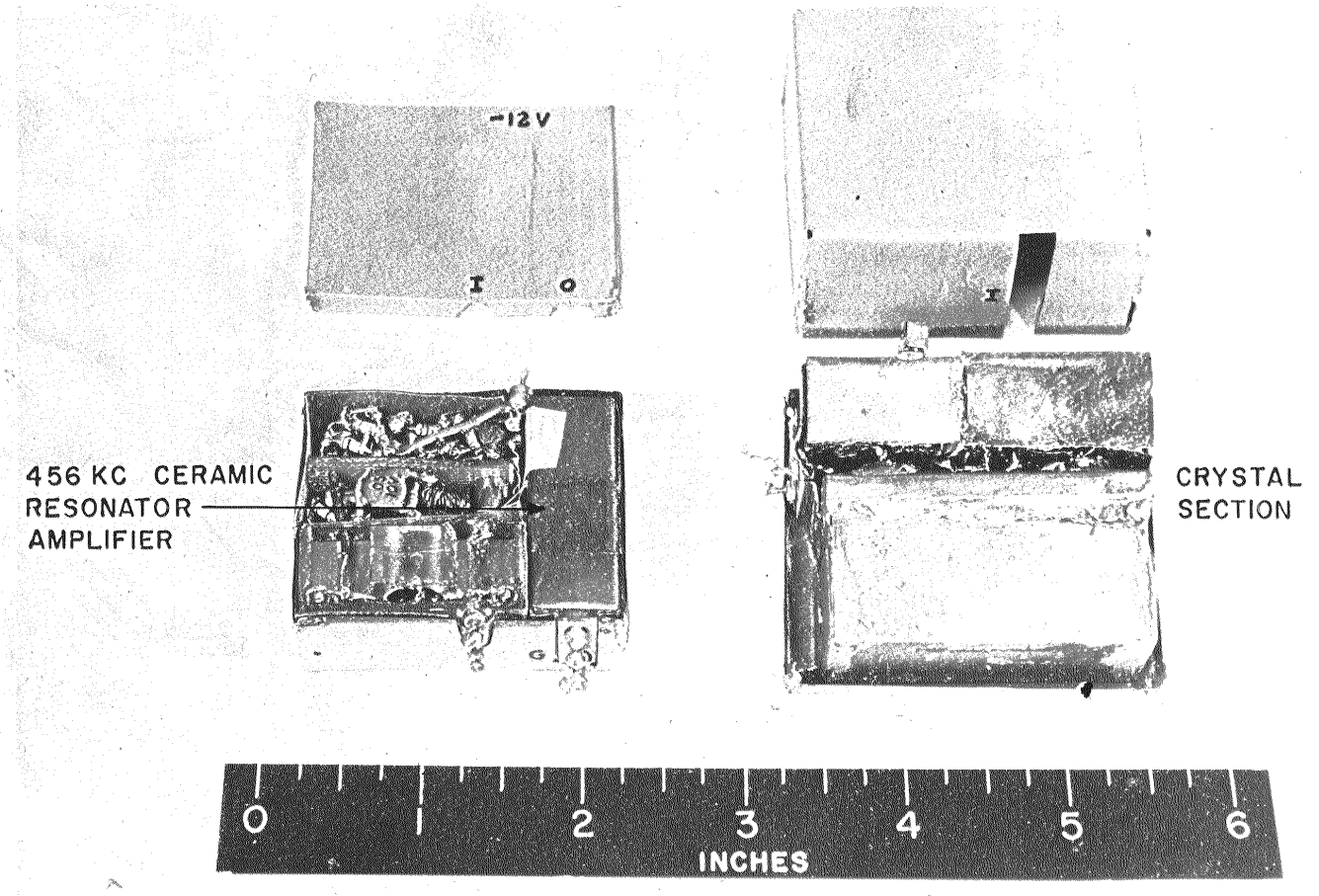


FIGURE 2



CERAMIC RESONATOR AND CRYSTAL FILTER I.F. AMPLIFIERS

FIGURE 3



CERAMIC RESONATOR AND CRYSTAL FILTER I.F. AMPLIFIERS (COVERS REMOVED)

FIGURE 4