80045 AKQ 19/368
PRODUCT NO. 3118

FINAL REPORT
FOR
SS/FM TELEMETRY SYSTEM STUDY AND DEVELOPMENT

CONTRACT NO. NAS-8-11988

PREPARED FOR
GEORGE C. MARSHALL
SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

AVCO
ELECTRONICS
DIVISION
CINCINNATI, OHIO 45241

FINAL REPORT

SS/FM TELEMETRY SYSTEM STUDY

July 1965 THRU February 1968

29 February 1968

Contract No.: NAS-8-11988

(AVCO Report No. 80045 AKQ 19/368)

FOR

GEORGE C. MARSHALL SPACE FLIGHT CENTER

HUNTSVILLE, ALABAMA

AVCO CORPORATION

ELECTRONICS DIVISION

CINCINNATI, OHIO

PREPARED BY: J W Mullaney
J. W. Mullaney

REVIEWED BY:
S. Hoffman

APPROVED BY:
L. A. Busby

TABLE OF CONTENTS

TABLE OF CONTENTS

FINAL REPORT

SS/FM TELEMETRY SYSTEM STUDY

I. INTRODUCTION

This report is in compliance with contract NAS 8-11988 issued by NASA/MSFC to AVCO Corporation, Electronic Division for the study and development of the SS/DSB Multiplexer.

The SS/DSB Multiplexer frequency multiplexes 19 data channels with information up to 3.0 kHz into a base band of approximately 100 kHz. Each channel is multiplexed into SSB or DSB with suppressed carrier. The output data plus two pilot tones for phase coherent regeneration are followed by an AGC amplifier for constant energy in the base-band.

A 1 kHz auxiliary channel (amplitude preserved) is also available for time sync information so that each channel may be time multiplexed for channel multiplication. Internal calibration of all channels is provided.

This report is compiled in sections of increasing detail concerning the design, operation and partial test results of the prototype model. No conclusions can be drawn at this time concerning the system's correspondence to anticipated results since fabrication was not completed. Individual modules have been built and tested, however, and the results are presented.

The appendices include: the filter tuning procedure, the prototype test procedure and data record sheet, and the preliminary breadboard report. The variations from breadboard to prototype design are noted in the appendix.

2.0 SPECIFICATIONS AND OPERATING INSTRUCTIONS

The prototype model is designed to conform to specification 110114A (NASA/MSFC). In addition, an amplitude linearity of 1%, a phase linearity of 1%, and a channel isolation greater than 60 dB are expected.

2.1 Data Input

The input signals for each of the 19 channels may consist of information up to 3 kHz with a positive amplitude of zero to 5 volts. Any channel may be modified for ± 2.5V inputs by moving the jumper wire at R32 on the channel board module from the negative supply pad to the ground pad. The input impedance for each data channel is 100 kilohm ± 1%.

2.2 Special Service Channel Input

The special service channel input may consist of information from 10 Hz to 1 kHz whose level is less than ± 10 volts. The special service channel input impedance is greater than 100 kilohms. This channel may be used to transmit sync information if the data channels are externally time multiplexed.

2.3 Calibration Input

A positive going pulse from 12 to 20 volts at the calibration input will decouple the input signal from all channels and connect the 400 Hz calibration sine wave with an equivalent amplitude of 1 vpp. The inputs will be reconnected and the calibration signal removed in 300 milliseconds if the calibration input is not pulsed again. Pulsing at a rate greater than 3.3 pps will allow continuous calibration.

2.4 Transmission Modes

Each channel may have either a 1.5 kHz bandwidth or a 3.0 kHz bandwidth. Either single sideband or double sideband modulation may be used on each channel, except that a 3 kHz bandwidth cannot be used on any channel directly below a 3 kHz double sideband mode channel unless the latter is channel 16.

Mode selection for each channel is accomplished by selecting the plug-in IF filter module. One module is a 7 pole upper sideband filter for lower side band transmission. The other module is a 5 pole filter for double sideband transmission.

2.5 Output

Each of the 2 isolated outputs contain the special service channel attenuated by less than 3 dB, and the data and pilot channels attenuated by the AGC. The output level may be independently varied from 250 to 350 millivolts RMS by adjusting potentiometers R9 and R27 on the AGC module. Neither output is affected by loading of 300 ohms and .05 microfarad.

2.6 Power Requirements

The nominal power consumption is 20 watts when supplied from a 24 to 32V DC supply.

Isolation is provided between the input power terminals, the calibration input terminals, the chassis, and the data input/output terminals.

2.7 Connector Pin Specification

Connector/Pin	Function
J1/T	Channel 1 Input
J1/U	Channel 1 Return
J1/R	Channel 2 Input
J1/S	Channel 2 Return
J1/N	Channel 3 Input
J1/P	Channel 3 Return
J1/L	Channel 4 Input
J1/M	Channel 4 Return
J1/J	Channel 5 Input
J1/K	Channel 5 Return
J1/G	Channel 6 Input
J1/H	Channel 6 Return
J1/E	Channel 7 Input
J1/F	Channel 7 Return
J1/C	Channel 8 Input
J1/D	Channel 8 Return
J1/A	Channel 9 Input
J1/B	Channel 9 Return
J1/V	Channel 10 Input
J1/W	Channel 10 Return
J1/q	Channel 11 Input
J1/r	Channel 11 Return
J1/n	Channel 12 Input
J1/p	Channel 12 Return
J1/k	Channel 13 Input
J1/m	Channel 13 Return
J1/h	Channel 14 Input
J1/i	Channel 14 Return

2.7 Connector Pin Specification - (Continued)

Connector/Pin	Function
J1/f	Channel 15 Input
J1/g	Channel 15 Return
J1/d	Channel 16 Input
J1/e	Channel 16 Return
J1/b	Channel 17 Input
J1/c	Channel 17 Return
J1/Z	Channel 18 Input
J1/a	Channel 18 Return
J1/j	Channel 19 Input
J1/X	Channel 19 Return
J1/Y	Chassis
J1/s	Spare
J1/t	Spare
J2/A	Calibration Control Input
J2/B	Calibration Control Return
J2/K	Special Service Channel Input
J2/L	Special Service Channel Return
J2/E	Output No. 1
J2/F	Output No. 1 Return
J2/C	Output No. 2
J2/S	Output No. 2 Return
J2/H	Chassis
J2/D,G,J	Spares
J2/M,N,P	Spares
J2/R,T,V	Spares
J3/A	28V Power Input
J3/B	28V Power Return
J3/C	Chassis
J3/D,E	Spares

3.0 THEORY OF OPERATION

The system block diagram is shown in Figure 1.

3.1 Data Modulation

Channel data is introduced into the first amplifier through an integrated switch. A calibration pulse input will throw this switch to the 400 Hz calibration signal for 300 ms. This is equivalent to placing the 1V p-p, 400 Hz sine wave on all inputs.

The channel data is next mixed with 14.22 kHz in a chopper-type suppressed carrier modulator. The signal spectrum then consists of information sidebands on the 14.22 kHz IF frequency and on all odd harmonics of the IF frequency. The signal is then passed through a buffer amplifier. All of the amplifiers shown on the block diagram are primarily used for impedance isolation rather than voltage gain.

The next block is an IF filter which removes the harmonic sidebands. The DSB IF filter (5 pole) will pass both fundamental sidebands while the alternate SSB IF filter (7 pole) will pass only the upper fundamental sideband.

Each channel's IF signal is then translated to its correct frequency slot in the output spectrum by a modulator identical to the IF modulator.

The chopper frequency of this modulator is 14.22 kHz above the center frequency of the channel's output spectrum. For example, if a 1 kHz tone is placed at the input to Channel 5, it will be modulated by the IF to produce fundamental sidebands at 13.22 and 15.22 kHz. The DSB IF filter will pass both these sidebands while the SSB IF filter will pass only 15.22 kHz. The second modulator for Channel 5 has a chopper frequency of (5 X 4.74) + 14.22 = 37.92 kHz. The fundamental sidebands produced are at 23.70 ± 1.0 kHz and 52.14 ± 1.0 kHz in the DSB Mode and 23.70 - 1.0 kHz and 52.14 + 1.0 kHz in the SSB mode.

Channel 5 output filter passes all frequencies from (5 X 4.74) - 3 kHz to (5 X 4.74) + 3 kHz so the output of the example is at 23.6 kHz (SSB or DSB) and 23.8 kHz (DSB).

3.2 Subcarrier Generation

The subcarriers consist of square waves at multiples of 4.74 kHz from 3 to 18 and 21 to 24. They are used for the two pilot tones and the chopper input of the IF modulators and output modulators.
All are produced by clocked, logical. division of the four oscillators.

The three voltage controlled oscillators are phase and frequency locked to the stable crystal oscillator by the use of phase-locked loops and presets. Each oscillator is followed by a digital divider chain, one of whose outputs is a 28.44 kHz (Ch. 6) square wave. Each phase-locked

3.2 Subcarrier Generation - (Continued)

loop adjusts the frequency and phase of its oscillator until its 28.44 kHz is synchronous with that of the crystal oscillator divider chain.

The crystal oscillator also produces a pulse with a 4.74 kHz repetition rate which presets all chains such that every synthesized subcarrier has zero phase angle when the preset pulse occurs. The final division block preceding each subcarrier output consists of a single flip-flop or divide by 2 network for symmetrical square wave output.

3.3 AGC and Output Circuits

AGC action is applied to all data channels and both pilot tones. Both pilot tone square waves are individually filtered to remove all harmonics before being combined with the channel outputs. The amplitude level of the upper pilot tone (17 X 4.74 kHz) is the same as the amplitude of any channel output when operated in the single sideband mode, with a 5 volt peak-to-peak sine wave at the input. The lower pilot tone (16 X 4.74 kHz) is twice the amplitude of the higher pilot tone. The AGC keeps the total level of all data channels plus the pilot tones constant within 5% regardless of channel usage. This output level can be set from 250 to 350 millivolts. Two output amplifiers provide separate output for the transmitter and for the ground equipment. These amplifiers combine the special service channel data with the AGC controlled data.

3.4 Power Supply

The power supply operates on a standard 28 volt line. The input is first regulated to 18 volts and then applied to a DC-DC converter. The 5 volt logic supply is taken directly from the converter while the ± 13 volts for the operational amplifiers are regulated to a nominal value ± 1%.

4.0 PROTOTYPE MODEL ANALYSIS

4.1 Channel Module

4.1.1 Channel Modulation

Each channel board frequency translates one data or calibration input into the output spectrum by a superhetrodyne process. The specification of constant input impedance, even during calibration, requires a high impedance amplifier. This is achieved by using the positive input of the operational amplifier. Since this configuration does not allow a voltage gain of less than unity, a resistive attenuator is placed at the input so that the maximum allowable signal will not over-drive the first mixer. A FET switch is used to apply the calibration signal when a positive voltage is placed on the control input. The switch is arranged to draw current only during calibration and the external resistors (15 Meg.) provide the required bias without exceeding the back current specification.

Both mixers on the board are balanced bridge types. The output consists of the input signal with polarity reversal at each change of state of the digital input. Since the digital subcarrier acts merely as a switch, small amplitude variations in either of its two states are not reflected onto the output. Variations in the switching level of the diodes are swamped by the series resistors. These resistors also prevent reflection of a non-linear impedance to the amplifiers which would cause harmonic distortion.

The output of the first mixer and buffer amplifier is an AM IF signal with suppressed carrier plus higher frequency terms which are attenuated by the IF filter. The signal received from the IF filter module is impedance buffered and mixed with a subcarrier whose frequency is equal to the channel center frequency plus the IF frequency. The output therefore contains the information in sidebands about a frequency equal to the sum of the channel frequency and two times the IF frequency plus higher frequency terms which will be attenuated by the channel filter. Only the sidebands about the channel center frequency will be passed.

Since the passed information results from the selection of the difference rather than the sum of the two input frequencies, the sidebands of the output will be reversed from those of the input. Lower sideband information on the IF becomes upper sideband information at the output. This fact helps to reduce the amplitude distortion error due to the filters.

The inherent arithmetic skewing of band-pass filters causes the phase shift at equal distances from the geometric center to be unequal in magnitude. The lower frequency phase shift (p1) will be greater in magnitude than the upper frequency phase shift (p2). When these sidebands are combined in the demodulation process this difference in phase shift will cause an error in amplitude.

4.1.1 Channel Modulation - (Continued)

In the DSB case, the IF and output filters have equal bandwidth so that a curve of phase shift versus normalized frequency would be identical for both filters. This is a monotonicly increasing curve passing through zero phase shift at channel center. The upper sideband therefore was a positive phase shift while the lower has a negative phase shift. The upper sideband of the IF would therefore receive a positive phase shift equivalent to p2 in the IF filter. It would then become the lower sideband due to the second mixer and receive a phase shift equivalent to -pl in the output filter. Since the mixer also reverses the sign of the phase shift, the phase shift at the output is -(pl + p2) on the upper sideband.

The lower sideband of the IF receives a negative phase shift equivalent to pl in the filter and a phase shift equivalent to p2 in the output filter. The output phase shift on the lower sideband is then + (pl + p2). Therefore; the phase magnitude on both sidebands is more nearly equal in magnitude. This effect, which reduces the demodulated amplitude error due to arithmatic skew, is most effective on the lower channels.

4.1.2 Channel Filters

The channel filters are designed by a predistorred pole technique which decreases the required Q of the inductors. The polynominal for .01 dB chebychef filter is first derived in factored form. A constant, termed "d" is then added to each root and the factors multiplied together to produce the distorted polynominal. This polynominal is then realized as the denominator of a transfer function using the Darlington single-loaded technique. The pole distortion is cancelled by adding resistance in series with all inductors and in shunt with all capacitors. The resulting network is then frequency scaled for correct bandwidth, bandpass transposed to the correct center frequency and impedance equalized for equal capacitors.

Each output filter (except Channel 1) has a 9 kHz, 0.1 dB bandwidth geometrically centered at the channels's center frequency. The center frequency for channels 1 to 15 is 4.74 kHz times the channel number. Center frequency for channels 16 to 19 is 4.74 kHz times the channel number plus 2. Channel 1 has a 0.1 dB bandwidth of 8.925 kHz, geometrically centered at 4.25 kHz. The lower frequency of this filter requires it to be different than the other channels so that its skewing will not interfere with channel 2.

The resulting filter is shown on the channel board schematic. (dwg. No. 360014S). The tuning of this filter consists of the following steps:

1. Each parallel and series RLC circuit must be tuned to the correct center frequency. This is accomplished by adding or subtracting turns from the toroid inductor.

4.1.2 Channel Filters - (Continued)

2. Each parallel and series RLC circuit must be adjusted to the correct bandwidth by varying the resistance. Double resistors are used so that 1% accuracies can be obtained with 5% resistors. The 3 dB bandwidth must be made equal to the ripple bandwidth times "d" (1.69 kHz).

3. The taps on each shunt coil must be adjusted so that the correct impedance match exists between adjacent tuned circuits. Since in this filter, any two adjacent circuits form an over-coupled pair, the degree of coupling can be determined by the amount of separation of the two peaks in gain which result when any two adjacent circuits are isolated.

   The formula is: $\Delta f = \sqrt{(nf_o)^2 - (1690)^2}$ may be used to set each top value.

   where: Δf is the separation in the two gain peaks in Hz.
   f_o is the channel center frequency in Hz.
   n is the fraction of the total number of turns corresponding to the tap point.

   Complete information on the coils is contained on drawing D360043.

After this preliminary tuning, the filter response should be very close to ideal. The response of a Channel 5 filter after this preliminary tuning is shown in Figure 2. The frequency response plot is folded over about the center frequency. The theoretical upper and lower responses then coincide as shown. In this filter and particularily in high frequency filters, problems such as electrostatic and magnetic coupling due to proximity, limited accuracy (one turn) in inductor tuning and core deformation in coil mounting may require additional final tuning. Although there is no analytic procedure available, several guide lines have been established:

1. Asymetrical ripple is usually due to one or more coils not resonating at the proper frequency. The coil at fault can best be found by varying the resistance of each section which will show one section to have more effect on the asymetry than the rest. This coil can then be adjusted to create a symmetrical pass band.

2. A gradual slope in the pass band is usually due to proximity coupling and can be corrected by slightly shifting the resonant frequency of the initial stages.

4.1.2 Channel Filters - (Continued)

3. Ripple can be smoothed by varying the resistance of the stages. The first stage has most effect at the edges and middle of the passband while the third stage has most effect at the center. The second and fourth stage have greatest effect between the center and edge of the passband. Variation of the load resistor can be used as a fine control to reduce the ripple. In general, the first stages have more effect on the pass band characteristic than those near the load.

4. Bandwidth can be corrected and some ripple improvement made by slight adjustments of the tap points.

Figure 3 shows the effect of final tuning on the response curve in Figure 2.

4.2 IF Modules

The DSB module is a 5 pole, 0.01 dB, Tchebychef filter with a 0.1 dB bandwidth of 9 kHz, geometrically centered on the IF frequency. This filter attenuates all IF harmonic sidebands by greater than 60 dB while passing the fundamental sideband with less than 0.1 dB amplitude ripple. This filter is identical to the channel 3 output filter. The SSB module is a 7 pole, 0.01 dB, Tchebychef filter with a 0.1 dB bandwidth of 5.2 kHz. The lower 0.1 dB point is at the IF frequency so that the lower sideband is attenuated. A bandwidth larger than required by data spectrum is used in both IF filters to reduce the group delay error which is greatest at the edges at the pass band.

4.3 Crystal Oscillator

A standard Pierce crystal oscillator is used for high stability. The crystal is electrically tuned by the voltage variable capacitor to the correct frequency. Small thermal reactance changes in the circuit are corrected by the temperature sensitive biasing resistors which change the voltage variable capacitance to maintain frequency stability. Buffer amplifiers couple and amplify the signal until its rise time and impedance level are sufficient to clock the digital divider chain.

.4 VCO and Phase Locked Loop

The VCO is a Colpitts oscillator capable of being tuned by its voltage variable capacitors with a frequency shift of 1% per volt. Distortion due to the non-linear varactors is reduced by using two devices connected such that odd harmonics which cause cross-over distortion are cancelled

4.4 VCO and Phase Locked Loop - (Continued)

in the same manner as in class B amplifiers. The phase detector, which compares the 28.44 kHz derived from the VCO with the same frequency signal derived from the crystal oscillator, is a digital "exclusive or" circuit. This type of detector is small and well suited to the phase comparison of digital signals. The output is a 56.88 kHz repetition rate digital signal whose duty cycle and therefore DC level is proportional to the phase difference between the inputs. When the loop is locked the two input signals will be in quadrature and the output duty cycle will be 50%, corresponding to a DC level of 2-1/2 volts. This signal is then integrated in a 3 pole low-pass filter, breaking at 8 kHz, to attenuate all but the DC information by a least 50 dB. In order to prevent changes in the digital logic supply level from affecting the DC level at which loop-lock occurs, the compliment of the output is also derived, integrated and subtracted from this signal. The output of the differential amplifier is therefore zero when the loop is locked, independent of fluctuations of the logic levels. The phase detector is followed by a lag-lead loop filter with break frequencies of 1.3 and 2.8 kilohertz. The resultant second order loop has a gain margin of 13 dB and a phase margin of 47°, insuring high stability.

4.5 Digital Divider Chains

4.5.1 Digital Synchronization

Four divider chain modules, each driven by an oscillator, are used to produce all the necessary internal frequencies. Each divider chain is composed of sequential, synchronously clocked, JK flip-flops. Gated feedback is used to set the devisors and gated feed-forward is used to suppress toggling of the flip flops on adjacent clock periods.

Since the VCO's are adjusted until 6F (6 X 4.74 kHz) in the oscillator divider chain is synchronous with 6F in the TCXO chain, it is necessary to preset the flip flops in each VCO chain so that they are synchronous with the output of the flip-flop producing 6F. This preset signal is derived within each divider chain by gating that chain's 6F with a signal "D" from the TCXO divider chain as shown in Figure 4. The signal "D" has a frequency of 1F and is derived by gating $\overline{1F}$, $\overline{2F}$, $\overline{4F}$, $\overline{8F}$, and $\overline{16F}$ from the TCXO devider chain. This signal is then delayed by four microseconds to overlap zero phase time in the TCXO. The delayed signal is gated with 6F from the VCO and then differentiated to form a preset pulse. The delay and differentiation process is necessary to overcome any VCO delay caused by the phase locked loop. The TCXO is preset without this delay.

4.5.2 Digital Phase Errors

The phase error between sub-carriers generated by the same divider chain is due to differences in time delay between flip-flops. The maximum specified difference in time delay here is 40 nanoseconds at 25°C. The change in time delay due to temperature and power supply changes is small and will be the same direction for all flip-flops in the chain and will therefore not affect the worst-case time delay difference.

Sub-carriers generated by different divider chains may have relative phase errors due to the phase-locked loop. The possible errors are:

a. A change in the reference (TCXO) frequency. This creates a maximum error of 1 nonosecond when the temperature compensating resistors are selected to lower the frequency error to ±10 parts per million.

b. VCO frequency change. Changes in the VCO frequency will be corrected by the phase-locked loop, but this creates a phase error. A ± 2% change in supply voltage will give a maximum time error of 40 nonoseconds.

c. Variation in VCO control voltage. The initial control voltage is accurately adjusted at room temperature for zero time error. Offsets of this voltage over temperature will cause a maximum of 18 nonoseconds time error. The method of phase detection does not allow variation in the logic levels or the 5 volt power supply to affect the VCO control voltage when the loop is locked This is achieved by adjusting R19 for symmetrical DC gain for both inputs of the phase detector. Temperature variation can only affect the logic levels and therefore does not affect the control voltage.

d. Ripple in the VCO control voltage. The three-pole detector filter and one-pole loop filter will not completely attenuate the 12F ripple. This will cause a phase modulation of the VCO with a maximum peak time error of 5 nonoseconds.

These errors when summed at room temperature give a worst case fixed time error of 40 nanoseconds maximum plus a varying error of 40 nanoseconds maximum, which together will give a maximum phase error of 3° in the 24F sub-carrier used on channel 19. With temperature variations, the varying phase error can increase in the worst case to 250 nanoseconds. This error can be lowered by temperature compensating the VCO (the main error source) by using capacitors with compensating temperature coefficients.

4.6 Power Supply

The power supply consist of a pre-regulator, a DC-DC convertor and two post regulators. A switching type inductive pre-regulator is used for high efficiency. Feedback varies the conduction time keeping a constant 19 volts at the input to the DC-DC convertor. The logic supply (+5 volts) is taken directly from the convertor output while the positive and negative 13 volt operational amplifier supplies are individually regulated to isolate them from any power line transient in the logic supply.

The load regulation of the 13V supply is shown in Figure 5. Figure 6 is a thermal analysis of the power dissipation in the power transistors.

4.7 Calibration

The calibration circuit produces a stable low distortion 400 Hz sine wave by using a modified Wien bridge oscillator. A non-loading detector senses the amplitude of the output. This level is compared to a level preset by R14 and the difference is used to force the amplitude of oscillations to the required level. Control is retained over every period of the 400 Hz signal to prevent the oscillator from saturating. Variation of the FET conductance is used to set the gain of the oscillator's amplifier while the frequency is set by the reactive positive feedback. The calibration signal is gated into the channel modules when the calibration control signal is grounded. A positive calibration command pulse above the noise margin of 12 volts is coupled to the control circuitry by a photon switch to provide isolation. The input impedance is greater than 1 megohm and the input will decay to a re-triggerable position before the 300 millisecond burst of 400 Hz is completed. The output of the photon isolator is amplified and applied to a one shot with a 300 millisecond pulse width. The calibration gate on the channel module is connected such that it draws power only during the calibration operation.

4.8 AGC

All data channel plus the pilot tones are summed in the first AGC amplifier. The summing resistors are located on their individual modules so that the summing node on the AGC board and on the mother board is a low impedance node. This node, or trace, on the mother board is flanked on either side by traces connected to the chassis to guard the summing node. After summing, the composite signal is attenuated for low AGC distortion. The AGC amplifier is followed by the two output amplifiers where the special service channel is added.

4.8 AGC - (Continued)

The output of the AGC amplifier is full-wave, average detected. The specification of equal attack and recovery time requires an averaging detector since a peak detector would inherently produce a longer recovery than attack time. The output of Q1 is therefore a DC level corresponding to the average amplitude of the spectrum, plus ripple. The rectified signal is supplied to a two-pole active low pass filter to remove the ripple. Filter theory states that the lower the frequencies to be attenuated in a low-pass filter, the greater the time delay of the DC response. Due to full-wave rectification, the lowest ripple frequency is twice the lowest frequency in the spectrum so that a minimum time delay is necessary in the filter.

The DC output of the filter is compared to a pre-set level (adjustable by R12) and the difference amplified and applied to Q3 to set its source to drain conductance. The gain of the AGC amplifier is R6 times the conductance of Q3. This conductance is linear over a 20 dB range of inputs to the AGC amplifier (Figure 7) which is sufficient because the input is only allowed to vary 14 dB due to the presence of the two pilot tones. Since Q3 is at the input to the amplifier, the amount of spectrum signal across it is small, and therefore, the distortion is also small.

Any ripple that is not completely attenuated by the filter will vary the conductance of Q3 and therefore modulate the entire output spectrum to a small degree. This modulation is less than 5% and since it is applied to the pilot tones as well as the information channel, the ground AGC can cancel this effect.

4.9 Special Service Channel

The special service channel filter is a ten pole, 0.05 dB ripple, active low-pass filter. The pass band extends from below 10 Hz to 1 kHz and all frequencies above 1. kHz are attenuated by more than 50 dB. Each stage of the filter realizes two conjugate poles whose break frequency and damping factor are set by the values of the two capacitors. The second stage has added feedback to produce a very small damping factor and an added emitter follower to improve the stage isolation. The capacitors used are the nearest 5% values to those required for a .05 dB ripple, so that the ripple of the actual filter, while less than 3 dB is not .05 dB.

4.10 Tone Filter

The two pilot tones (16 X 4.74 kHz and 17 X 4.74 kHz) are filtered on the tone filter module. Each pilot tone square wave, from the digital logic, is amplified and limited in a stage powered from 13 volts to remove the ripple on both levels of the logic signal which is inherent in JK flip-flops and caused by the clock and input gates. The square wave level produced is set by the collector resistor. This state is followed by a 3 pole 0.01 dB ripple, Tchebychef filter to attenuate the first harmonic of the square wave to 1% of the fundamental.

4.11 System

Circuitry guarding is accomplished by a chassis shield on the component side of all modules except the digital board and the power supply, by shielding of the flex print and by the location of the power lines and chassis lines on the mother board. Three separate internal grounds are used. The 5V return for the digital logic is connected to the plus and minus 13 volt return at only one point, the power supply. A separate return is used for the output of the second modulator and the output filter and its buffer amplifier. These returns are joined to the ± 13 volt return at the AGC module. This prevents undesired signals from flowing in the grounds of the initial and final stages of modulation. The separation of these three ground is enabled by the use of input and output transformers on the mixers.

5.0 INITIAL DATA AND PRODUCTION NOTES ON THE SYSTEM MODULES

5.1 TCXO

The module has been tested and is operational but the frequency is .02% high. This can be corrected by changing C2 and/or C3.

The temperature compensating resistors are omitted and the open end of R1 is grounded.

5.2 VCO Assemblies

5.2.1 Test

The oscillators on all three VCO assemblies are operational but the stability of operation for VCO 1 and 2 is dependent on the control voltage. To correct this, change C1 on VCO 1 to 470 pf and C1 on VCO 2 to 680 pf. To adjust the frequency on the VCO, ground test point one and set C15 to the middle of its range. C14 should then be selected for the approximate center frequency of 6.54 MHz for VCO 1, 5.18 MHz for VCO 2 and 1.88 MHz for VCO 3. C15 can then be adjusted for the exact frequencies.

5.2.2 Construction Notes

(a) Assembly drawing 360003 - Note that lead 1 on transformer 1 is color coded and is not labeled.

(b) PC Board - The test receptical pads are too small. The connector staking pin near connector pin A should be moved. Component C8 should be separated from the adjacent jumper wire. The bround plane must be removed from the area at the end of the jumper wire near Z1.

(c) PL 360003 - Item 31 should be changed to CM05D471J03 for dash 1, CM05D681J03 for dash 2, CM05D472J03 for dash 3. Items 41, 42, and 43 should be changed to the values selected for C14.

5.3 Special Service Channel

5.3.1 Test

Component C9 is not assembled and R1 must be changed to 100K. The card has been tested with equivalent components and has a 3 dB bandwidth from 5 Hz to 999 Hz and a 0.5 dB ripple from 100 Hz to 800 Hz. When the system is assembled, set the output amplifier for 350 millivolts output with no input on the special service channel. Then set the service channel for an attenuation of 0 dB at 100 Hz by redefining R7 and R25 on the AGC module.

5.3.2 Construction Notes

(a) PL 360006 - Item 11 should be RC05 GF104J. Items 29 to 34 should be MC 602 and MC 502 type capacitors.

5.4 Calibration Oscillator

5.4.1 Test

The assembly is operational. The calibration time is approximately 250 milliseconds. The following adjustments should be made: Set R14 for a dc voltage of approximately 2 volts at TP4. The exact voltage is dependent on the particular FET (Q1) used, and will determine the amplitude change over the temperature range. R7 should be set to give the specified output amplitude of 0.161 Vpp at TP3 with the output loaded by the channel inputs.

5.4.2 Construction Notes

(a) PC Board - More area should be provided for R10 and the connector pads in the lower row should be moved to the left. Both drains of Q2 should be connected to +13V.

(b) PL 360007 - The transipad for Item 13 should be added. Item 30 should be Aerovox type MC602C105M. Item 37 should be RN 65C2003F.

5.5 AGC

5.5.1 Test

The assembly is operational. Make the final adjustments on the circuit by performing 5.1.5 in the test procedure. The voltage at TP1 should be approximately 1 volt RMS maximum. R12 should be adjusted for between 60 and 70 millivolts RMS at TP3. The difference in levels at TP3 for high and low input levels should be less than 0.4 dB. R22 may be increased to reduce the output distortion and the attack and decay times can be affected by changing C11 and C12. Increasing R16 will decrease the output variations, but will also lower the stability margin of the loop.

5.5.2 Construction Notes

(a) PC Board - Space is marginal for Items 10, 12, and 28. The shielding plane is too close to the strip near Item 15 and there should be an open area in the plane at the point where it is connected to its connector pin by the z wire.

5.5.2 Construction Notes - (Continued)

(b) Drawing 360012 - The transipad for Item 12 should be Item 3, the transipad for Item 10 should be Item 4.

5.6 Tone Filter

The tone filter is operational and both filters have been tuned.

5.7 Power Supply Construction Notes

(a) Drawing 360042 - Item 18 is R8, not R18.

(b) PC Board - Space provided for T1 is marginal.

(c) PL 360042 should be changed as follows: Delete Item 30, change Item 35 to CS13BB337K, Change Item 23 to Spectral type 50-3-1/1K. Change Item 24 to Spectral type 50-3/50K.

5.8 Channel Modules

5.8.1 Test

Initial data on four of the channel modules is:

(a) Channel 10 - .60 dB at upper band-edge, -.3 dB at lower band-edge, .3 dB ripple, 1° phase shift at center frequency.

(b) Channel 17 - .3 dB at lower band-edge, -.7 dB at upper edge, less than .3 dB ripple, less than 1/2° phase shift at center frequency.

(c) Channel 18 - .5 dB at upper band-edge, -.5 dB at lower band-edge, ripples less than .4 dB, 6° phase shift at center frequency.

(d) Channel 19 - .25 dB at lower band-edge, ripple .3 dB, less than 1° phase shift at center frequency.

Since Channel 1 filter is slightly different from the others, the individual stages must be tuned to 1.57 kHz rather than 1.69 kHz bandwidth.

5.8.2 Construction Notes

The input terminals of the FET switch on the channel board has been reversed. This means that the 400 Hz calibration signal will be applied to all channel inputs unless a calibration control signal is applied.

5.8.2 Construction Notes - (Continued)

This can be corrected by using output pin A instead of pin F on the one shot (Z4) on the calibration card. If the increase in supply current this causes is intolerable, then terminals 9 and 4 must be reversed on Z1 on each channel board.

5.9 IF Modules

Initial data on the three single sideband IF modules is:

(a) Module 1 - 1.8 dB at upper band-edge, -1.0 dB at lower band-edge, .5 dB ripple at center frequency less than 1/2° phase shift.

(b) No. 2 - -1.5 dB at upper band-edge, -.7 dB at lower band-edge, .4 dB ripple, 1° leading phase shift at center frequency.

(c) No. 3 -.3 dB at upper band-edge, + .1 dB at lower band-edge 1.6 dB ripple, 1° leading phase shift at center frequency.

Initial data is available on four DSB IF modules:

(a) No. 1 - -.5 dB at upper band-edge, -.3 dB at lower band-edge, .5 dB ripple less than 1/2° phase shift at center frequency.

(b) No. 2 - 0 dB at upper band-edge, + .25 dB at lower band-edge, .5 dB ripple, 3° lagging phase shift at center frequency.

(c) No 3 - 0 dB at upper band-edge, 0 dB at lower band-edge, .3 dB ripple, less than 1/2° phase shift at center frequency.

(d) No. 4 - 0 dB at upper band-edge, .2 dB at lower band-edge, .5 dB ripple, less than 1/2° phase shift at center frequency.

6.0 SS/DSB MULTIPLEXER DRAWINGS

PL 360000	Multiplexer Assembly
PL 360001	Power Supply Assembly
PL 360002	TCXO Assembly
PL 360003	VCO Assembly
PL 360006	Aux. Channel Assembly
PL 360007	Calibration & Osc. Assembly
PL 360012	Tone Filter Assembly
PL 360013	IF Filter Assembly
PL 360016	Tone Filter Assembly
PL 360017	Parent Board Assembly
PL 360029	Retainer Support, Center
PL 360039	Retainer Support, Side
A319058	Holder, Crystal
B360019	Inductor, Heatsink
B360020	Choke
B360023	Guide
B360024	Guide
B360025	Guide
B360026	Block, Heatsink
B360031	Support, Center
B360032	Spacer
B360036	Insulator
B360037	Cushion
B360041	Bracket
B360048	Transformer (VCO)
B360051	Transformer (AGC)
C360018	Transformer (Pwr. Supply)
C360022	Crystal Unit
C360027	Block, Heatsink
C360028	Block, Heatsink
C360034	Cover, Top Assembly
C360035	Cover Top Assembly
D360002	TCXO Assembly
D360003	VCO Assembly
D360006	Aux. Ch. Assembly
D360007	Calib. & Osc. Assembly
D360013	Filter Assembly
D360029	Retainer Support, Center
D360030	Retainer Support, Side
D360033	Cover
D360039	P.C. Board
D360040	P.C. Board
D360043	Transformer, Filter
D360046	P.C. Board
D360047	P.C. Board
D360049	P.C. Board

6.0 SS/DSB MULTIPLEXER DRAWINGS - (Continued)

E360012	AGC and Output Assembly
E360014	Chan. Board Assembly
E360016	Tone Filter Assembly
E360038	P.C. Board
E360042	Pwr. Supply Assembly
E360044	P.C. Board
E360050	P.C. Board
J 360015	Chan. Assembly
A360013 S,D	IF Filter Schematic
A360016S	Tone Filter Schematic
B360002S	Temp. Compensated Crystal Osc. Schematic
B360003S-1,2,3	VCO Schematic
B360007S	Calibration Schematic
B360012S	AGC Schematic
C360006S	Spec. Service Ch. Schematic
C360008S	TCXO Counter Schematic
C360009S	VCO-1 Counter Schematic
C360010S	VCO-2 Counter Schematic
C360011S	VCO-3 Counter Schematic
C360014S	Channel Board Schematic

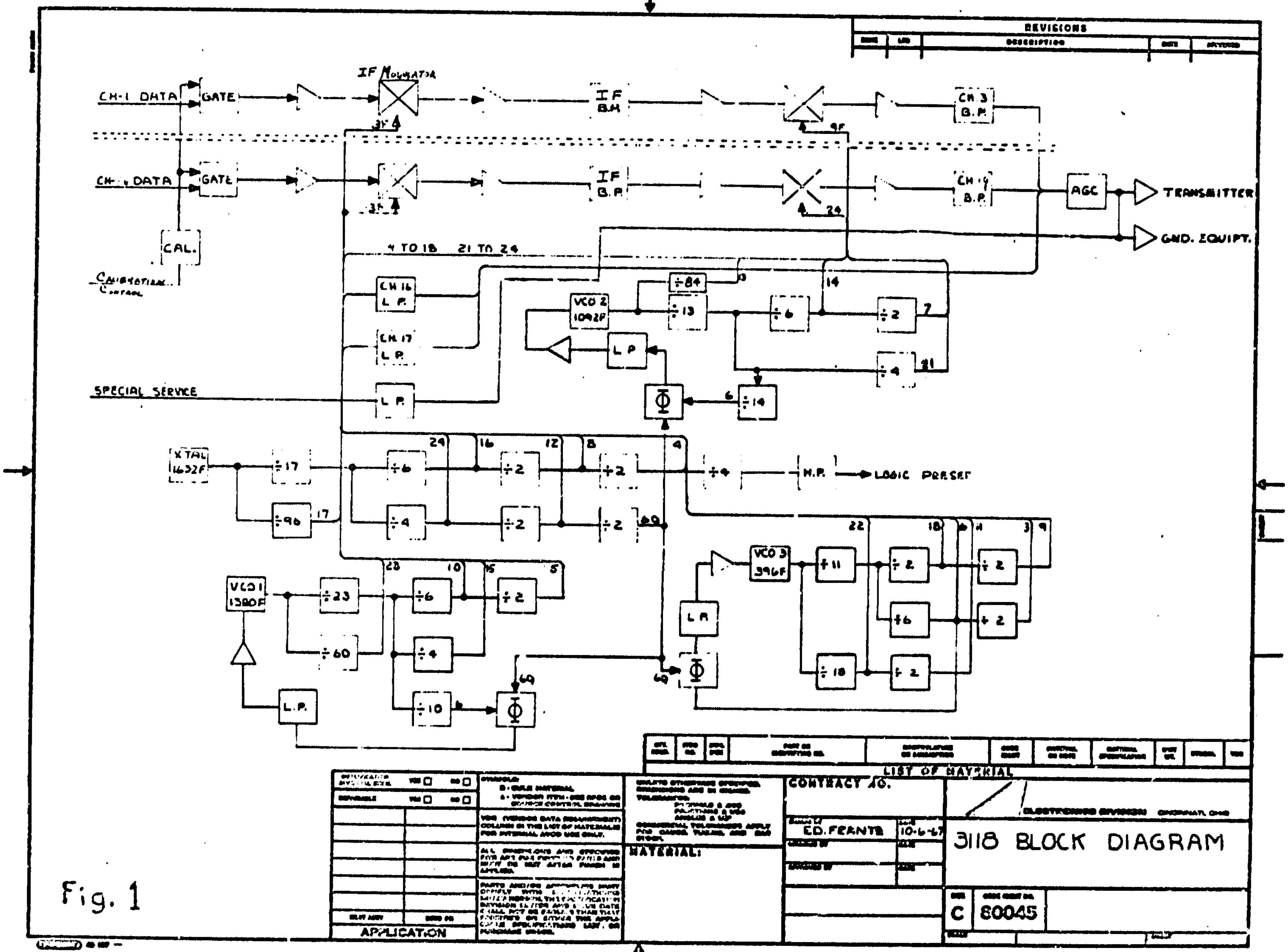
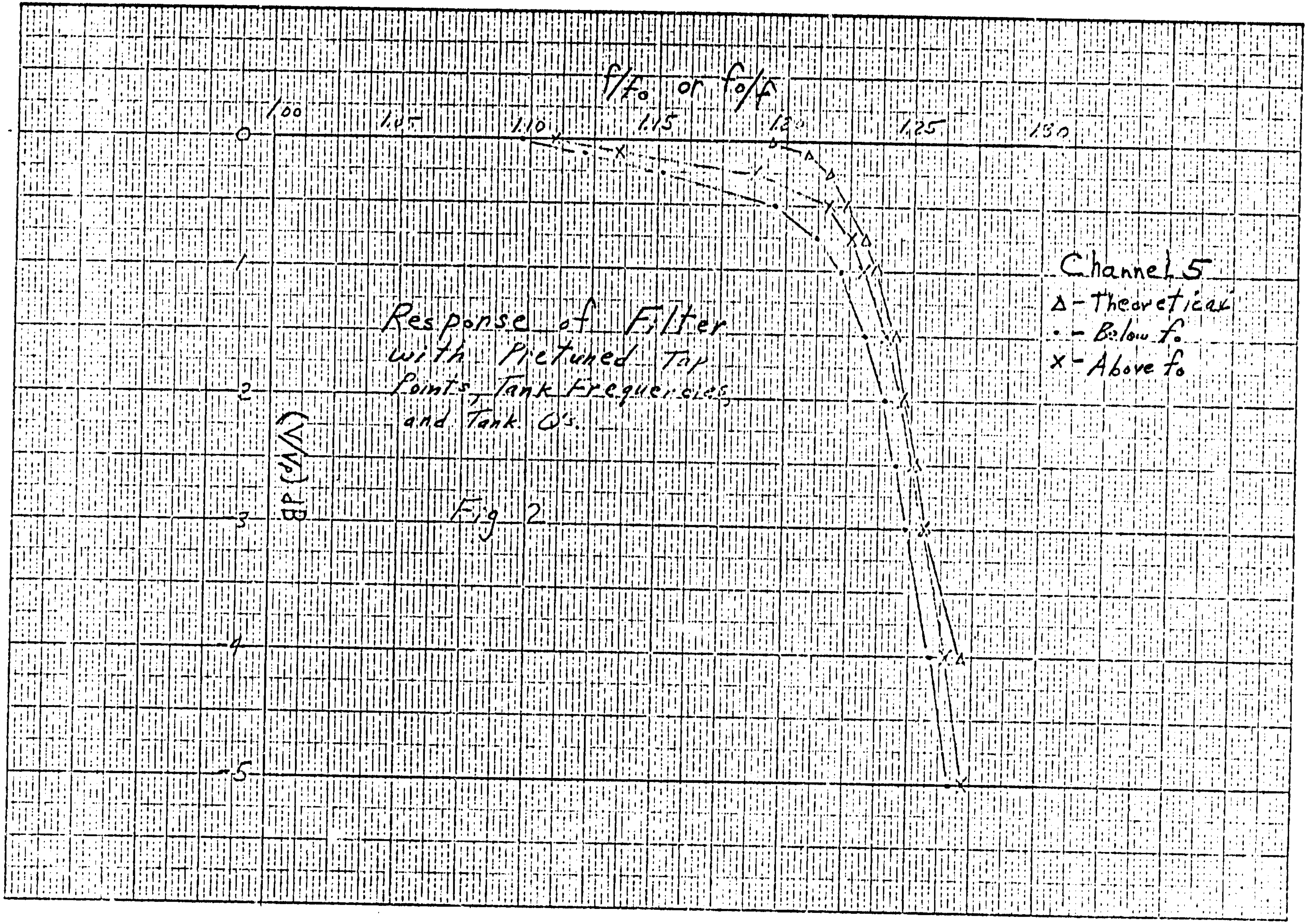
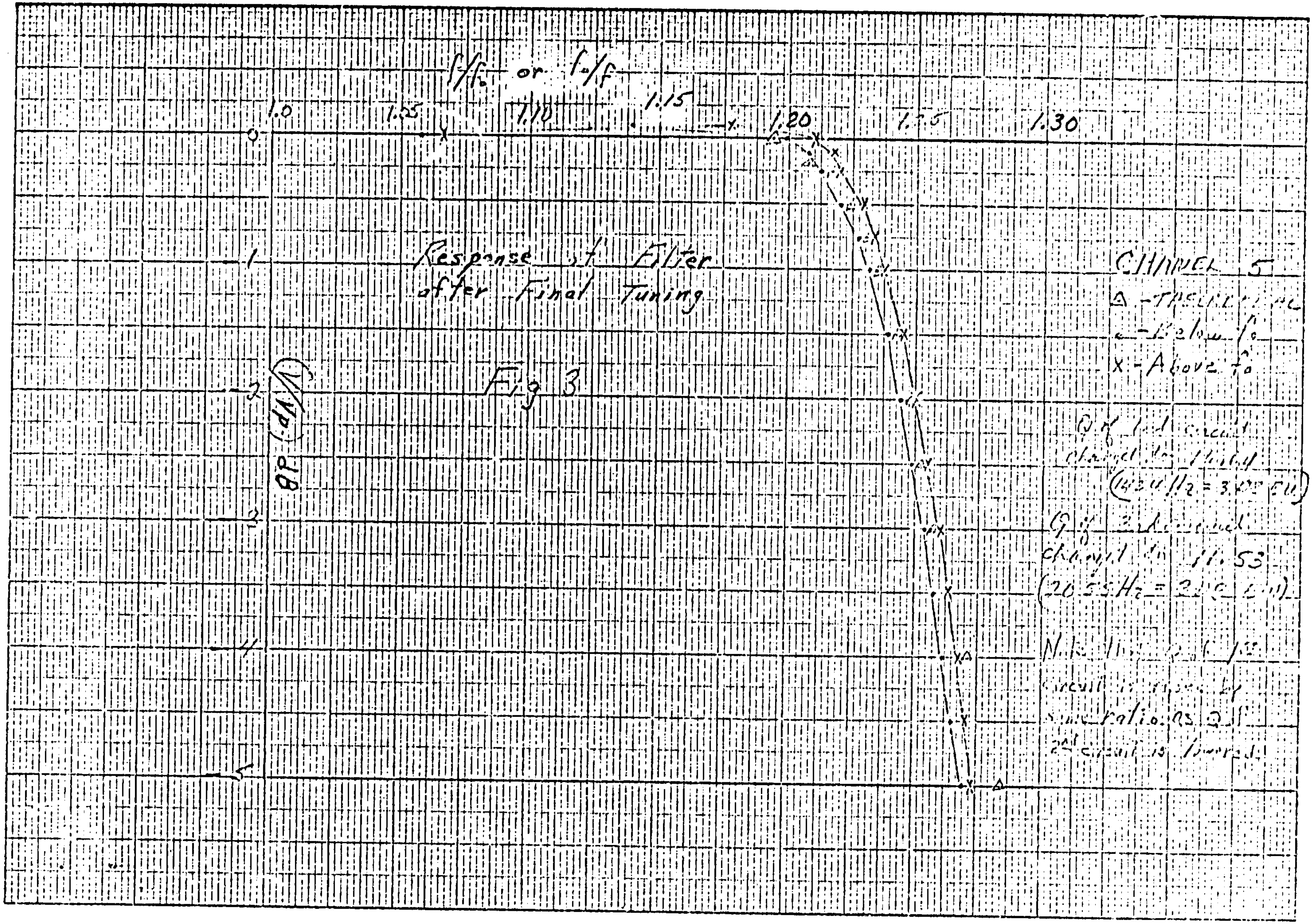

REVISIONS
CH-1 DATA
GATE
IF MODULATOR
IF B.P.
CH 3 B.P.
CH-4 DATA
GATE
IF B.P.
CH 4 B.P.
AGC
TRANSMITTER
GND. EQUIPT.
CAL.
CALIBRATION CONTROL
4 TO 18 21 TO 24
CH 16 L.P.
CH 17 L.P.
SPECIAL SERVICE
L.P.
VCO 2 1092F
÷84
÷13
÷6
÷2
÷4
÷14
L.P.
Φ
XTAL 1632F
÷17
÷96
÷6
÷4
÷2
÷2
÷2
÷2
÷4
H.P.
LOGIC PRESET
VCO 1 1380F
÷23
÷60
÷6
÷4
÷10
÷2
L.P.
Φ
VCO 3 396F
÷11
÷18
÷2
÷6
÷2
÷2
÷2
L.P.
Φ
3F
9F
24
14
7
21
6
24
16
12
8
4
17
69
22
18
4
3
9
23
10
15
5
6
69
LIST OF MATERIAL
CONTRACT NO.
ED. FRANTZ
10-6-67
MATERIAL:
APPLICATION
3118 BLOCK DIAGRAM
C
80045

Fig. 1



Response of Filter with Pretuned Tap Points, Tank Frequencies and Tank Q's.

Fig 2



Response of Filter after Final Tuning

Fig 3

CHANNEL 5

Δ - Theoretical

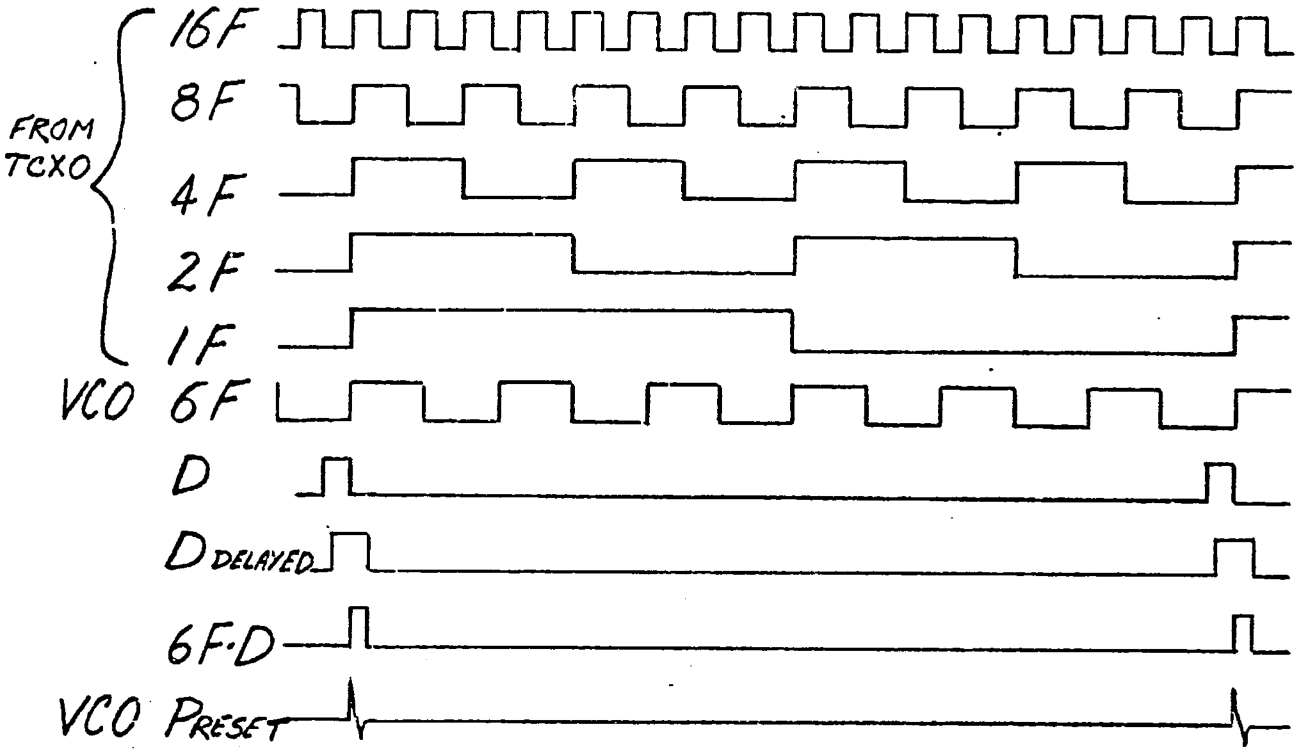
• - Below f_0

x - Above f_0

Q of 1st circuit changed [illegible] [illegible] ([illegible] Hz = 3.[illegible] [illegible])

Q of 2nd circuit changed to 11.53 (20.55 Hz = 2.[illegible] [illegible])

Note [illegible] Q of 1st circuit is raised by same ratio as Q 2nd circuit is lowered.



VCO PRESET GENERATION

FIG. 4

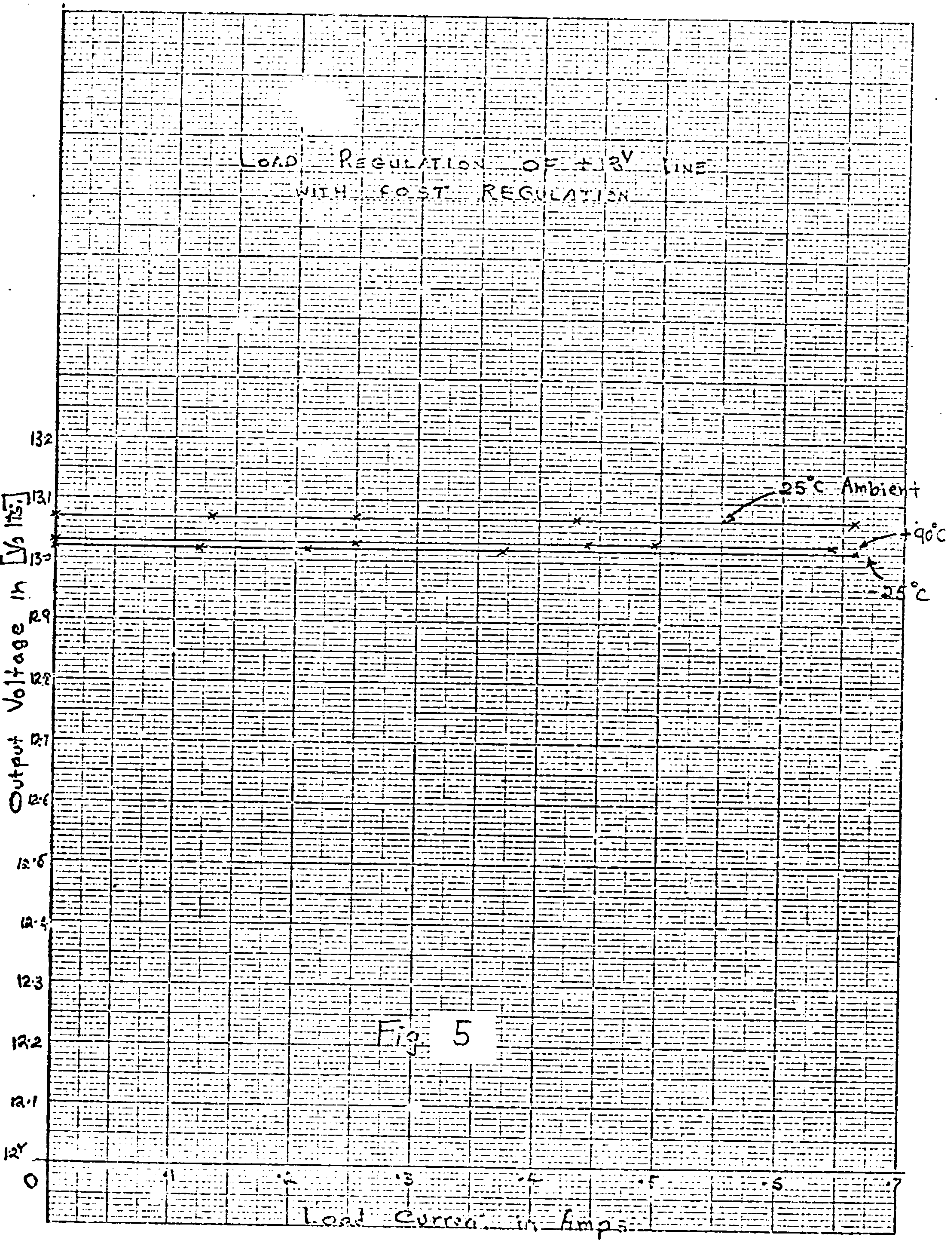

LOAD REGULATION OF +13V LINE
WITH POST REGULATION

Fig. 5

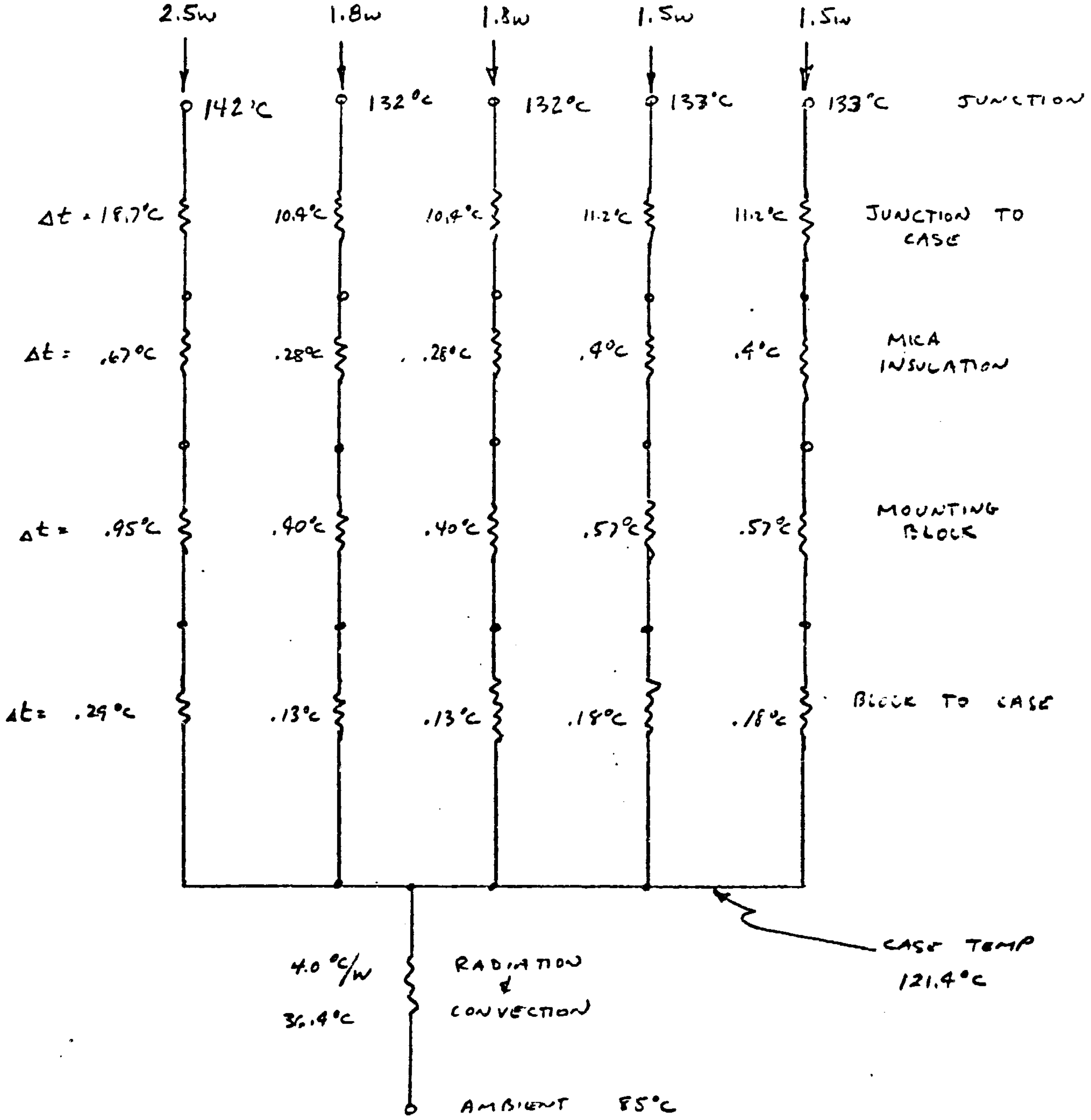
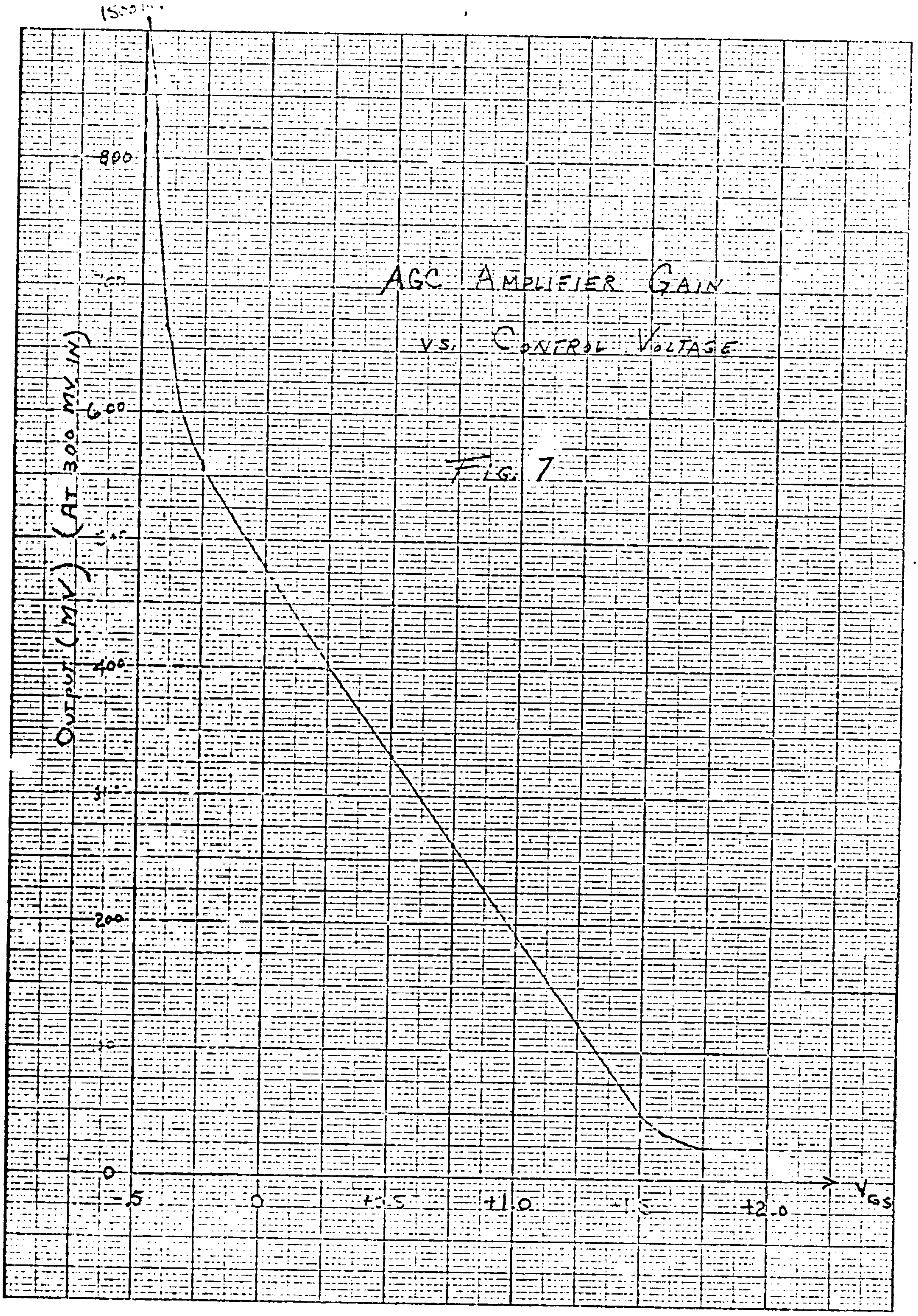


Fig 6

Power Supply Thermal Network



AGC AMPLIFIER GAIN VS. CONTROL VOLTAGE

FIG. 7

APPENDIX A

TABLE OF CONTENTS

PAGE

DISCUSSION:

SYSTEM DESCRIPTION:

COMPONENT DESCRIPTION:

PROTOTYPE REVISIONS FROM BREADBOARD MODEL

1. Two output amplifiers are added.

2. An AGC network and a special service channel are added.

3. A calibration network, housing, and printed interconnection of all components and connectors are added.

4. The crystal oscillator frequency is raised from 2.28 MHz to 7.75 MHz.

5. Three phase-locked-loops and three digital counter modules are added to generate 22 synchronous sub-carrier frequencies instead of 7.

6. The method of presetting the digital counters is changed.

7. The upper pilot tone is generated digitally rather than by mixing 5F and 12F.

8. The pilot tone filters are 3 pole instead of 2 pole.

9. The DSB IF filter is 5 pole instead of 4 pole and 19 are provided instead of 1.

10. The channel filters are 5 pole instead of 4 pole and geometrically rather than arithmatically centered on the channel center frequency. 19 channel filters are provided instead of 3.

LIST OF FIGURES

INTRODUCTION

This is the final report on contract NAS-8-11988 covering the period from August 1965 to March 1967. The contract required a two-phase study program concerning techniques applicable to the NASA/MSFC SS/FM Telemetry System. The first phase of the contract was anlytical in nature; the second, experimental. The object of the program was to investigate and develop new techniques to improve and update the existing SS/FM Telemetry System.

The primary goal of the program was to provide an SS/FM Telemetry breadboard with the following characteristics:

1. Data Bandwidth
   a) Single sideband; 10 Hz to 3000 Hz at 0.1 db points.
   b) Double sideband; DC - 3000 Hz at 0.1 db points.
2. 1% system amplitude accuracy using calibration.
3. Phase consistency between channels.
4. Interchangeability between SSB and DSB channels in the final system.
5. Significant hardware improvements such as easier alignment, reduced size, weight and cost in the vehicle-borne equipment.

SUMMARY OF RESULTS

The results of the design study, Phase I, indicated that a double modulation scheme for all channels would provide the best channel-to-channel amplitude and phase characteristics. It also provided for the basic design of L-C filters using practical components.

Breadboard system measurements show that the basic design using digital frequency synthesis, double modulation and distorted-pole filters is feasible. The goal of 0.1 db maximum pass bnad ripple was not achieved on all filters.

SUMMARY OF RESULTS - (Continued)

System measurements show that the amplitude response of each channel (SSB mode) is dependent, primarily, upon the characteristics of the 3F filter common to all SSB channels. The DSB filters cause a slight high frequency roll-off for the lower numbered channels due to phase nonlinearity at the band edges. Amplitude control can be provided by resistive voltage dividers associated with each filter.

DISCUSSION

Phase I

During Phase I of this program, several approaches to meeting the primary system goals were investigated. The most critical problem area was the selection of filter types and filter operative frequencies.

With the data bandwidth requirement of DSB, DC-3 kHz, flat within 0.1 db and SSB, 10 Hz-3 kHz, also flat within 0.1 db, it was necessary to consider several types of filters and modulation schemes.

Results of a detailed investigation indicated that L-C filters could meet the electrical requirements and were practical in a double modulation system. The critical parameters in the design of L-C filters for the required frequency range are temperature stability and "Q" of the toroids. High "Q" requirements lead to impractically large cores. A very important factor therefore was a design approach using the lowest possible "Q" in the individual cores. The method of predistorted poles was selected as the most practical approach since it allows minimum "Q" designs of Butterworth and Chebyshev filters.

The required filter frequency stability was determined to be approximately ± 0.125% at the channel 5 frequency in order to meet system requirements. Stabilized cores with guaranteed inductance change of less than ± 0.25% (±0.125% frequency change) over the temperature range of -65°C to +125°C were selected. Since the system temperature requirements are less stringent, -20°C to +85°C, the cores were judged suitable for critical muli-pole applications at channel 5 or lower frequencies.

Estimated maximum volumes of complete 6-pole filters indicated the advantage of avoiding the use of L-C filters above 55 kHz. Since any double-modulation scheme which met this criterion would use an I-F frequency, it seemed logical to investigate a hybrid approach using single modulation for selected low channels and double-modulation for channels. The system would be tailored to the characteristics of L-C channel filters, using them only at the lower frequencies where they are small and most stable.

At low center frequencies, however, the skirt selectivity is skewed toward the high frequency side due to the high ratio of 3 db bandwidth to center frequency. Therefore, it is necessary to use double modulation on some of the lower channels to prevent excessive upper sideband feed through into the adjacent channel.

After considering further the natural filter skew, it was decided to use double modulation on all channels for several reasons.

1. Double modulation provided increased selectivity against the undesired sideband by taking advantage of skirt skewing.
2. Double modulation provided the flexibility required to allow optimum design of small, stable L-C filters.
3. Only four different SSB filters and four different DSB filters were required for all 15 channels.

DISCUSSION - (Continued)

4. Simple, stable oscillator divider-chain frequency synthesis was possible using integrated circuits and no selective filters.
5. Using double modulation on all channels further assured consistent channel-to-channel performance.

After further consideration and discussion, MSFC Engineering Personnel decided that all data channels should be modulated with the channel 3 carrier in the first stage. The succeeding filter is then either a channel 3 SSB or 3.0 kHz DSB type. In this scheme, the channel 3 SSB filter with 7 poles is the most complex. All other filters are relatively wide 4-pole DSB filters that are used for both SSB and DSB operation. This system requires a more complicated frequency synthesizer since the subcarriers for all 21 channels must be derived. However, the end product should be a more uniform airborne system offering more consistent channel-to-channel amplitude and phase characteristics.

PHASE II

The second phase of the program was devoted to building a breadboard and proving the feasibility of the system developed in Phase I. Figures 1 and 2 show block diagrams of the airborne and ground systems as they are at the present time.

A description of the over-all system is presented. In addition to this, the individual components of the system are described.

System Description

Airborne Subcarrier Generation

A block Diagram of the system is shown in Figure 1.

Airborne Subcarrier Generation - (Continued)

A 2.275 MHz oscillator is used as the clock in digital count-down chains to produce synchronous waves at the subcarrier frequencies. (Figure 2)

Channel one subcarrier square wave is differentiated and used to preset all the counter chains so that all generated square waves go positive synchronously with channel one. Channel 17 pilot tone is produced by taking the product of channel 5 and channel 12 quadrature. This sin-cos product gives a sin output from the mixer.

The unwanted outputs are attenuated by a simple 2-pole filter so that all parasitic frequencies are attenuated by a least 50 db.

The harmonics of the channel 16 square wave are similarly reduced by the simple channel 16 filter. The transmission of these two pilot tones provides all the information necessary to regenerate all of the required subcarriers in phase synchronism on the ground.

Airborne Modulation

The information intended to occupy channel "N" is first used to amplitude modulate a channel 3 subcarrier. A filter selects either the upper or both sidebands for mixing with the N+3 subcarrier in the second modulator. A simple 4-pole filter selects either the lower or both sidebands for frequency multiplexing into the composite output signal.

This superheterodyne procedure allows all channels to be filled using only N simple output filters while only one highly selective SSB filter is required following each first modulator. In DSB operation, a low-pass filter following the sensor will provide the high selectivity required external to the airborne unit.

Ground Subcarrier Generation

All carriers are digitally regenerated on the ground (Figure 3). AVCO is used to clock digital count-down chains producing the subcarrier frequencies and their quadratures (Figure 4). The regenerated channel 16 square wave and the channel 16 sine wave received are passed through a phase detector (Figure 5). The difference in phase between these two waves is converted to a DC voltage which varies the frequency of the VCO to lock the channel 16 regenerated subcarrier in phase with the received subcarrier. Due to the nature of the phase detector, the generated subcarrier is produced in quadrature with the received subcarrier.

Although channel one is generated with the correct frequency, it has 16 possible phase relationships with the airborne channel one. For this reason, channels 16 and 17 pilot tones are mixed to produce a channel one frequency in phase synchronism with the airborne, but in quadrature with it (Figure 6).

Channel 16 is used to clock a digital chain to produce a channel one frequency. This is fed to a phase comparator with the channel one mentioned above. Any phase difference is detected as a DC output by the low pass filter.

If a negative output occurs, one pulse initiated by CH½ is added to clock pulse train. If a positive output occurs, one clock pulse is inhibited so that the channel one produced is stepped into synchronism with the airborne system. This mechanism allows phase correction in the direction which requires a minimal time. This channel one is actually out of phase with channel one airborne due to filter delays as will be discussed later.

The square wave thus generated is differentiated and used to preset all the ground digital chains to assure phase coherence.

Ground Demodulation

Each channel is removed from the signal by a double sideband filter. Single sideband transmission is demodulated by the polyphase demodulator while double sideband is demodulated by mixing with the subcarrier in quadrature. A 3 KHz low pass filter is followed by the audio power amplifier.

Component Description

Filter Design

For the airborne SSB channel 3 filter following the first mixer stage, amplitude and selectivity requirements lead to a 7-pole Chebyshev design having .001 db ripple. This in turn leads to a "Q" requirement of 40 for a distorted-pole design having a 3.6 KHz 0.1 db bandwidth and a low pass equivalent "Q" of 10. The required temperature stability to limit the filter drift with temperature to ±30 HZ is equal to ±0.2%. Phase slope in the filter passband is approximately 0.175 degrees fro each HZ of frequency drift so that a ±30 HZ drift of the filter response curve is equal to a phase error of ±5.25 degrees.

All other filters in the modulation scheme are simple bandpass filters with relatively wide band. A 4-pole filter following the second mixer and centered on each channel was found satisfactory for all three operating modes, SS, DS (1.5 KHz) and DS (3.0 KHz), making it unnecessary to switch this filter when changing modes. To change modes requires only a change of the channel 3 filter following the first mixer stage.

The channel filters preceding the polyphase demodulator in the ground station are essentially the same design as the 4-pole channel filters in the airborne system.

Digital Phase-Lock-Loop (Figure 4)

This system uses a digital loop which senses the phase difference between ground and air channel 1 carriers. At 422 us intervals, it corrects the phase by 22.5° increments. The increment is always made in the correct direction so that sync correction takes a minimum of time.

Channel 8 $^{60^\circ}$ (not used in demodulation) is digitally generated to have the phase relationship with channel 16 shown in Figure 7. Correction of phase can occur once every 16 cycles of channel 8 $^{60^\circ}$ using the positive half cycle to blank a clock pulse and its leading edge to add a clock pulse. The filter is designed for maximum attenuation of unwanted frequencies while the step input response is adequate to provide a corrective voltage output within the allowed time interval. A 2-pole LC low-pass filter 3 dB down at 1.13 KHz with a damping factor of 0.7 is used resulting in an attenuation of 24 dB for the lowest undesired frequency and a time response to a step DC input of 97%, after 422 us.

Two operational amplifiers are used as sign and level detectors. This enables the detection of three levels; greater than 0.35V, from -0.45V to 0.35V, and less than -0.45V. The DC output in sync is 0.1V while the levels corresponding to one phase increment on either side of this are +0.98V and -0.8V. The per cent frequency shift of channels 16 and 17 necessary to move the sync output to -0.45V or +0.35 V is defined as the digital loop bandwidth.

Analog Phase-Lock-Loop (Figure 3)

A second order phase-lock-loop is used to lock the voltage controlled oscillator's 126th subharmonic (channel 16) to the received channel 16

Analog Phase-Lock-Loop (Figure 3) - (Continued)

pilot tone. The loop filter is optimized for minimum time delay and maximum signal-to-noise gain assuming white noise on channel 16 received.

The noise bandwidth is further reduced by 24 dB per octave beyond the bandwidth of the equivalent bandpass filter to reduce frequency jitter. Although a second order loop has a capture range less than the lock-in range, the capture range was made as wide as possible to minimize the time delay to the VCO.

Polyphase Demodulator

An ideal polyphase demodulator completely rejects one sideband while passing the other.

The information at the carrier frequency to be detected is mixed with its carrier and with its quadrature. If upper sideband information were on the channel, the outputs of the two mixers would have a phase difference of 90°. Lower sideband information would result in a phase difference of 90°C. By creating a 90° phase difference between the two outputs, one sideband can be made to cancel, while the other reinforces. The phase shifting networks limit the single sideband selection capability of the device to from 10 Hz to 3 kHz.

Test Results

Phase versus frequency response for the individual filters in the airborne and ground systems are presented in Figures 6 through 13. Figure 14 is the amplitude response of channel 3 USB filter common to all channels.

Figure 15 through 17 represent the phase versus frequency response through the entire system for channels 2, 12, and 21.

Test Results - (Continued)

Amplitude response of the three channels is shown in Figures 18 through 23 and represent data for both SSB and DSB operation.

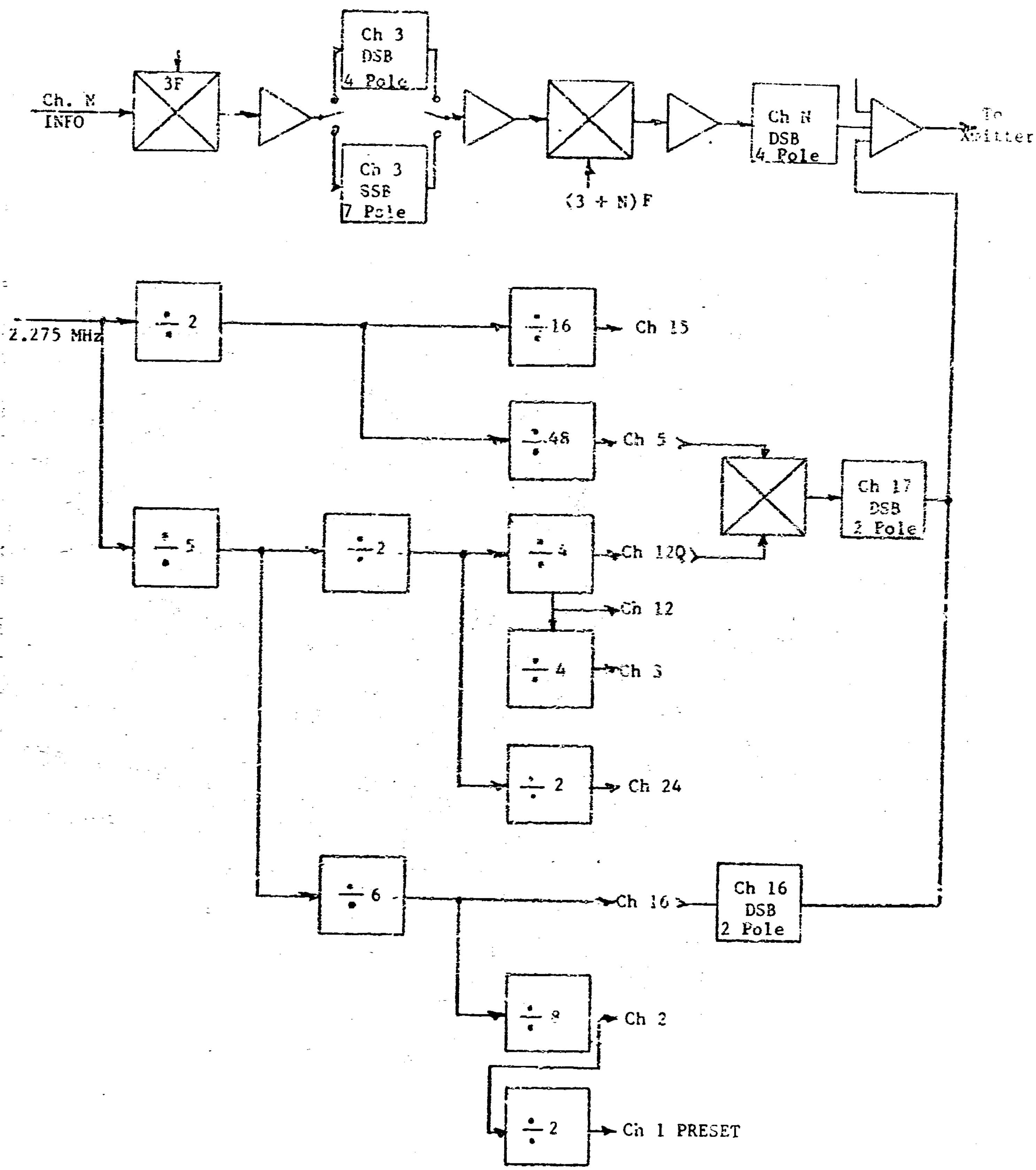
Time delay measurements of a tone burst were made to determine the delay from input to output.

The pictures of Figure 24 illustrate the results for SSB and DSB configurations. It appears that transients decay within 2 milliseconds for a 1 Kc tone burst.

Phase-lock-loop measurements were made to determine capture range and lock range. Using channel 1, (4.74 Hz) as the reference frequency, capture was obtained at 4.729 KHz and a 4.770 KHz. Phase lock was retained between 4.715 KHz and 4.776 KHz. Thus, the capture bandwidth is 41 Hz (0.8%) and the lock bandwidth is 61 Hz (1.3%). The design bandwidth is 37.5 Hz. Similarly, the digital-loop lock bandwidth was 43 Hz.

Due to the difficulty of simulating worst case tape recorder effects, no tracing data was taken.

Figure 25 shows the system linearity of the three breadboard channels, using a 2 KHz signal. Up to 400 mv rms input, the linearity appears to be better than -.2 db which is approximately the resolution of the test equipment used. No attempt was made to equalize the insertion loss of the filters. By use of attenuators on filters and variable resistors on operational amplifiers, the system gain can be adjusted for equal insertion loss for SSB and DSB operation.



BLOCK DIAGRAM AIRBORNE SYSTEM

FIGURE 1

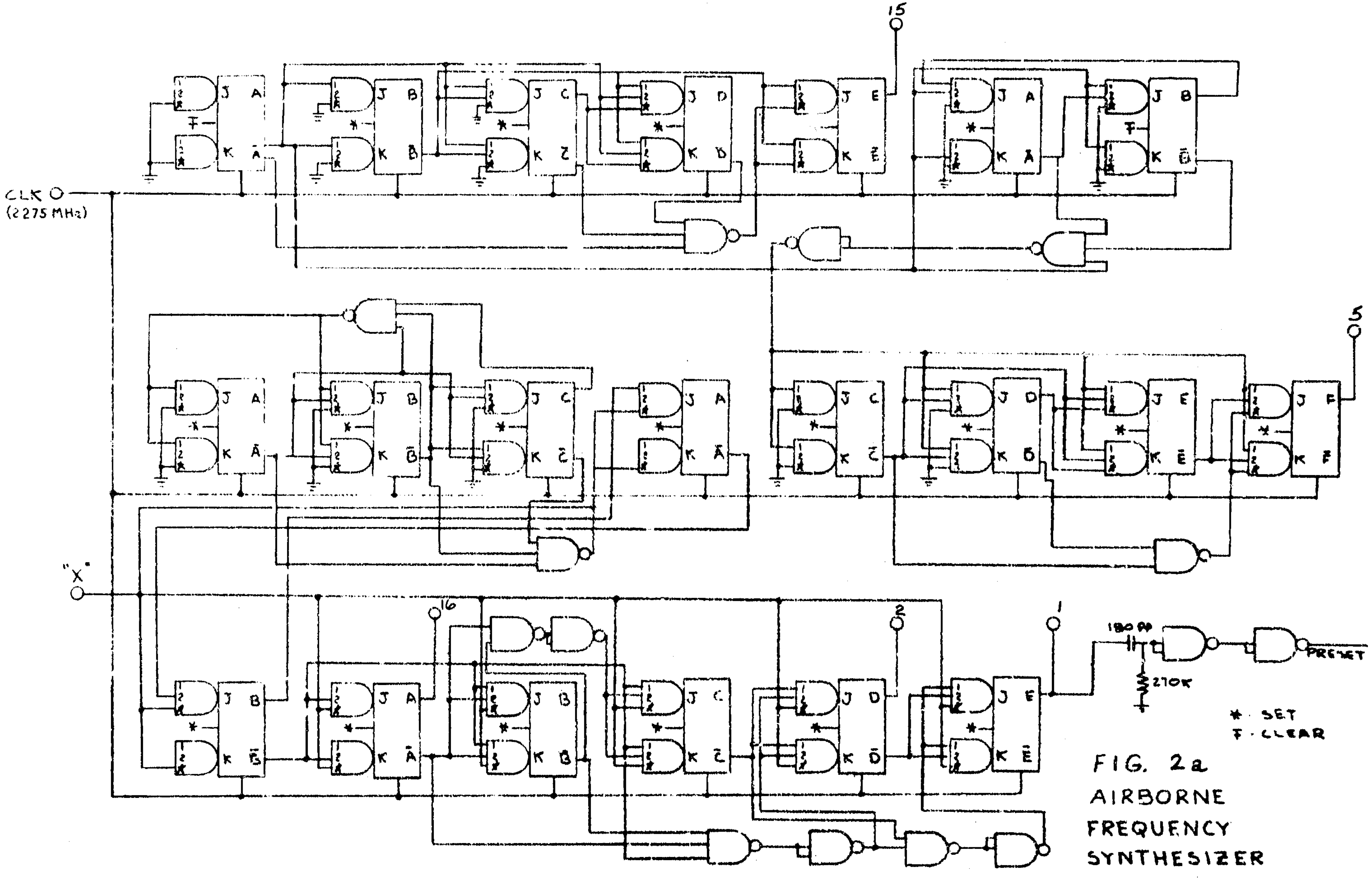
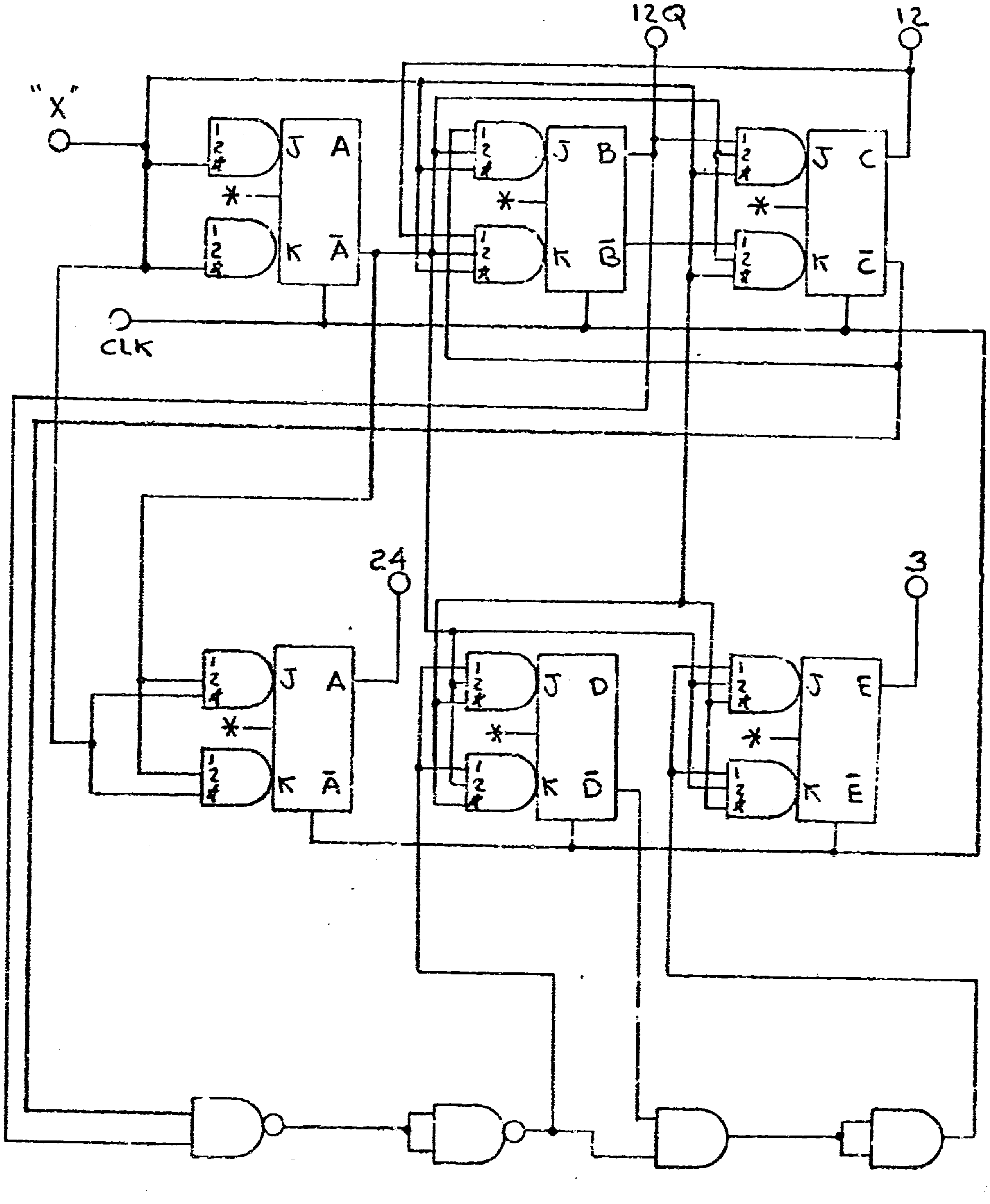


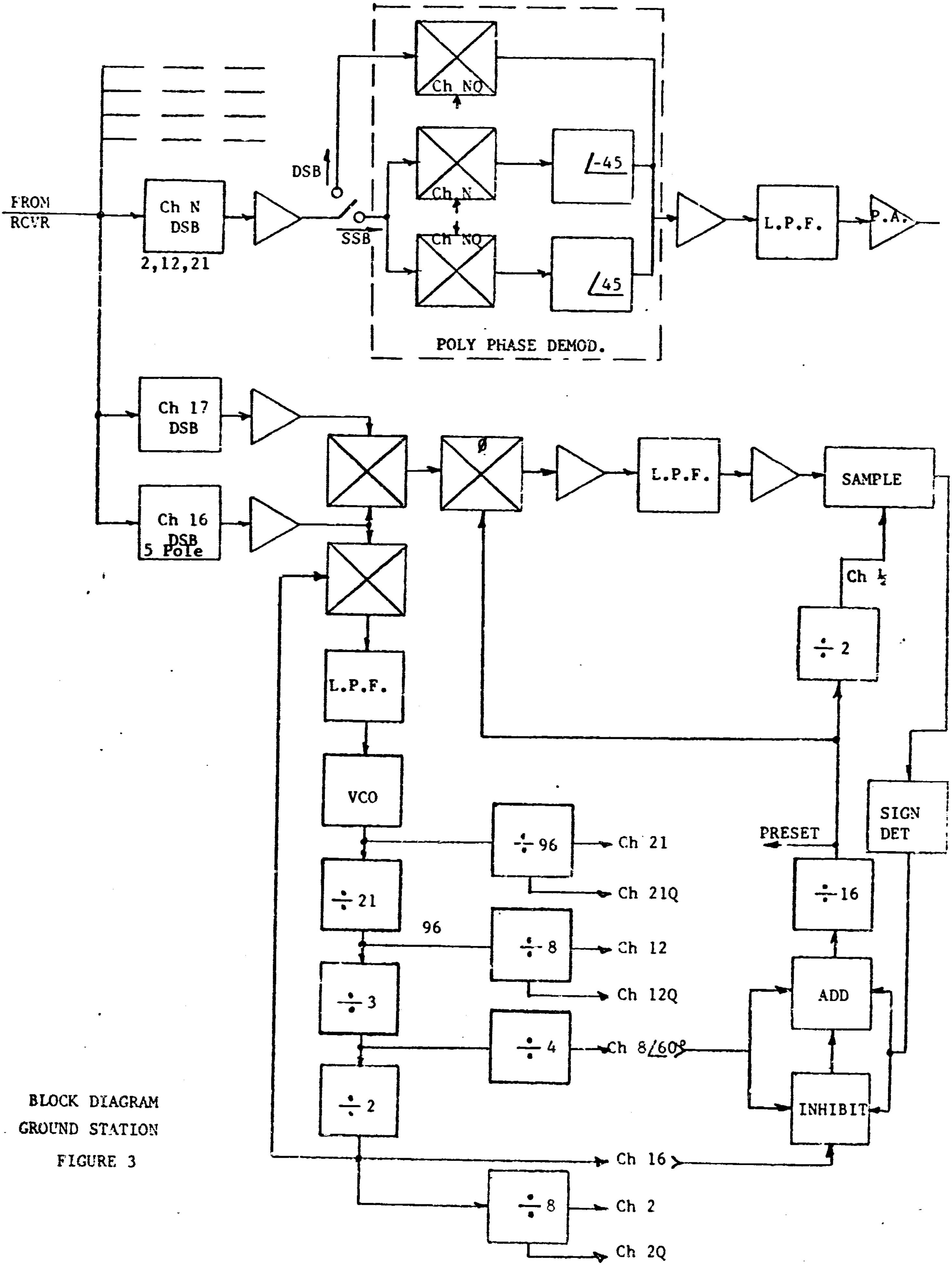
FIG. 2a
AIRBORNE
FREQUENCY
SYNTHESIZER



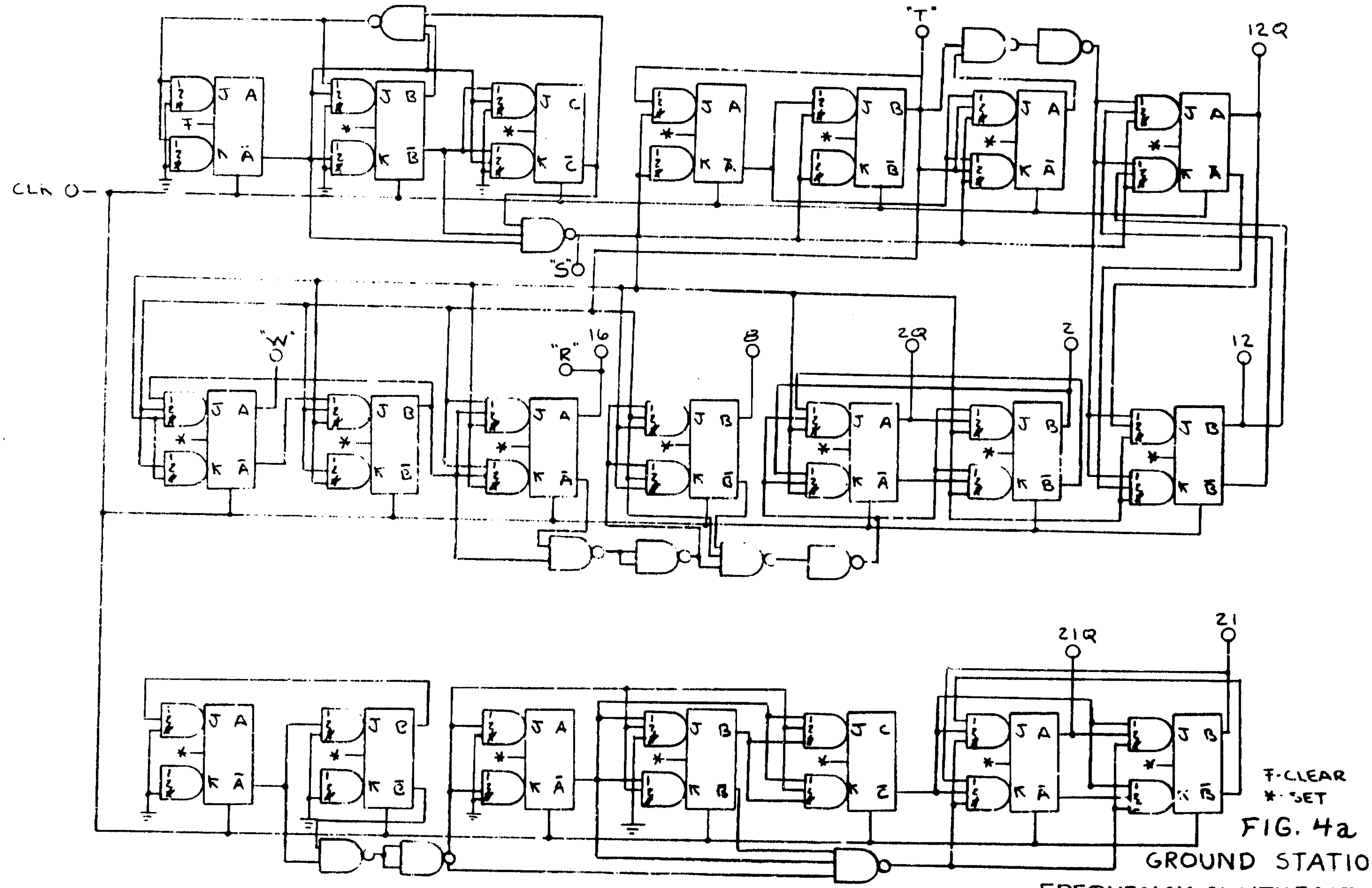
* - SET

AIRBORNE FREQUENCY SYNTHESIZER

FIG. 2b



BLOCK DIAGRAM
GROUND STATION
FIGURE 3



Ŧ·CLEAR
✱·SET

FIG. 4a
GROUND STATION
FREQUENCY SYNTHESIZER

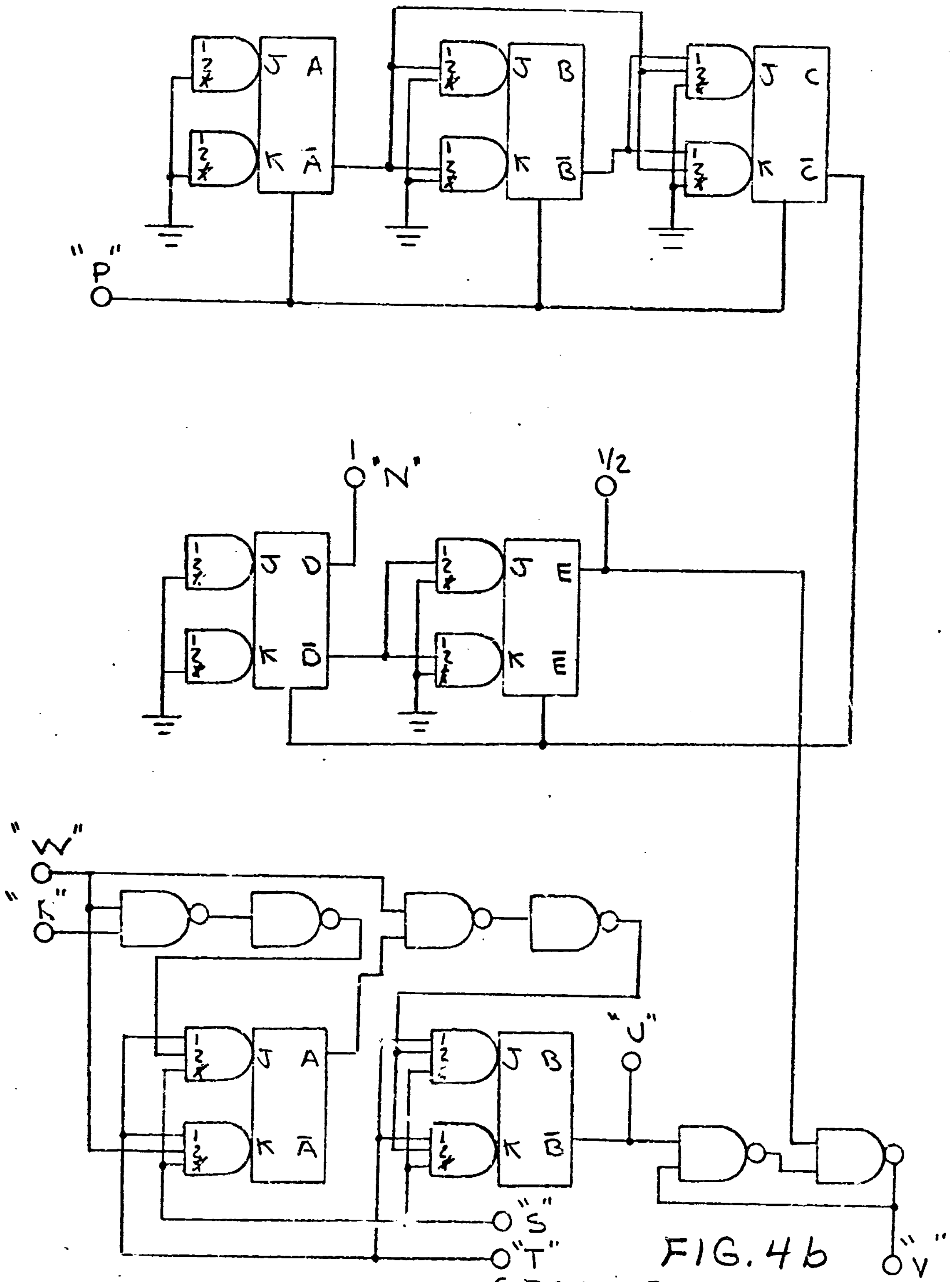


FIG. 4b
GROUND STATION
FREQUENCY SYNTHESIZER

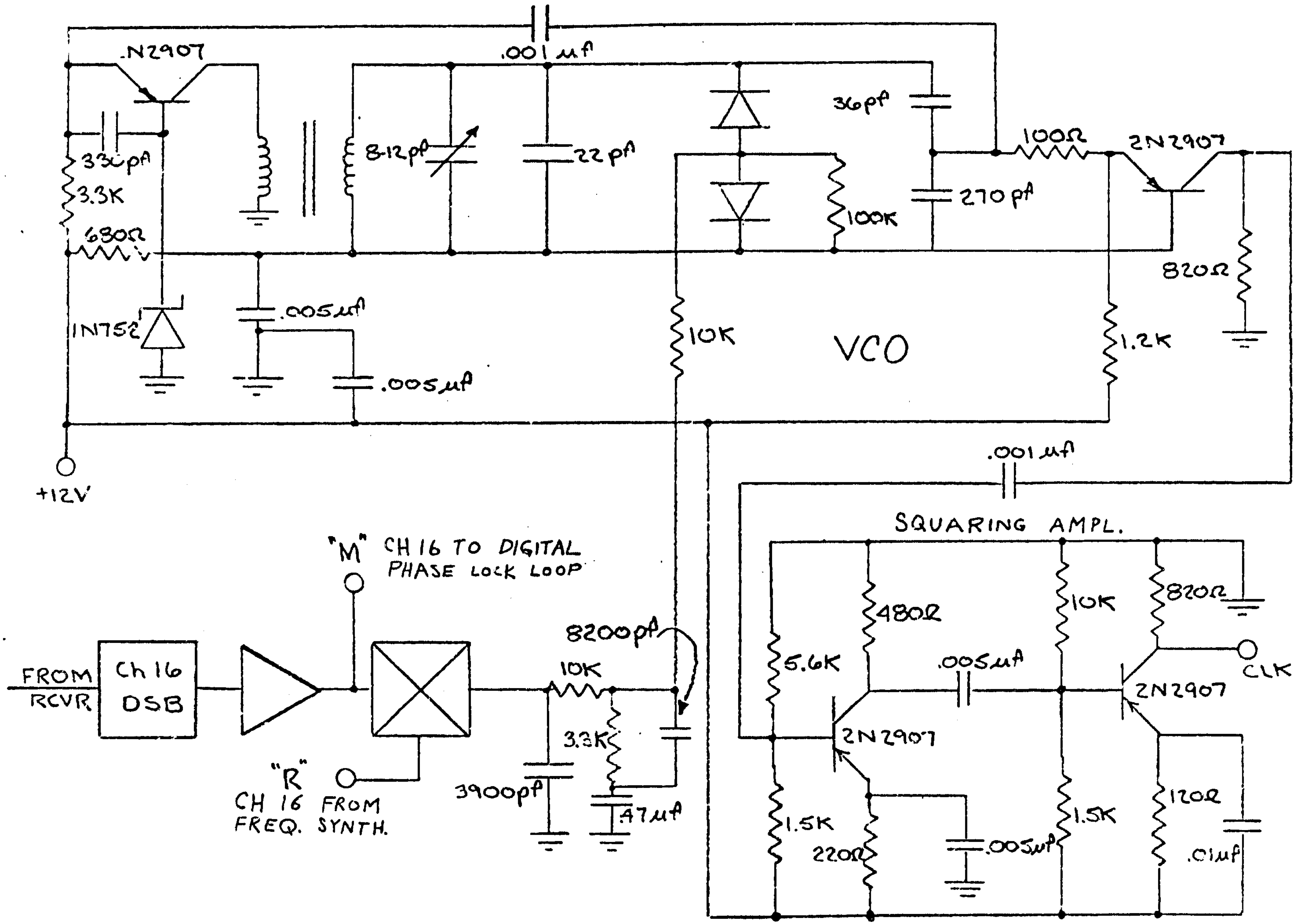


FIG. 5 ANALOG PHASE LOCK LOOP

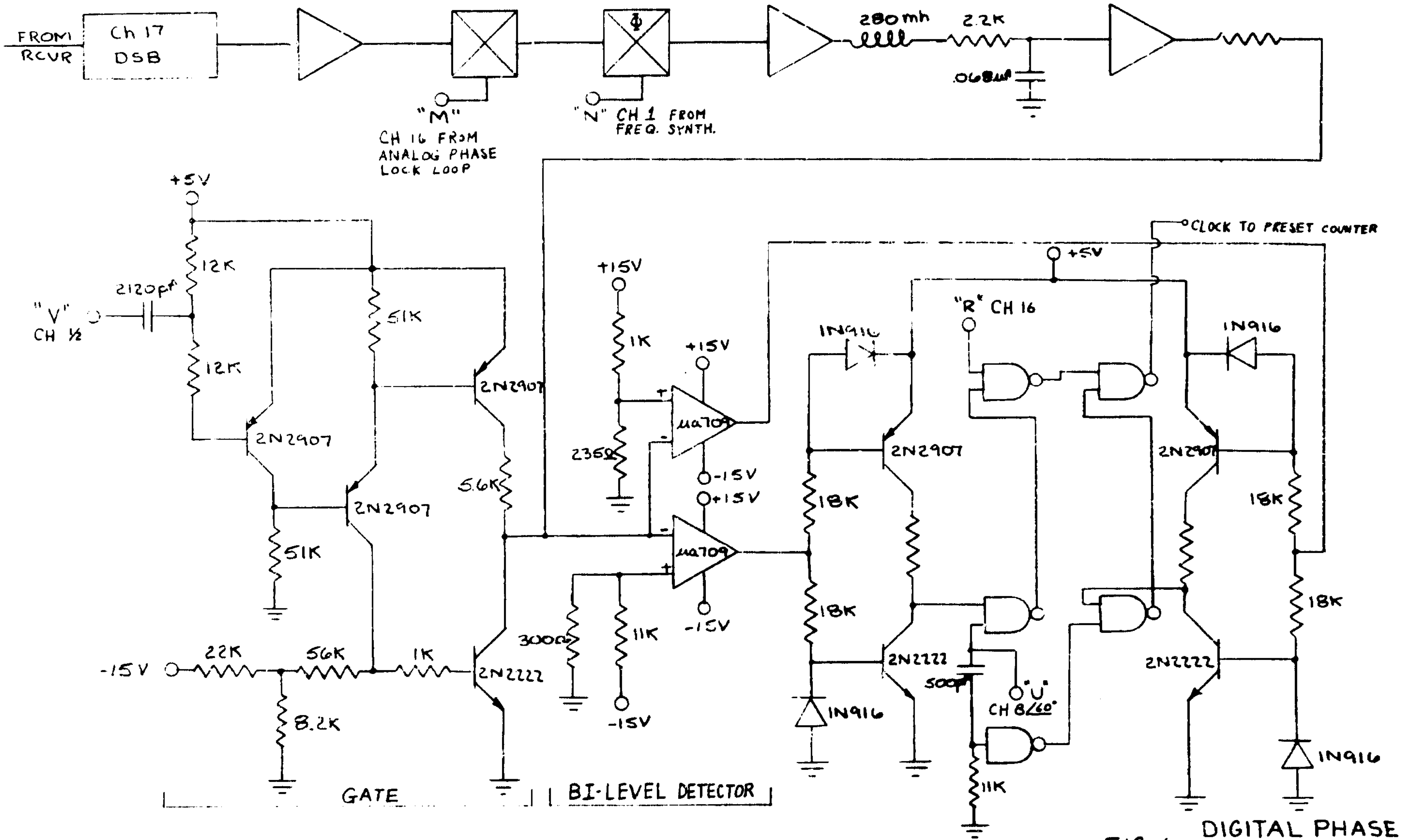
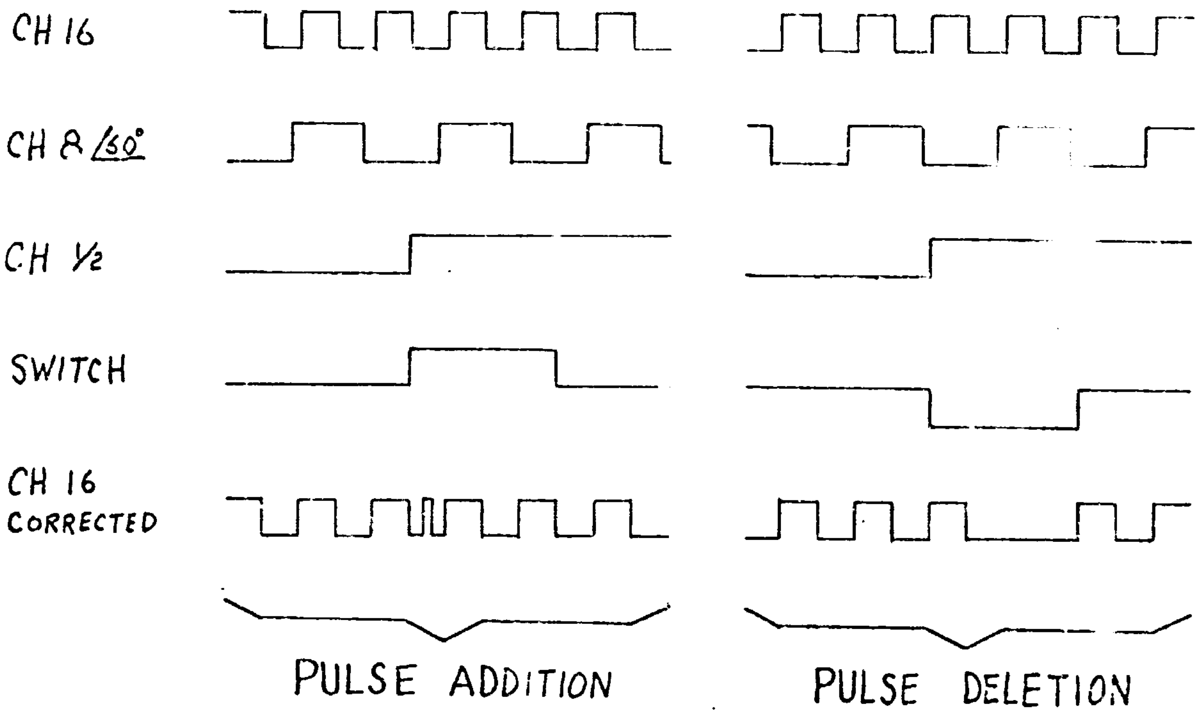
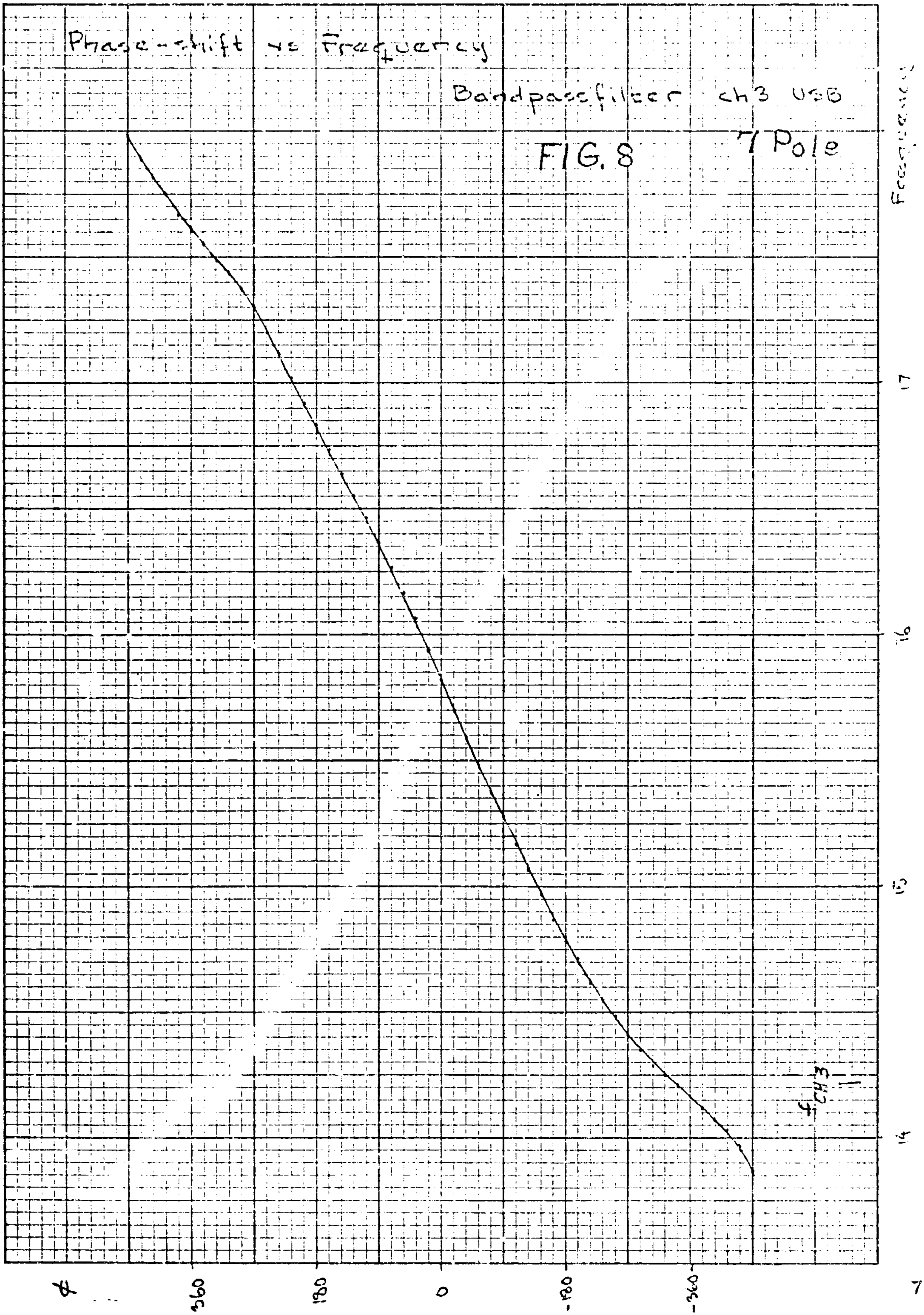


FIG. 6 DIGITAL PHASE LOCK LOOP



DIGITAL PHASE LOCK LOOP
PHASE CORRECTION

FIG. 7


Phase-shift vs Frequency

Bandpassfilter ch3 USB

FIG. 8

7 Pole

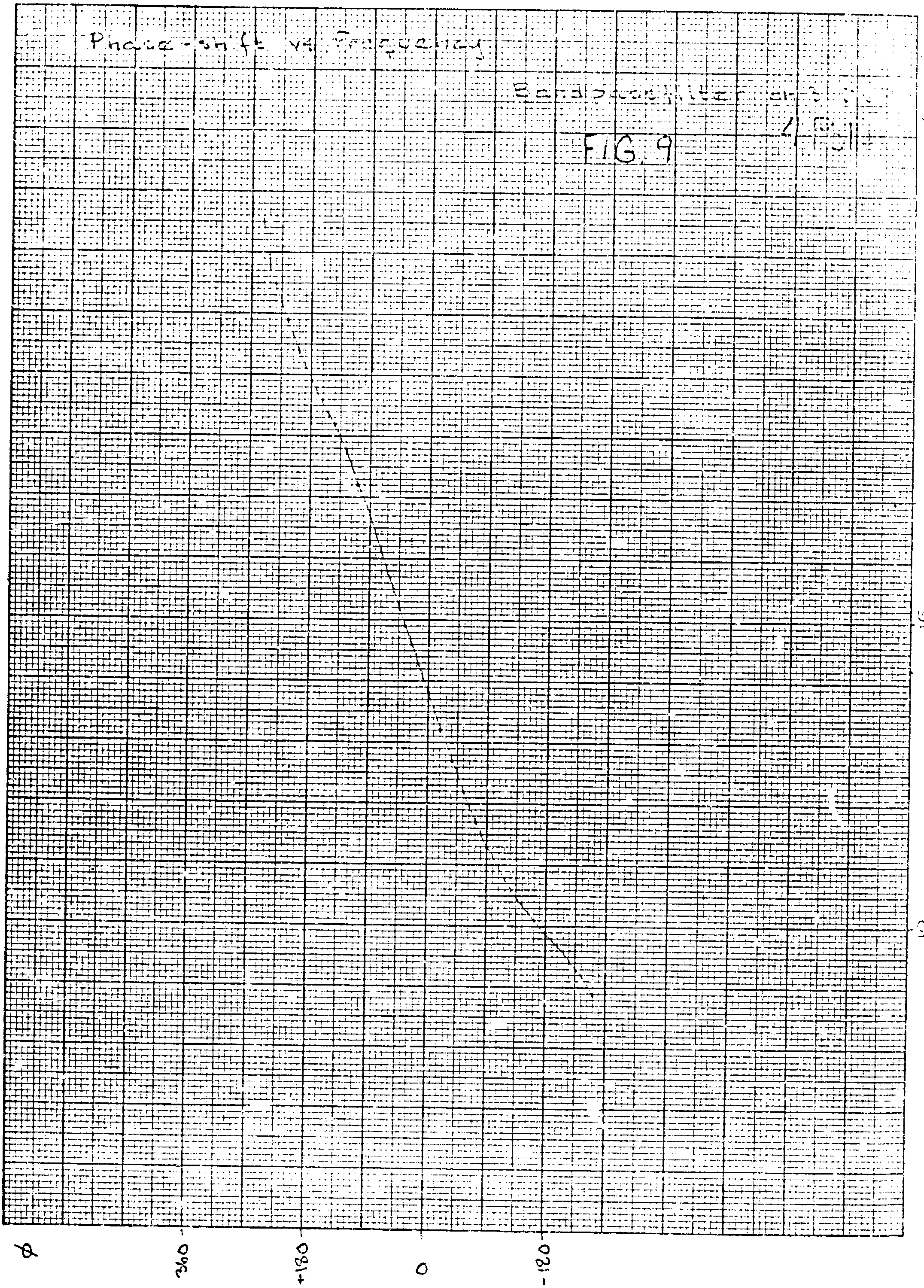

Phase-shift vs Frequency
Bandpass filter
ϕ
360
+180
0
-180
15
10

FIG. 9

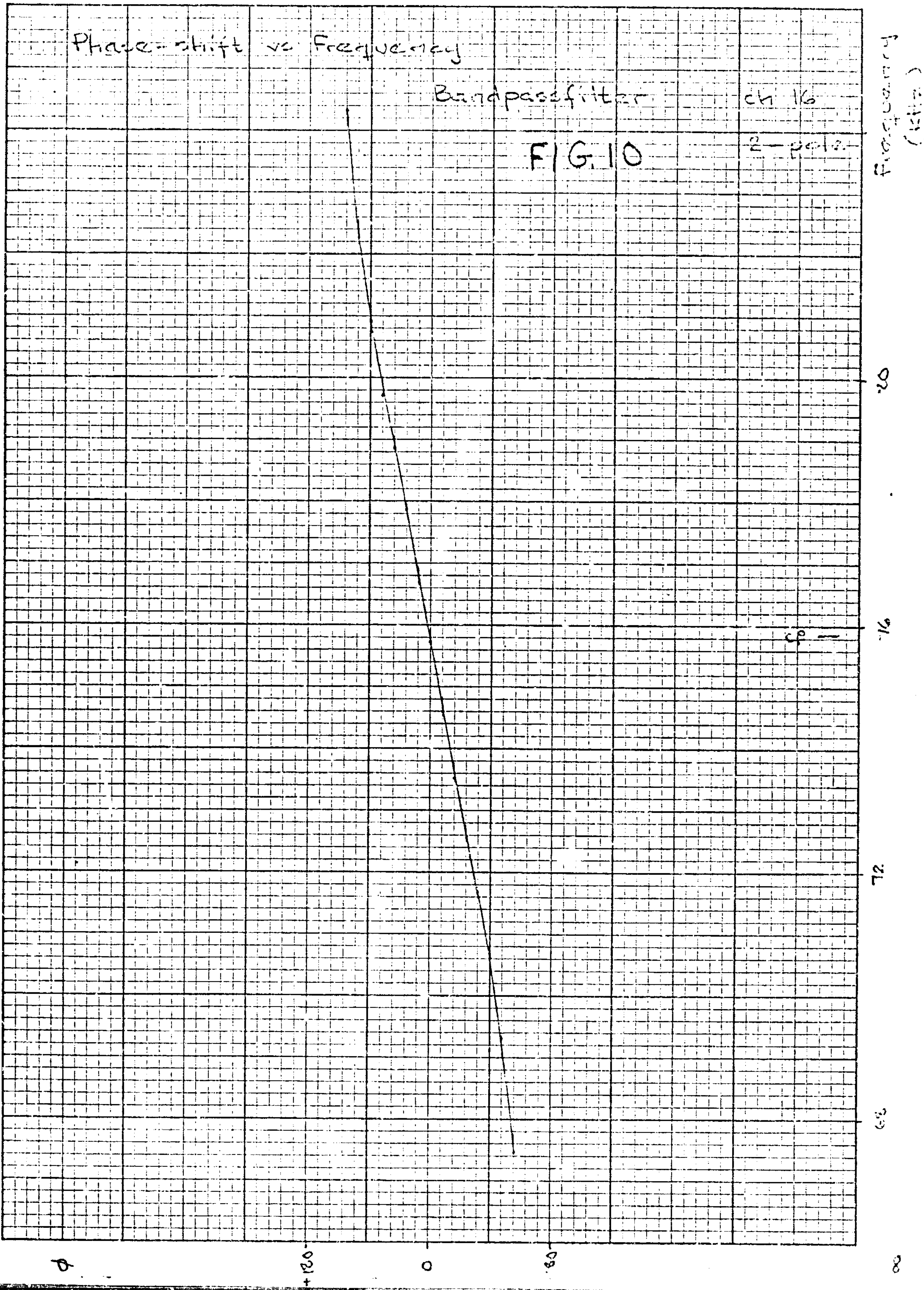

Phase-shift vs Frequency
Bandpassfilter
ch 16
2-pole
Frequency (kHz)
20
16
fp
12
8
φ
+20
0
-20

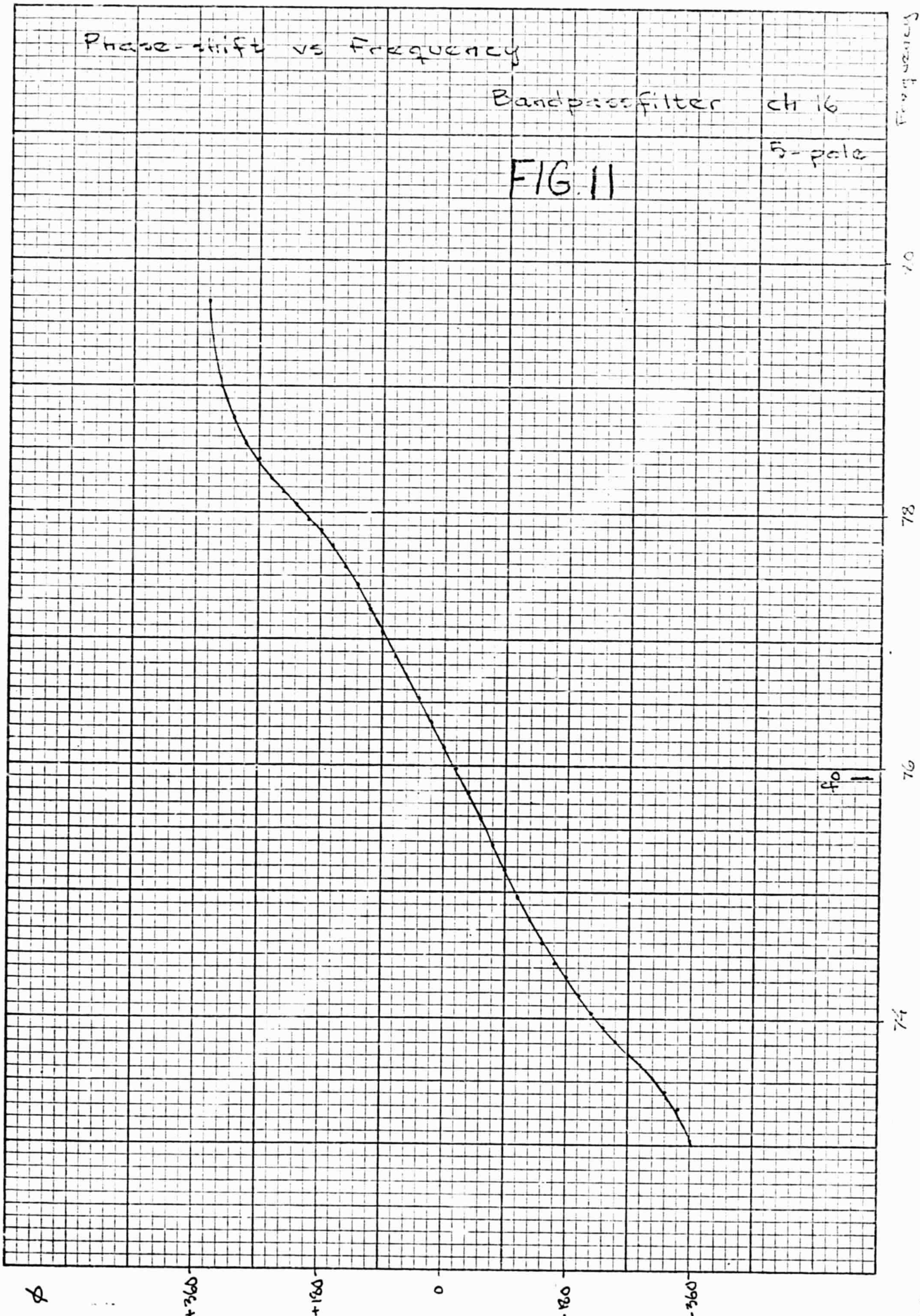
FIG.10

Phase-shift vs Frequency

Bandpass filter ch 16

5-pole

FIG. 11



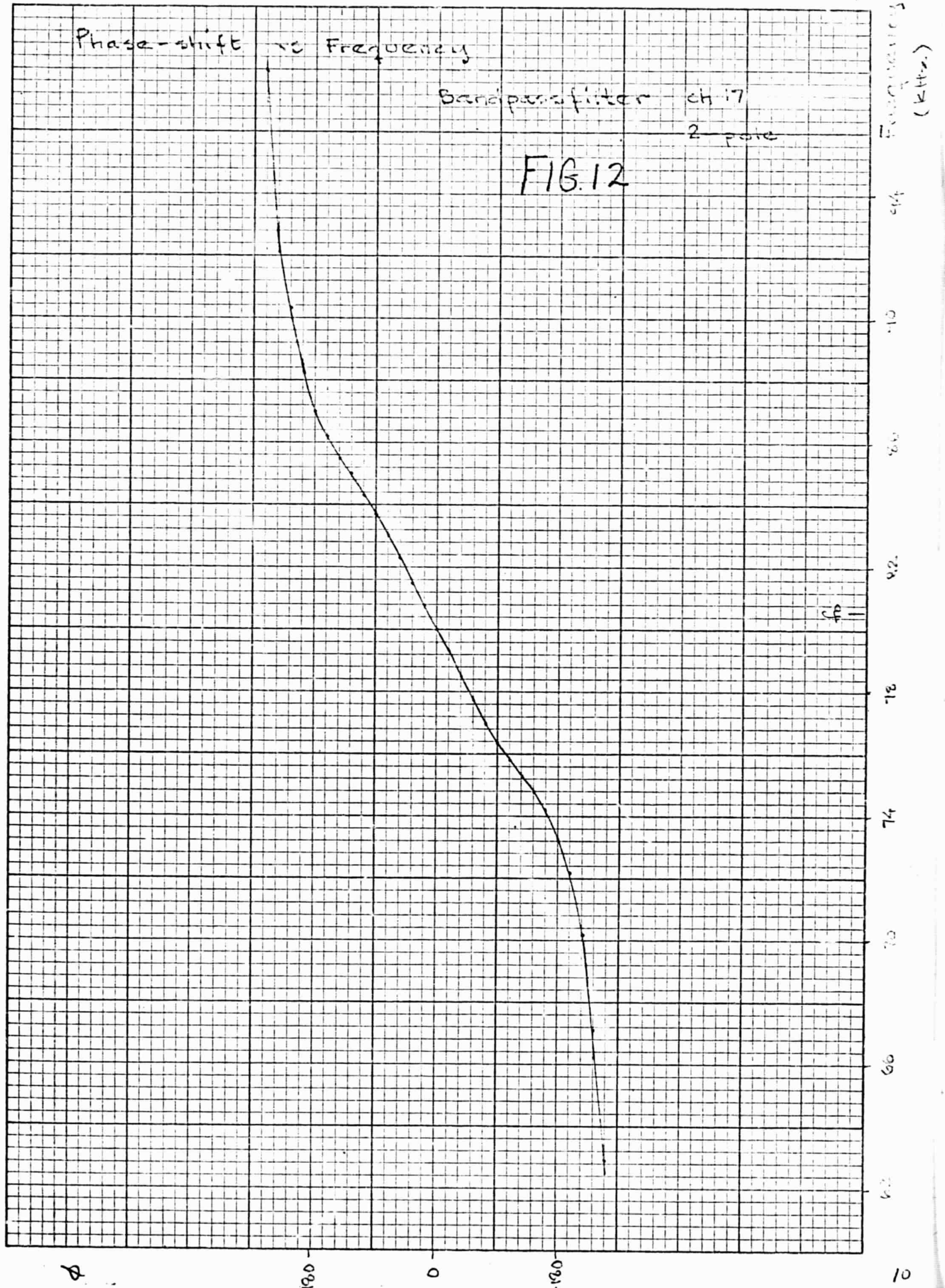

Phase-shift vs Frequency
Bandpass filter ch 17
2 pole
Frequency (kHz)
94
90
86
82
cf
78
74
70
66
62
φ
180
0
-180

FIG.12

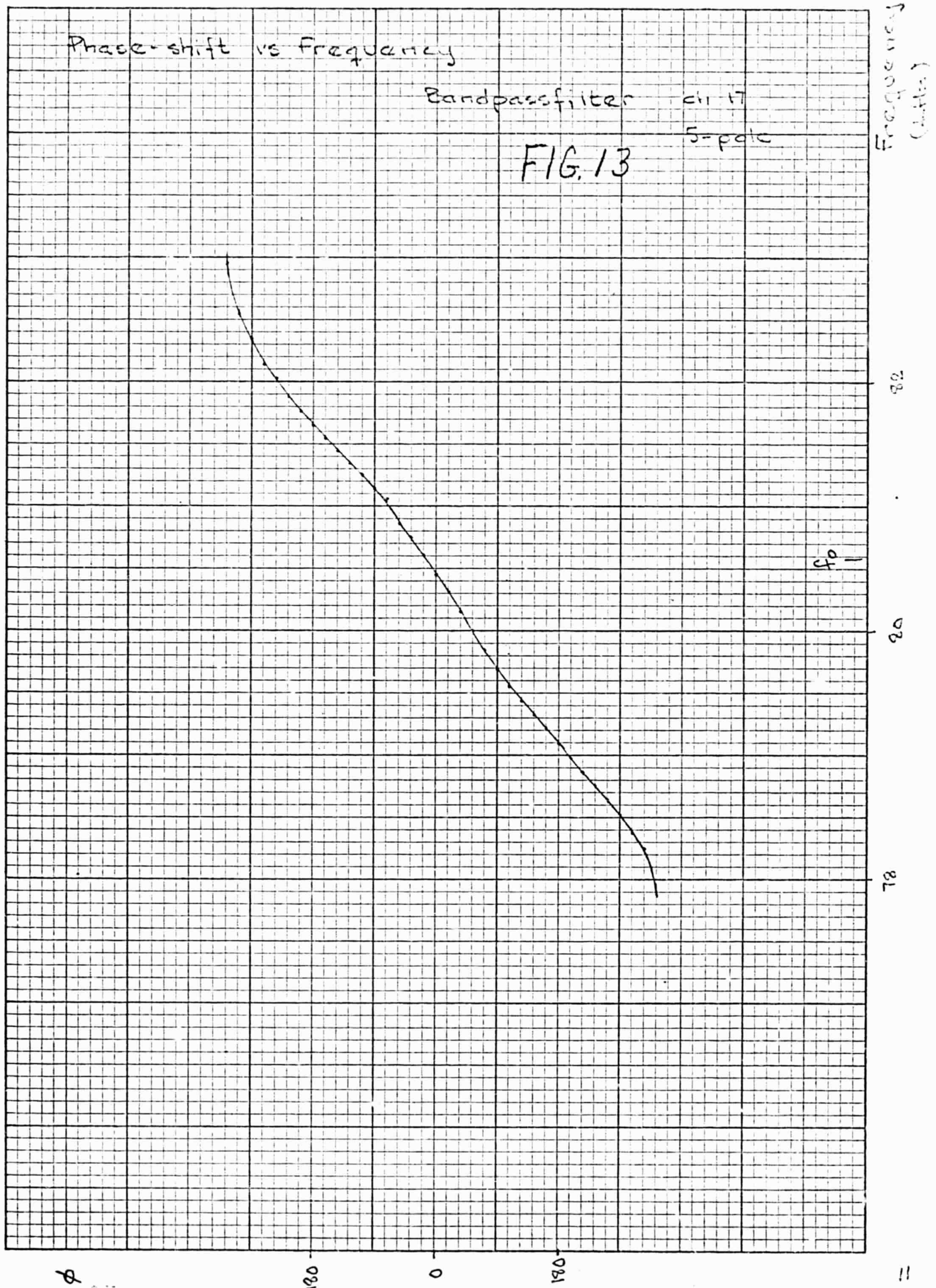

Phase-shift vs Frequency
Bandpassfilter ch 17
5-pole
Frequency
82
80
78
4°
φ
180
0
-180

FIG. 13

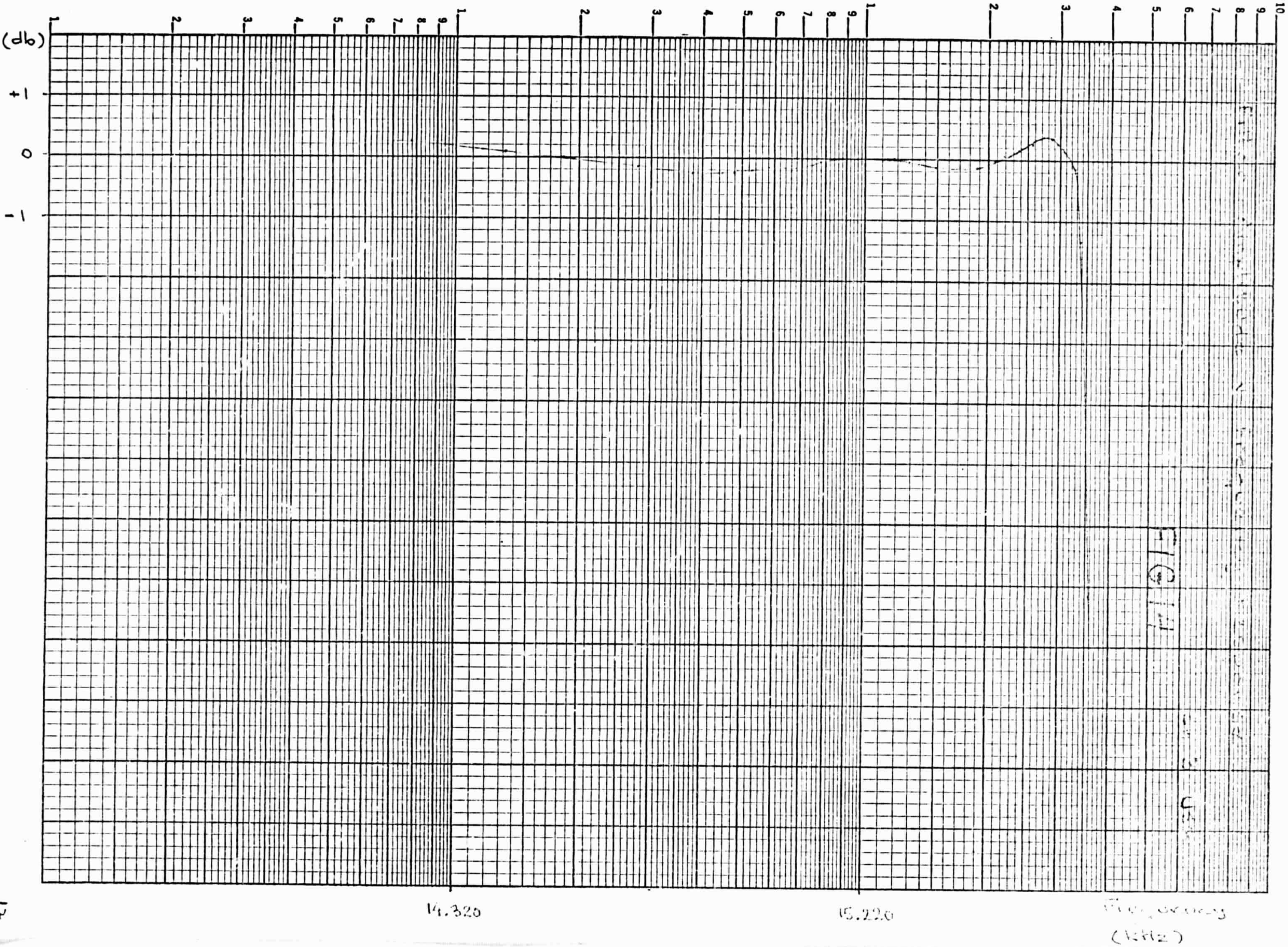
K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
(db)
+1
0
-1
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
1
2
3
4
5
6
7
8
9
10
14.320
15.220
Frequency
(kHz)
[illegible] Amplitude v Frequency Response

FIG. 14

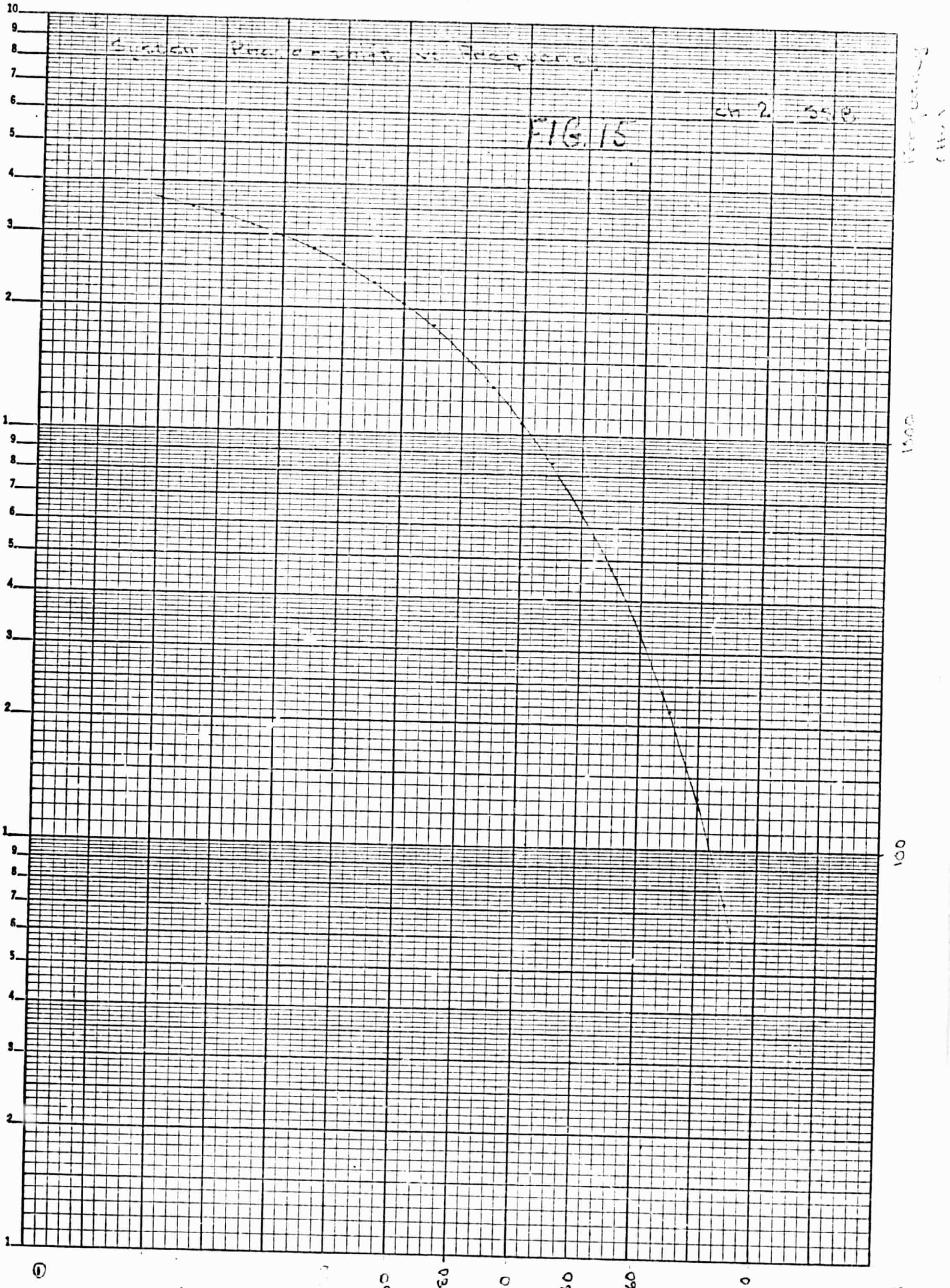

System Phaseshift vs Frequency
ch 2 558
Frequency (cps)
1000
100
①
360
+180
0
-180
360
0
SEMI-LOGARITHMIC 359-
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
10
9
8
7
6
5
4
3
2
1

FIG. 15

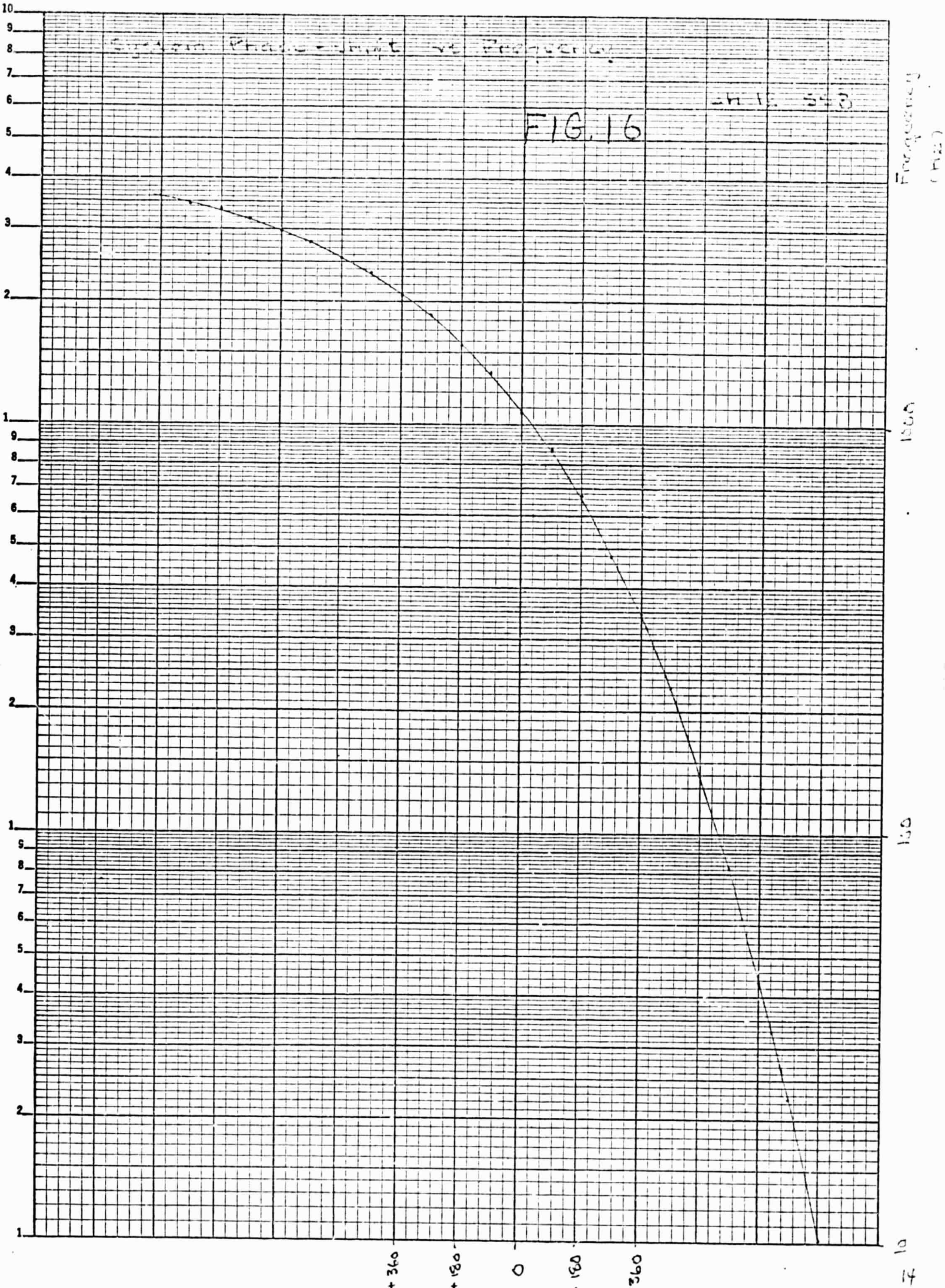
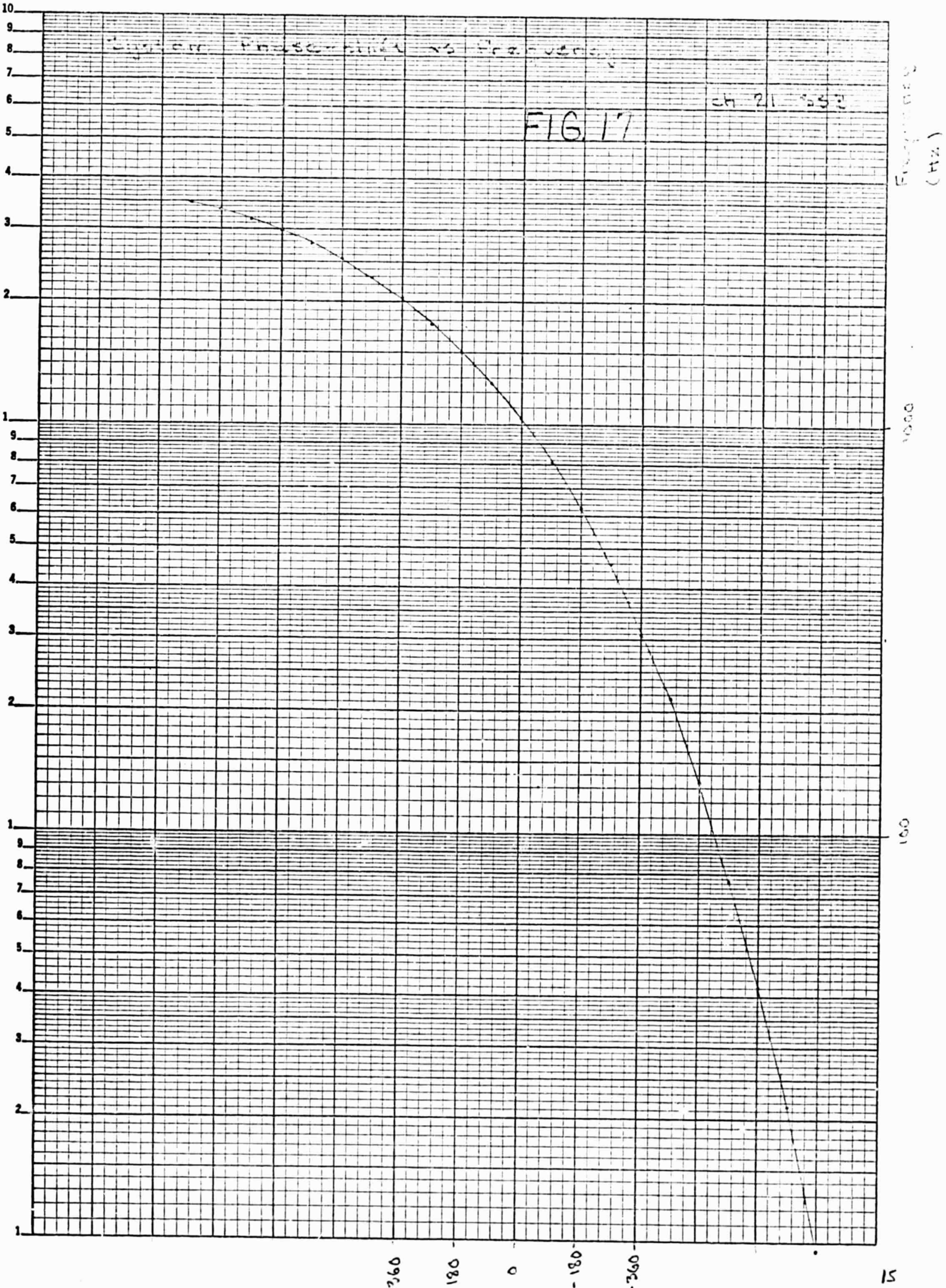


FIG. 16

System Phase-shift vs Frequency
Frequency (Hz)
1000
100
10
+360
+180
0
-180
-360
10
9
8
7
6
5
4
3
2
1
SEMI-LOGARITHMIC 359-71
3 CYCLES X 70 DIVISIONS

FIG. 17


System Phase-shift vs Frequency
ch 21 332
Frequency (Hz)
10
9
8
7
6
5
4
3
2
1
1000
100
360
180
0
-180
-360

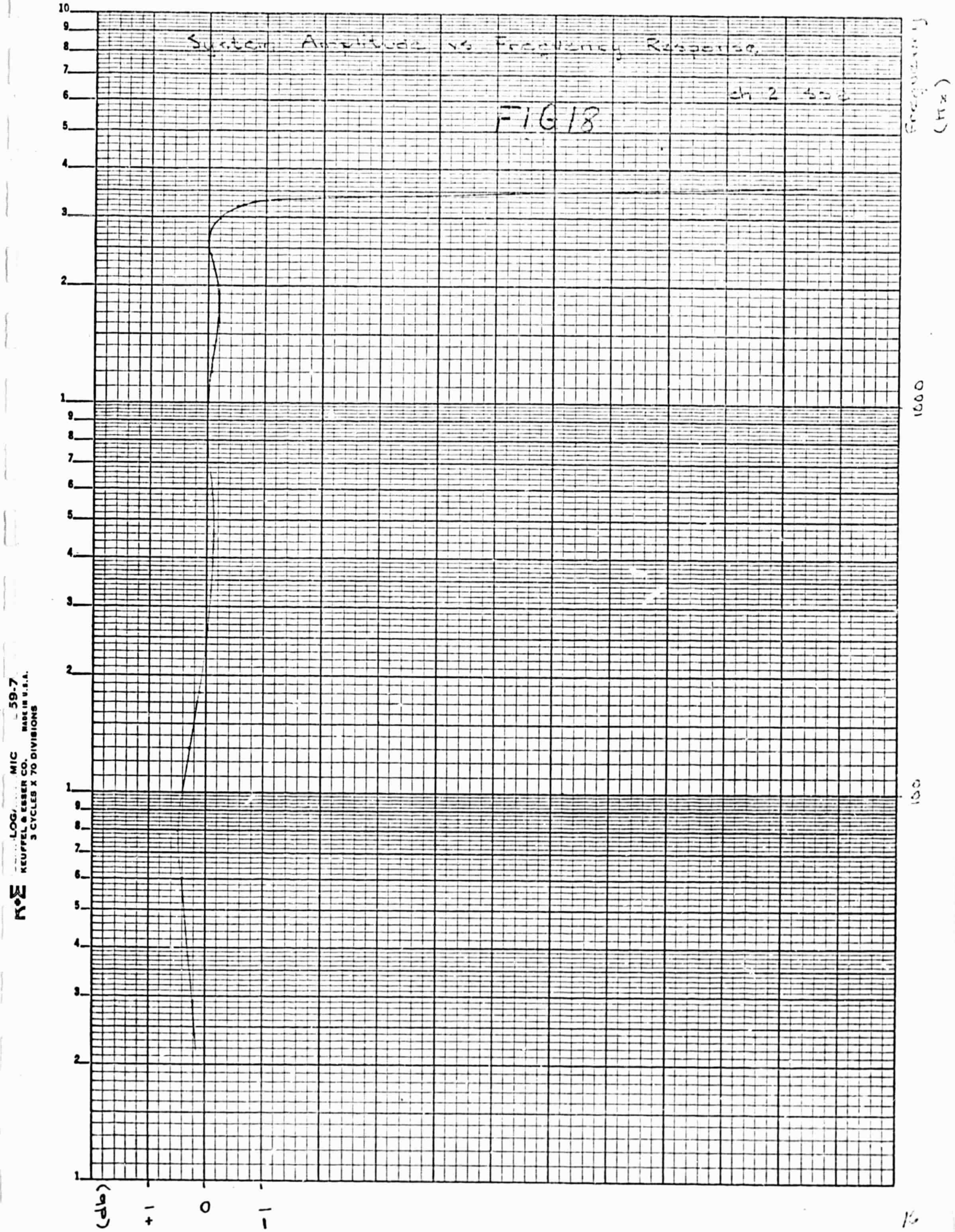
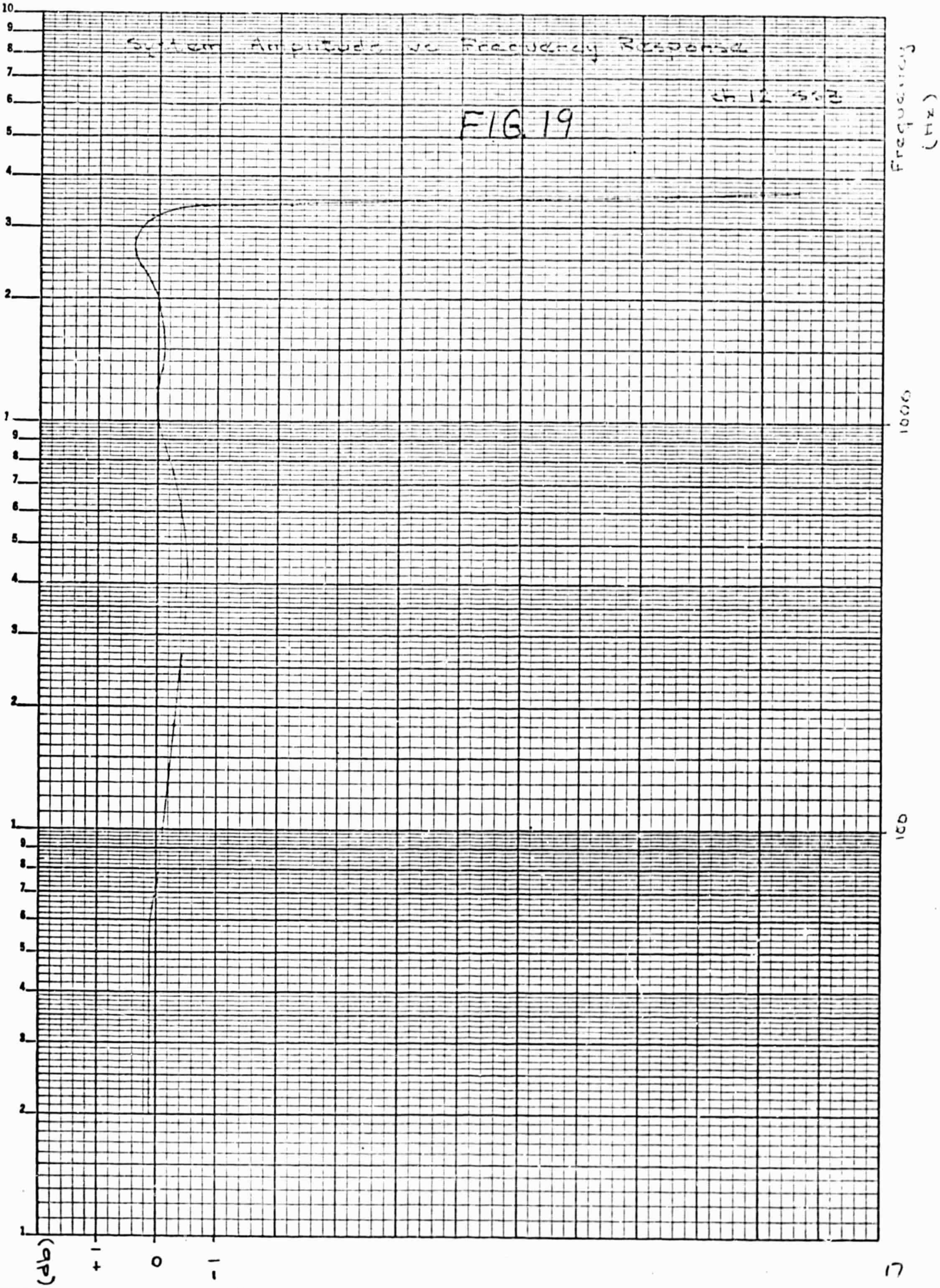


FIG 18

System Amplitude vs Frequency Response.
ch 2
Frequency (Hz)
1000
100
(db)
+
0
1
10
9
8
7
6
5
4
3
2
1
LOGARITHMIC 359-7
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS



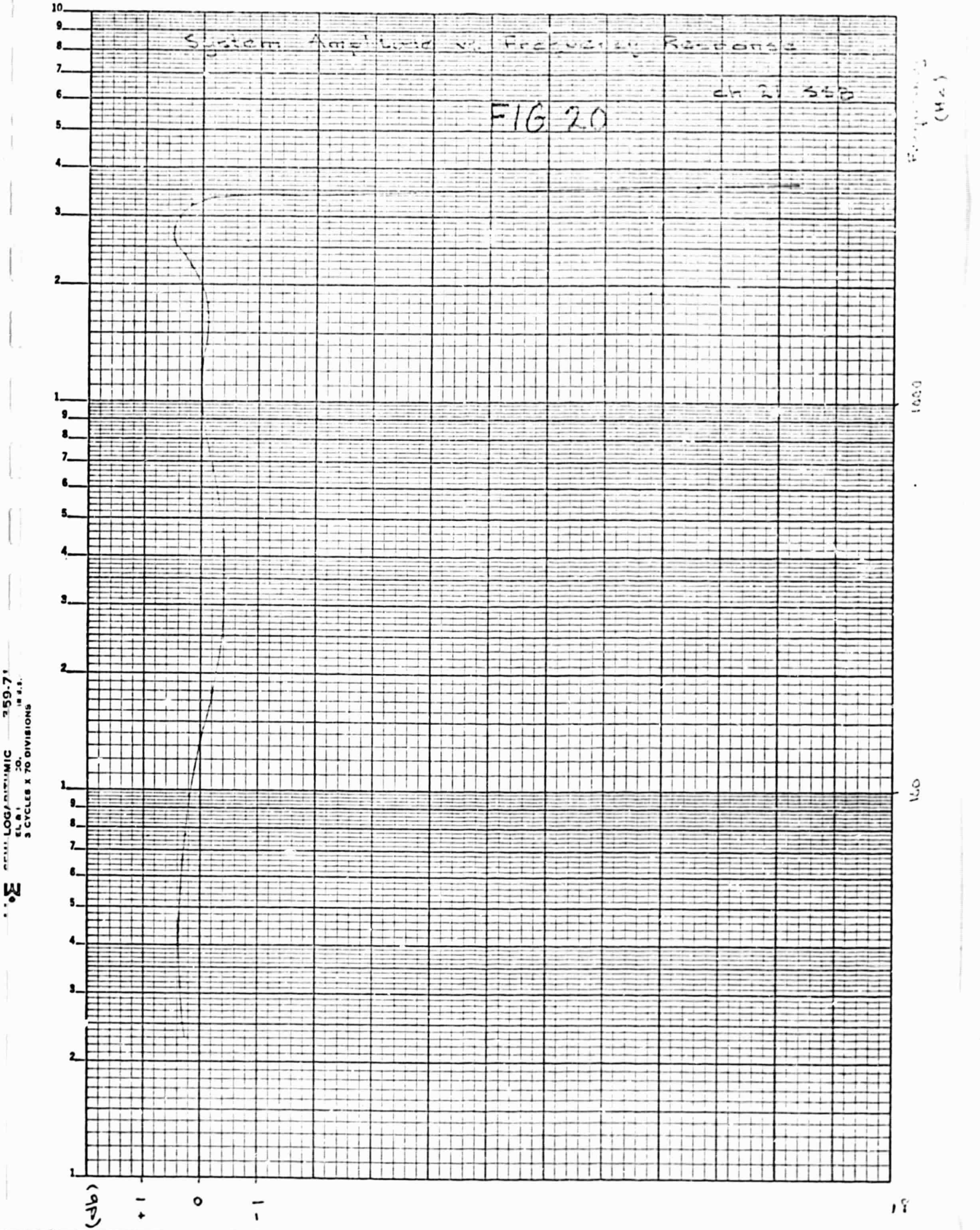
System Amplitude vs Frequency Response

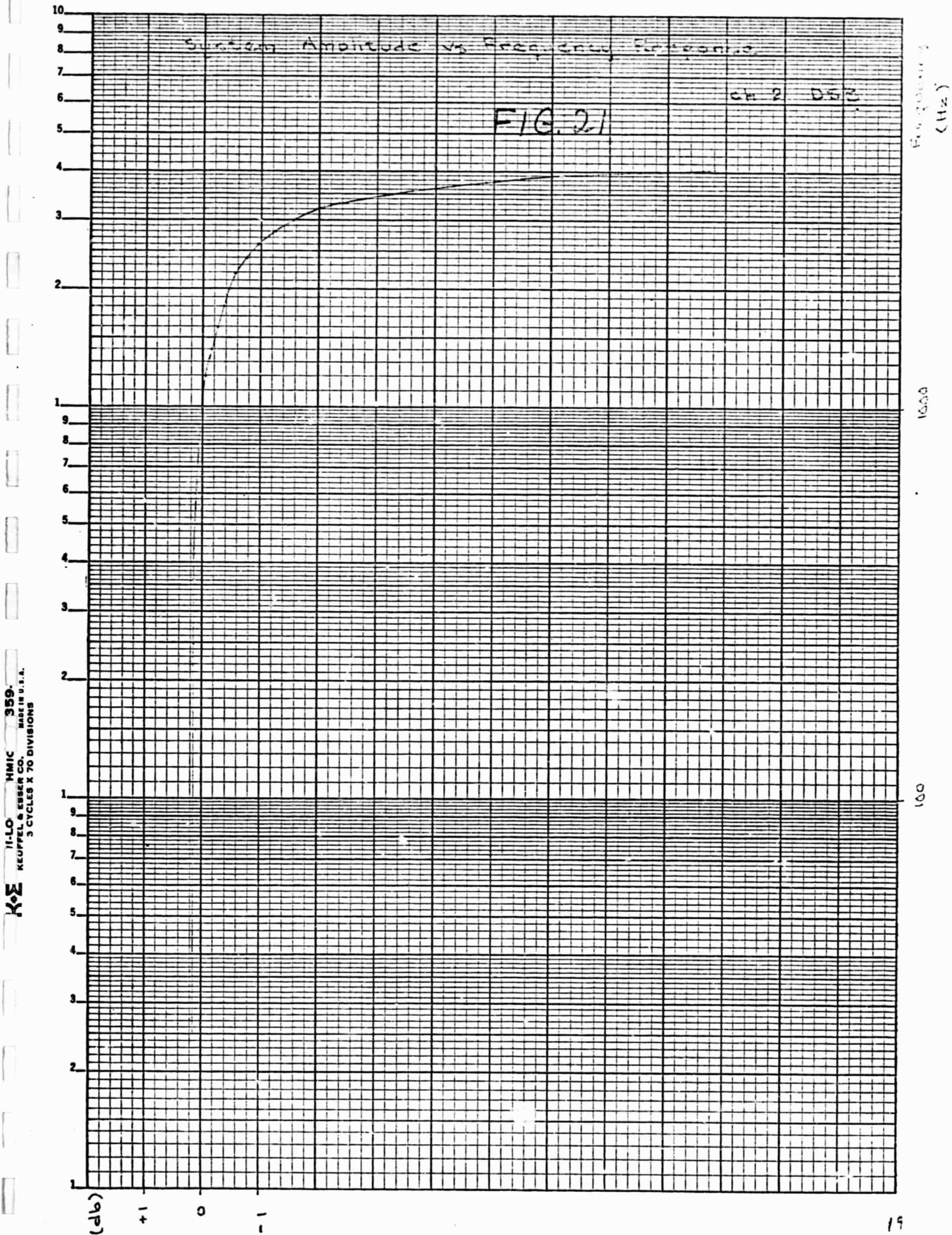
FIG. 19

System Amplitude vs. Frequency Response

ch 21 558

FIG 20





System Amplitude vs Frequency Response

FIG. 21

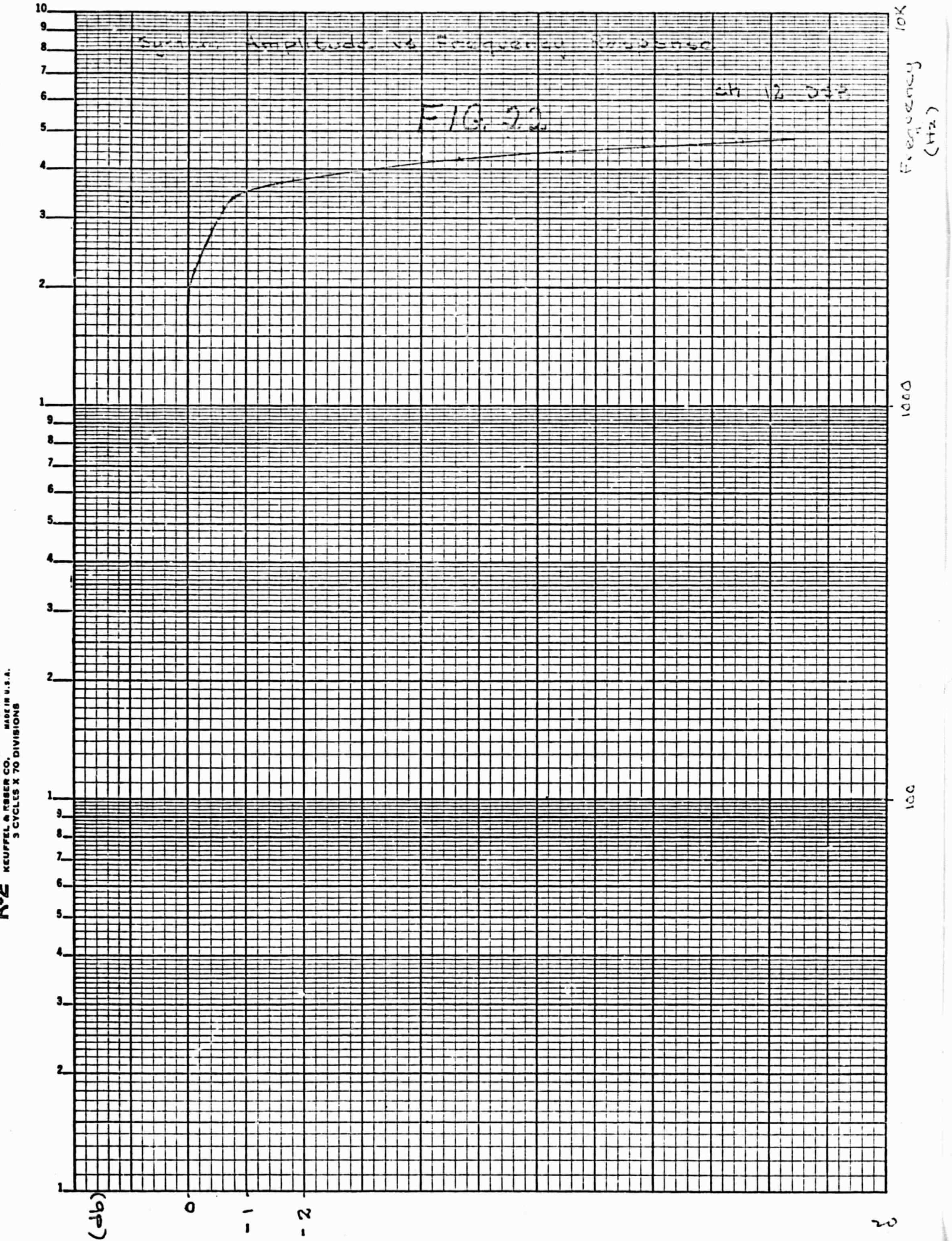


FIG. 22

System Amplitude vs Frequency Response
ch 12
10K
1000
100
Frequency (Hz)
(db)
0
-1
-2
K&E SEMI-LOGARITHMIC 359-
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

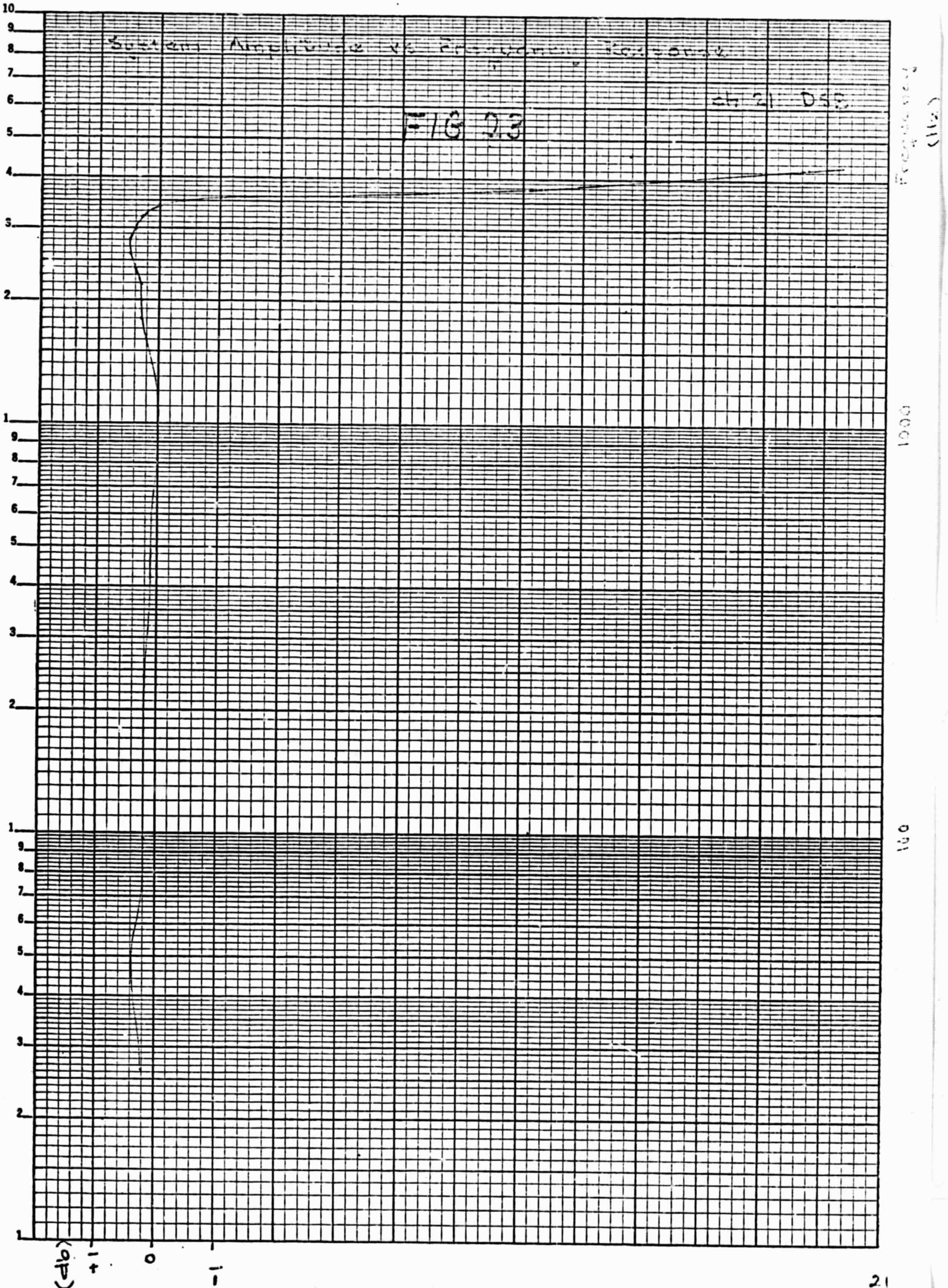
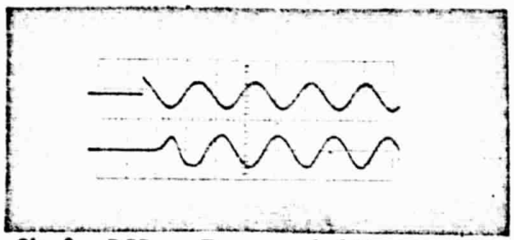
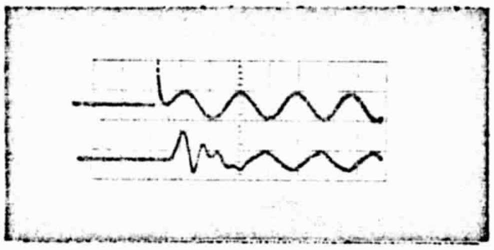

System Amplitude vs Frequency Response
ch 21 DSB
Frequency (Hz)
1000
100
(db)
+1
0
-1
K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS

FIG 23

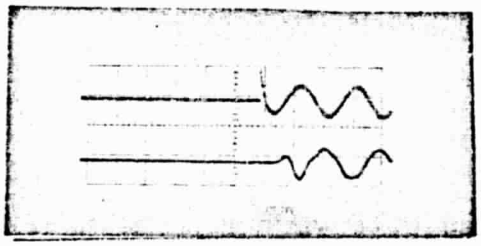
SYSTEM TIME DELAY



Ch 2, DSB. Freq. 1 kHz
Time-Scale 0.5 ms/div.

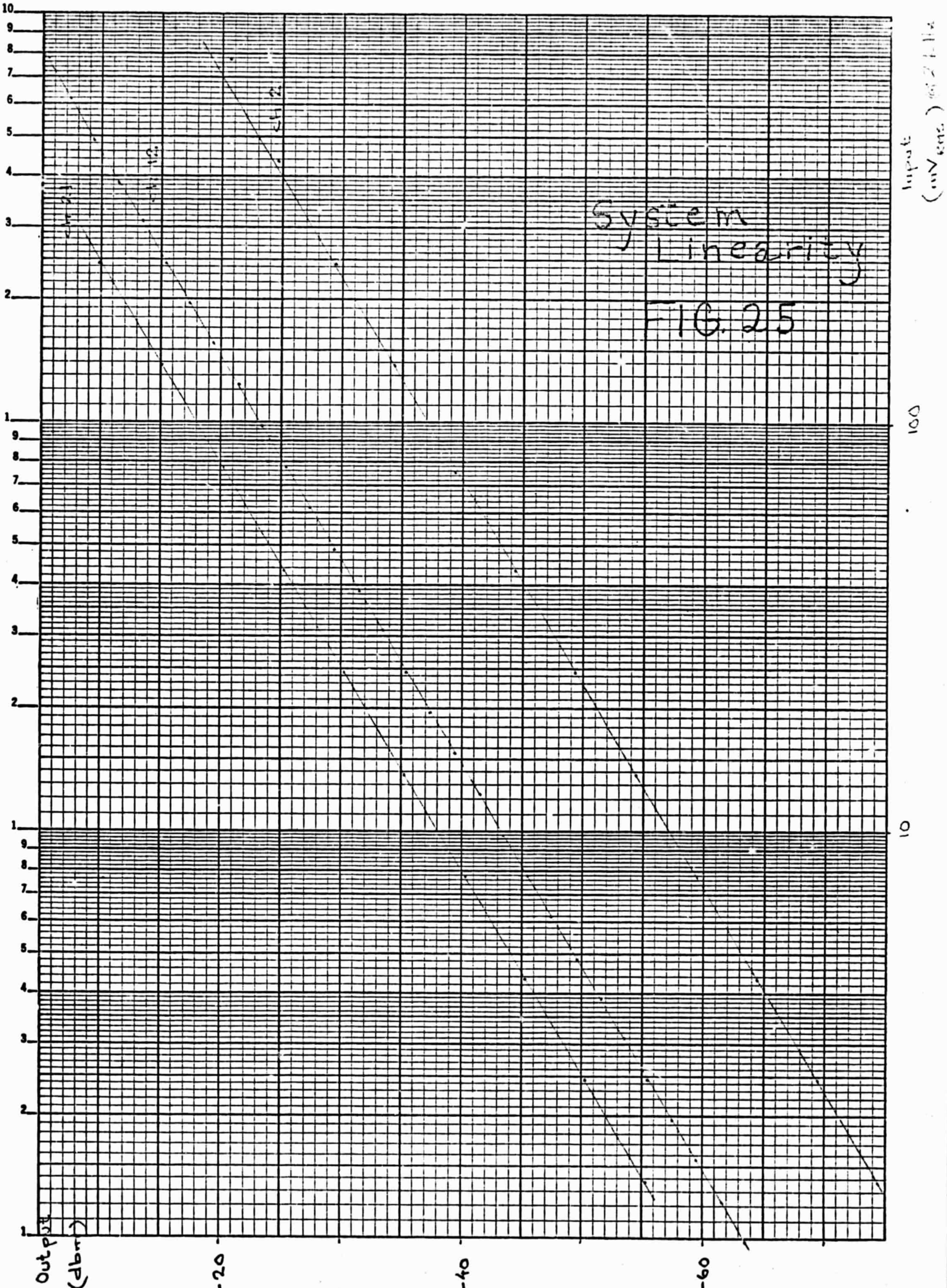


Ch 12, DSB. Freq. 1 kHz
Time-Scale 0.5 ms/div.



Ch 21, DSB. Freq. 1 kHz
Time-Scale 0.5 ms/div.

FIGURE 24



System Linearity

FIG. 25

TABLE I - BREADBOARD COMPONENTS

CARD	AIRBORNE COMPONENTS
A12	4 4-Input Power Gates and Pulseshape Circuits
A 1	3 J-K Flip-Flops (7470)
A 2	J-K Flip-Flops
A 3	9 3-Input Gates in 3 Packages (7410) (4 unused)
A 4	3 J-K Flip-Flops
A 5	J-K Flip-Flops
A 6	12 2-Input Gates in 3 Packages (7400) (1 unused)
A 7	3 J-K Flip-Flops
A 8	J-K Flip-Flops
A 9	J-K Flip-Flops
A10	J-K Flip-Flops
A11	J-K Flip-Flops
A13	Unused
A14	Mixer (inf X Ch 3F)
A15	Filter (Bandpass Ch 3; DSB <u>or</u> SSB).
A16	2 Amplifiers (Before mixer 1F; after mixer 17)
A17	Mixer (inf. converted to Ch 3 X Ch (3 + N)F)
A18	Filter (Ch. N DSB)
A19	1 Amplifier (After mixer 14)
A20	Mixer (Ch. 5F X Ch. 12FQ)
A21	Unused
A22	2 Amplifiers (Summing output; unused)
A23	Filter (Bandpass, Ch. 17)
A24	Filter (Bandpass, Ch. 16)

TABLE I - BREADBOARD COMPONENTS - (Continued)

CARD	GROUND COMPONENTS
GO	VCO
G1	4 4-Input power gates in 2 Packs & Pulseshapes
G 2	3 J-K Flip-Flops
G 3	J-K Flip-Flops
G 4	J-K Flip-Flops
G 5	J-K Flip-Flops
G 6	J-K Flip-Flops (1 unused)
G 7	J-K Flip-Flops
G 8	J-K Flip-Flops
G 9	J-K Flip-Flops
G10	Mixer (Ch. 16 Air X Ch. 16 Ground)
G11	Low-Pass Filter & Amplifier
G12	3 J-K Flip-Flops (1 unused)
G13	J-K Flip-Flops
G14	6 3-Input & 2 4-Input Gates (3 3-Input used)
G15	12 2-Input 2 4-Input Gates (1 unused)
G16	Sample-Circuit
G17	Sign-Det. (2 Op. Amplifier uA 709)
G18	Mixer
G19	Low-Pass Filter and Amplifier
G20	8 2-Input gates in 2 Packages & Add-inhibit circuit 2 4-Input gates (Unused)
G21	Mixer (Ch. 16 X Ch. 17)
G22	Filter (Bandpass Ch. 17)
G23	Filter (Bandpass Ch. 16)
G24	2 Amplifiers (After filter G22, After filter G23)
G25	Filter (Ch N, DSB)
G26	2 Op. Amplifiers (After filter G25, unused)

EFFECT OF TAPE RECORDER

An analysis of the effects of tape recorder wow and flutter is given in the Appendix.

From EQ I. The maximum percent "wow and flutter" tolerable by the digital loop is:

$$w_w T_v \text{ max.} = \frac{\pi/16}{(w_{17}(T_f - T_e) - w_1 T_g)}$$

$$= (\pi/16) \quad (506 \times 10^3 (.387 \times 10^{-3} - .241 \times 10^{-3}) - 29.8 \times 10^3 \times .233 \times 10^{-3})$$

$$= .282\%$$

This is less than the given value of .396% through which range lock cannot be retained. The solution is apparently to reduce the channel 17 filter delay time if such a large range is necessary.

Equation 2 is the channel to channel phase error due to the recorder. Channel 2 and 21 have an error of:

$$\Delta\theta_{2,\,21} = 21 = \pm T_v w_w \; w_{21} (T_g + T_e - T_{21}) - w_2 (T_g + T_e - T_2) + w_I (T_2 - T_{21})$$

$$= \pm .00396 \quad 625(.233 + .241 - .077) - 59.5(.233 + .241 - .082 + 18.8\ (.005)$$

$$= \pm .893 \text{ radians or } \pm 51.2^\circ$$

The error is nearly proportional to the difference in channel numbers and the above is the worst case. One solution is to reduce the difference between T_n and $T_g + T_e$.

The problem is that the carrier generation is delayed by about 475 μs while the signal is only delayed by about 80 us before it is joined with the carrier in the demodulation process.

Narrowing the information channel filters bandwidth and/or increasing the number of poles will raise its delay. The present bandwidth is about 1 KC greater than the required 6 KC so that the only significant improvement in the signal delay is to increase the number of poles in the filter. Increasing the present four poles to eight would only double the delay time, a por trade off.

A second possibility is to increase the delay time of the channel filters by using all pass delay filters in series with the present filters. Preliminary analysis indicates that a minimum of 6 reactors per all pass would be needed. Although this approach is theoretically capable of reducing the phase ambiguity to zero, the attendant increase in hardware volume is prohibitive.

The third possible approach is to lower the delay time for carrier regeneration due to the channel 16 filter and the phase-locked loop.

The present channel 16 filter has a 4.74 KC half bandwidth at 50 db. The nearest signal energy is due to channel 15's upper sideband signal. This would receive an attenuation of only 30 db being 3.24 KC below channel 16. If the 50 db bandwidth were allowed to occupy the full space from channel 15 + 1.5 KC to channel 17, the same type filter would satisfy the complete attenuation requirements with an attendant dely time increase of only about 20%. The phase-lock-loop bandwidth could then be made very large, reducing its delay to a very small value.

Alternatively, the phase-lock-loop can be made to do most of the filtering and the attenuation and attendant delay of the channel 16 filter could be reduced. It is felt that some decrease in delay time through the filter and loop can be made while still fulfilling the attenuation requirements (all unwanted energy down 50 db). Whether sufficient time delay reduction to completely cancel the phase error is possible is not known.

If the phase error is too large for the application, an effort would first be made to lower the pilot tone delay time as mentioned. If this is not sufficient, channel delay networks can be designed to further reduce the error to a tolerable level.

The digital-loop phase-lock problem is due to the difference in time between generating a channel one carrier and receiving the channel one produced by beating channel 16 and 17 pilot tones.

If the present phase error is acceptable, then the digital phase-lock-loop bandwidth may be widened to accept the specified wow and flutter by beating channel 17 received with channel 16 generated and then increasing the delay of the channel 17 filter by a factor of about 2 by narrowing its bandwidth. This easily corrects the digital-loop problem.

If it is decided to reduce the phase error, this method can still be used if the reduction is only about one half of the present error (to about 30°). If it is desired to further reduce the error between channels, then a system can be used which, once locked, remains locked until an error is sensed for more than the maximum wow period.

Theoretical Phase Delay of SSB System - (Continued)

Channels 16 and 17 pilot tones are passed through filters "c" and "d" respectively to become, before transmission: $K_2 \sin (w_{16} (t - T_c) - \theta c)$ and $K_2 \sin (w_{17} (t-T_d) - \theta d)$ where T_c and T_d are the group time delays of channels 16 and 17 at center frequency. θc and θd are the phase shifts of these filters at center frequency. After transmission, reception and tape transmission, channel 16 and 17 become respectively: K2 sin $\left[w_{16} (t - T_c + T_v \sin w_w t) - \theta c\right]$ and $K_2 \sin \left[w_{17}(t-T_d + T_v \sin w_w t) - \theta d\right]$.

Channel 16 and 17 are then filtered by filters "e" and "f". The resulting waveforms are: $K_2 \sin \left[w_{16} (t-T_c-T_e + T_v \sin w_w t) - \theta c - \theta e\right]$ and $K_2 \sin \left[w_{17} (t-T_d-T_f + T_v \sin w_w t) - \theta d - \theta f\right]$ where:

> T_e is the group time delay and θe is the phase shift of filter "e" at $w_{16} (1 + T_v w_w \cos w_w t)$
> T_f is the group time delay and θf is the phase shift of filter "f" at $w_{17} (1 + T_v w_w \cos w_w t)$.

Channels 16 and 17 are mixed to produce $\cos \left[w_1 (t + T_v \sin w_w t) + w_{16} (T_c + T_e) - w_{17} (T_d + T_f) - (\theta d - \theta c) - (\theta f - \theta e)\right]$ plus higher frequencies.

The phase-locked-loop, when presented with the Channel 16 pilot tone give above produces: $w_{16} (t - T_c - T_e - T_g + T_v \sin w_w t) - \theta - \theta e - \theta g$ where the loop acts as filter "g". This is divided by 16 to produce channel one: $\sin \left[w_1 (t - T_c - T_e - T_g + T_v \sin w_w t - T_h) - (\theta c + \theta e + \theta g - 2n\pi)/16\right]$ where T_h is the divider time delay due to clocking the chain with channel 16.

When the two channel one's are mixed, the low frequency output is:

$$\sin \Big[w_{16} (T_c + T_e) + w_{17} (T_d + T_f) + 2n\pi/16 - w_1 (T_c + T_e + T_g + T_h) - 1/16 \, (\theta + \theta e + \theta g) - (\theta e - \theta f) - (\theta c - \theta d) \Big]$$

Assuming, for this part, that all group delays are constant with frequency, the above wave is rewritten with the values for phase shift substituted and all constant terms represented by the symbol ψ:

$$\sin \Big[(T_f \, w_{17} - w_{16} (T_e + T_e/16 + T_g/16) \Big] w_w \, T_v \cos (w_w t + \psi).$$

The condition for the digital phase lock to retain phase stability is then:

$$\Big[w_{17} T_f - w_{16} (T_e + T_e/16 + T_g/16) \Big] w_w \, T_v \leq \pi/16 \qquad \text{EQ 1}$$

$$\frac{17}{16} (T_f - T_e) - \frac{1}{16} \, T_g < 104 \text{ us}$$

Channel "N" ground carrier is given by:

$$\sin (w_N (t - T_c - T_e - T_g + T_v \sin w_w t) - \frac{N}{16} \, (\theta c + \theta e + \theta g)).$$

Channel N is passed through filter j to produce:

$\sin \Big[(w_N - w_I) (t + T_v \sin w_w t) - w_N (T_b + T_j) + w_3 T_a + w_I (T_a + T_b + T_j) - \theta a - \theta b - \theta j \Big]$ where θj and T_j are respectively the phase shift and time delay of filter "j" at frequency $(w_N - e_I)(1 + w_w T_v \cos w_w t)$. These waves are mixed to produce: $\cos \Big[w_I t + w_N (T_b + T_j - T_c - T_e - T_g) - w_3 T_a - w_I (T_a + T_b + T_j - T_v \sin w_w t) - \frac{N}{16} (\theta c + \theta e + \theta g) + \theta a + \theta b + \theta j \Big]$. If channel M were similarly transmitted and passed through filter "k' instead of "b" and "m" instead of "j", it would produce a wave whose phase difference $(\Delta \theta)$ from that on channel N is $\Delta \theta = (w_N - w_M) \Big[(-\frac{\theta\theta c + \theta e + \theta g}{w_{16}} - (T_c + T_e + T_g) \Big] + w_n (T_b + T_j) - w_N (T_k + T_m) + \theta b + \theta j) - (\theta k + \theta m)$.

Theoretical Phase Delay of SSB System - (Continued)

Assuming again linear phase delay, the wave is rewritten with the values for phase shift substituted and all constant terms neglected:

$$\Delta\theta_{mn} \text{ due to recorder} = w_w T_v \left[\cos w_w t\right]\left[w_m (T_e + T_g - T_m) - w_N (T_e + T_g - T_j) + w_I (T_m - T_j)\right] . \qquad \text{EQ. 2}$$

APPENDIX B

FORM 821-E

AVCO ELECTRONICS DIVISION
CINCINNATI, OHIO 45241
CODE IDENT. NO. 80045

NO. ES 150.001
REV.
PAGE NO. 1 OF 70

REV. FOR ISSUE DATE, SUPERSEDED ISSUE DATES AND CHANGE NOTICE NUMBERS, SEE THE REVISION RECORD PAGE.

INITIAL FILTER TUNING
PROCEDURE FOR
SS/DSB MULTIPLEXER
AED PN 360000

PREPARED BY: J.W. Mullaney
APPROVED BY:
DATE: 15 December 1967

REV.

FILTER TUNING PROCEDURE
FOR
SS/DSB MULTIPLEXER

P/N 360000

1.0 Introduction

This tuning procedure specifies the initial tuning of the RLC five and seven pole filters used on the SS/DSB Multiplexer. These are the o.1 db chebychef designs used in the channel board and IF assemblies. The design is a distorted pole ladder network driven from a voltage source and terminated in a prescribed load resistance.

2.0 Equipment

2.1 Oscillator 1KC to 120 KC.
2.2 Power Supply (2) 13V at 30 ma.
2.3 Oscilloscope Voltage Probe, x10, 10 Megohm, 7 pf.
2.4 Oscilloscope Current Probe, Tektronix Type 134 or equiv.
2.5 Oscilloscope
2.6 Frequency counter, 5 place reading.
2.7 AC Voltmeter, Ballantine Model 643 or equiv.
2.8 Decade Resistance Box with metal case and terminal, 1 ohm to 1K ohm, 1K ohm to 1M ohms.

3.0 Preliminary tuning of five pole filters for channel board assemblies (P/N 360014-2 thru 19).

3.1 Assembly Information

These filters must be tuned before assembly is completed. Referring to P/N 360014 schematic or assembly drawing, this procedure must be executed before assembly of L1 thru L5, R1 thru R11, and lead 4 of T1. C1 thru C7, R12 thru R14, A1, and T.P. 1 thru 4 must be already assembled. Assembly of the remaining components on the channel board is not pertinent to the tuning procedure.

REV.

3.2 Test Set-Up

The test equipment configuration is shown in Figure 1 with reference made to the equipment specified in Paragraph 2.0. Reference is also made to temporary test points shown on the schematic and assembly drawings by letter designation.

3.3 Tuning of Resonant Circuits

3.3 1 Tuning of L1, Selection of R10 and R11

Connect a decade resistance box from T.P. 4 to lead 2 of L1 (clip type connection). Set the resistance to 50 ohms. Solder lead 1 to the board by removing the wire insulation with Formvar. Leave sufficient lead length for about 1/4" slack when the inductor is mounted. Place the current probe around one lead of the decade resistance box. Connect test point B (clip type connection) to T.P. 2.

3.3.2 Series Tuned Circuit Adjustment

3.3.2.1 Adjust the oscillator frequency for a maximum indication on the output meter. Place an ungrounded voltmeter across the inductor and set the oscillator level for a reading of 0.5 VRMS. Disconnect this voltmeter.

3.3.2.2 Adjust the oscillator frequency for a maximum indication on the output meter. The vertical trace on the oscilloscope should never be more than full scale. The vertical volts per centimeter scope control may be adjusted for full scale or zero db deflection of the output meter. Record this voltage as V_1. Raise and lower the oscillator frequency until the output indication drops by 3.0 db. Record these frequencies as f_1 and f_2.

3.3.2.3 Calculate V_2 as shown on the work sheet. Adjust the decade resistance box to produce a reading of V_2 on the output meter at the peak frequency.
A Again perform Paragraph 3.3.2.1.

3.3.2.4 Again perform Paragraph 3.3.2.2. Do not record the voltage. Record the frequencies as f_3 and f_4. Calculate f_5 as shown on the work sheet.

3.3.2.5 Add two turns to the coil using lead 2 of the inductor. These turns must be added in the same directions as the previous windings. This is termed the plus direction. Perform Paragraph 3.3.2.2 recording the frequencies only as f_6 and f_7. Calculate f_8.

3.3.2.6 Calculate T as shown on the work sheet. Add (T-2) turns in the plus direction (same direction as previous winding) if f_5 is greater than the value shown. If f_5 is less than the value shown, turns must be removed. The first two turns may be removed. To remove more than these two turns, turns must be added in the minus direction (opposite to the original winding direction).

3.3.2.7 Perform Paragraph 3.3.2.2, noting only lower 3.0 db frequency. Adjust the decade resistance box and repeat Paragraph 3.3.2.2 until the lower 3.0 db frequency corresponds to the value shown. Sufficient accuracy is achieved if the resistance is determined to three significant figures.

3.3.2.8 Check that the upper 3 db frequency (found by repeating Paragraph 3.3.2.2) corresponds to the value shown.. If the actual value is too high (low) add one turn in the plus (minus) direction to lead 2 of the coil and repeat Paragraphs 3.3.2.7 and 3 3.2.8.

3.3.2.9 Record the value of resistance and remove the decade box. Mount lead 2 of the coil allowing1/4" slack lead and assemble the mounting screw and washer by holding the washer and turning the screw finger-tip tight. Do not cut lead 2 of the coil. Remove

REV.

3.3.2.9 (Continued)

only sufficient Formvar to make the solder connection and allow the end of the lead to extend through the board.

3.3.2.10 Select resistor R10 whose value is the smallest resistor provided, which is greater than the value adjusted on the decade resistance box. Mount R10. Remove the test lead on test point B and place it on test point C. Connect the decade resistance box across R10. Adjust the resistance in 5% RMA value steps and perform Paragraph 3.3.2.6 until the value of lower 3.0 dB frequency is closest to that shown on the work sheet. This is the value of resistor R11. Mount R11 and remove the test connector between T.P. 2 and test point C.

3.3.3 Tuning of L3, Selection of R6 and R7.

3.3.3.1 Connect a decade resistance box from T.P. 4 to lead 2 of L3 (clip type connection). Set the resistance to 50 ohms. Solder lead 1 to the board by removing the wire insulation with Formvar. Leave sufficient lead length for about 1/4" slack when the inductor is mounted. Place the current probe around one lead of the decade resistance box. Connect test point D (clip type connection) to T.P. 2.

3.3.3.2 Perform Paragraph 3.3.2.1 thru 3.3.2.9.

3.3.3.3 Select resistor R7 whose value is the smallest resistor provided which is greater than the value adjusted on the decade resistance box. Mount R7. Move the test lead from lead 2 of L3 to test point E. Connect the decade resistance box across R7. Adjust the resistance in 5% RMS value steps and perform Paragraph 3.3.2.6 until the value of lower 3.0 db frequency is closest to that shown on the work sheet. This is the value of R6. Mount R6 and remove the two test connectors.

REV.

3.3.4 Tuning of L5, Selection of R1, R2, and R3.

3.3.4.1 Connect a decade resistance box from T.P. 4 to lead 2 of L5 (clip type connection). Set the resistance to 50 ohms. Solder lead 1 to the boards by removing the wire insulation with Formvar. Leave sufficient lead length for about 1/4" slack when the inductor is mounted. Place the current probe around one lead of the decade resistance box. Connect test point F (clip type connection) to T.P. 2.

3.3.4.2 Perform Paragraphs 3.3.2.1 thru 3.3.2.9.

3.3 4.3 Mount resistors R1 and R2. Remove the test connector from T.P. 2 to test point F. Calculate R3 as shown on the work sheet. Mount R3.

3.3.5 Tuning of L2, Selection of R8, R9.

Solder lead 1 of L2 to the board by removing the wire insulation with Formvar. Leave sufficient lead length for about 1/4" slack when the inductor is mounted. Connect a decade resistance box from T.P. 4 to lead 4 of the coil (clip type connection). Set the resistance to 50K ohms. Connect test point G (clip type connection) to lead 4 of the coil. Place the voltage probe on test point G.

3.3.6 Shunt tuned circuit adjustment.

3.3 6.1 Adjust the oscillator frequency for a maximum indication on the output meter. Adjust the oscillator level for an absolute value of 1.4v pp. Record the output meter reading. Move the voltage probe to T.P. 4 and record the output meter reading as V2. Return the probe to lead 4 of the coil.

REV.

3.3.6.2 Adjust the vertical volts/cm oscilloscope control for a full scale or zero db deflection of the output meter. Raise and lower the oscillator frequency until the output indication drops by 3.0 db. Record these frequencies as f1 and f2.

3.3.6.3 Calculate R8 as shown on the work sheet and set the decade resistance box to R_B. Adjust the oscillator level for an obsolute reading of 1.4V pp on the oscilloscope.

3.3.6.4 Perform Paragraph 3 3.6 2, recording the frequencies as f3 and f4. Calculate f5 as shown.

3.3.6.5 Add two turns in the positive direction to the coil using lead 4. Perform Paragraph 3.3.6.2 recording the two frequencies as f6 and f7. Calculate f8 as shown.

3.3.6.6 Calculate T as shown on the work sheet. Adjust turns as shown (refer to Paragraph 3.3.6.6 for more explicit information).

3.3.6.7 Perform Paragraph 3.3.6.2 noting only the lower 3 db frequency. Adjust the decade resistance box until this frequency is closest to that specified on the work sheet Three significant figure accuracy of resistance is sufficient.

3.3.6.8 Check that the upper 3 db frequency (found by repeating paragraph 3.3.6.2) corresponds to the value shown. If the actual value is too high (low), add 1 turn to the coil in the plus (minus) direction and repeat Paragraphs 3.3.6.7 and 3.3.6.8.

3.3.6.9 Record the value of resistance and remove the decade box and test connection to lead 4. Mount lead 4 of the coil allowing about 1/4" slack lead. Do not cut lead 4 of the coil. Remove only sufficient Formvar to make the solder connection and allow the end of the lead to extend through the board. Do not mount the center screw and washer.

3.3.6.10 Select resistor R8 whose value is the largest resistor provided, which is less than the value adjusted on the decade resistance box. Temporarily connect R8 from T.P. 4 to one lead of the decade resistance box. Connect the other lead of the box to test point G. Adjust the decade resistance box in 5% RMA value steps and perform Paragraph 3.3.6.2 noting only the lower 3 db frequency until this frequency is closest to that specified on the work sheet. Select R9 whose value is that adjusted on the resistance box. Mount R8 and R9. Remove the decade resistance box.

3.3.7 <u>Tuning of L4, Selection of R4 and R5</u>.

Solder lead 1 of L4 to the board by removing the wire insulation with Formvar. Leave sufficient length for about 1/4" slack when the inductor is mounted. Connect a decade resistance box from T.P. 4 to lead 4 of the coil (clip type connection). Set the resistance to 50K ohms. Connect test point H (clip type connection) to lead 4 of the coil. Place the voltage probe on test point H.

3.3.7.1 Perform Paragraphs 3.3 6.1 thru 3.3.6.9.

3.3.7.2 Select resistor R4 whose value is the largest resistor provided, which is less than the value adjusted on the decade resistance box. Temporarily connect R4 from T.P. 4 to one lead of the decade resistance box. Connect the other lead of the box to test point H. Adjust the decade resistance box in 5% RMA value steps and perform Paragraph 3.3.6.2 noting only the lower 3 db frequency until this frequency is closest to that specified on the work sheet. Select R5 whose value is that specified on the work sheet. Select R5 whose value is that adjusted on the resistance box. Mount R9 and R5. Remove the decade resistance box.

REV.

3.4 Tap Adjustment

A 3.4.1 Adjustment of Tap Lead 3 of L2

Temporarily connect T.P. 4 to test point E. Temporarily connect test point D to lead 3 of L2. Place the voltage probe on test point D.

3.4.2 Method of Tap Adjustment

By varying the oscillator frequency, the output meter can be observed to produce a maximum indication at two frequencies. Adjust the oscillator to one of these frequencies

3.4.2.1 Place the voltage probe on test point G and set the oscillator level for a 1.4V pp absolute reading on the oscilloscope. Return the voltage probe to test point D.

3.4.2.2 Adjust the oscillator frequency and record the two frequencies at which the output meter gives a maximum indication. Calculate the difference in these two frequencies. By adding turns to the coil with the tap lead, this frequency difference should be brought as close as possible to the value given on the work sheet. If the frequency difference is too small, add turns in the positive direction which is the direction in which the coil is wound. Adding turns in the opposite (negative)direction will decrease the frequency difference.

3.4.2.3 Remove the test connection from test point E. Remove the test connection between test point D and lead 3 of L2. Be careful not to change the turns on lead 3 of L2.

3.4.3 Adjustment of tap lead 2 of L4

Temporarily connect test point D to T.P.4. Temporarily connect lead 2 of L4 to test point E. Place the voltage probe on test point E.

3 4 3 1 Perform Paragraph 3 4.2 Place the voltage probe on test point H and set the oscillator level for a 1.4V pp absolute reading on the oscilloscope. Return the voltage probe to test point E.

3.4.3.2 Perform Paragraph 3.4.2.2.

3.4.3.3 Connect tap 2 of L4 to the board. Remove only sufficient wire insulation to make the solder connection. Do not cut the lead but allow the excess length to extend through the board. When the coil is mounted the lead should have about 1/4" slack.

3.4.3.4 Remove the two test connnections.

3.4.4 Adjustment of tap lead 3 of L4

Temporarily connect T.P. 3 to T.P.4. Temporarily connect lead 3 of L4 to test point F.

3.4.4.1 Perform Paragraph 3.4.3.1 but return the voltage probe to test point F,

3.4.4.2 Perform Paragraph 3.4.3.2. Connect tap 3 of L4 to the board as in Paragraph 3.4.3.3. Remove the two test connections.

3.4.4.3 Mount the nylon screw and washer to secure L4 to the board by holding the washer and turning the screw. Tighten the screw with finger tip pressure only.

3.4.5 Adjustment of tap lead 2 of L2.

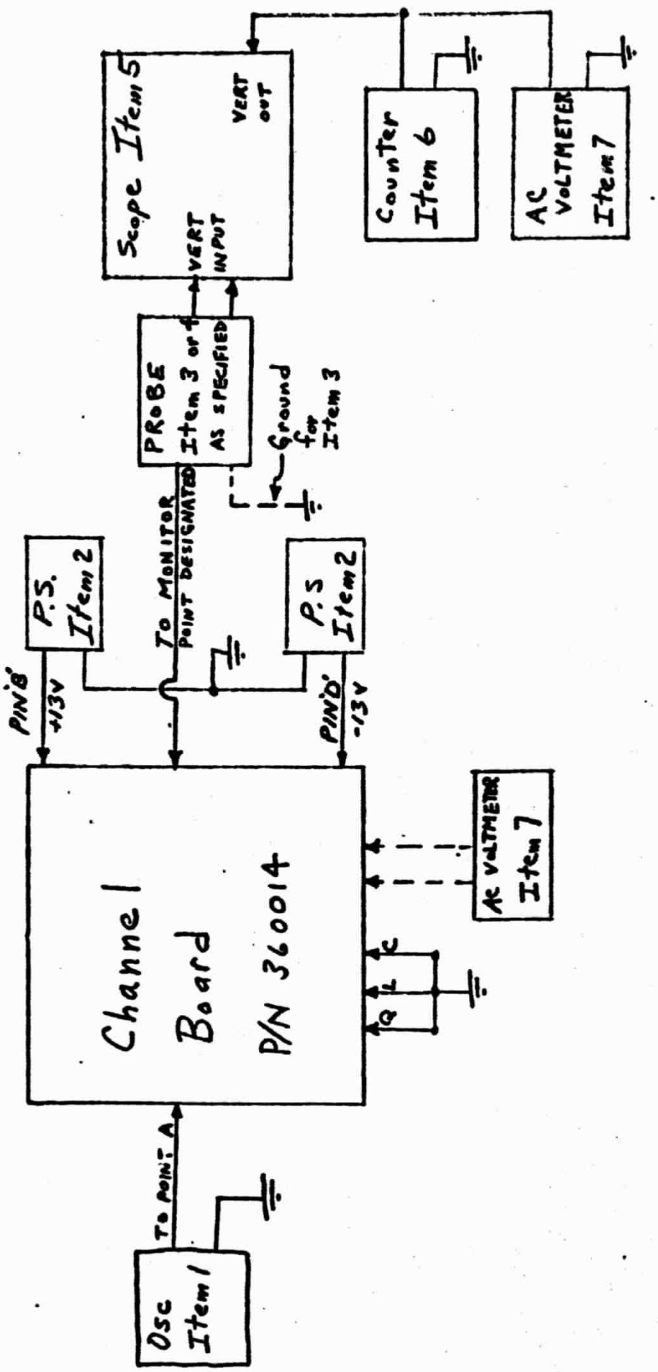
Temporarily connect lead 2 of L2 to test point C. Place the voltage probe on test point C.

3.4.5.1 Perform Paragraph 3.4.2. Perform Paragraph 3.4.2.1 except return the voltage probe to test point C.

3.4.5.2 Perform Paragraph 3.4.2.2. Remove all test connections. Connect leads 2 and 3 of L2 to the board as in Paragraph 3.4.3.3. Mount the nylon screw and washer as in Paragraph 3.4.4 3.

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED



Channel Board Filter Test Configuration

Fig. 1

REV.

P/N 360014- 2 Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)

Upper 3 db Frequency = ______ KHz (f1)

Lower 3 db Frequency = ______ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) / (1.69 \text{ KHz})\right] (V1)$ = ______ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)

Lower 3 dB frequency = ______ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ______ KHz (f6)

Lower 3 dB frequency = ______ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 9.48\text{KHz})\right] / \left[(9.48\text{KHz})(f5 - f8)\right]$ = ______ turns (T)

Add (T-2) turns in + direction if f5 > 9.48 KHz

Add (T-2) turns in - direction if f5 < 9.48 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 8.693 KHz

3.3.2.8 Check that upper 3 dB frequency = 10.311 to 10.414 kHz

Read decade box R = ______ Ohms

REV.

P/N 360014- 3 Coil L ______

WORK SHEET

(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db Frequency = ____________ KHz (f1)

Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]\ (V1) =$ __________ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - \underline{14.22\text{KH}})\right]\ /\ \left[(\underline{14.22\text{KHz}})(f5 - f8)\right] =$ ________ turns (T)

Add (T-2) turns in + direction if f5 > 14.22KHz

Add (T-2) turns in - direction if f5 < 14.22KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 13.400 KHz

3.3.2.8 Check that upper 3 dB frequency = 15.015 to 15.166 KHz

Read decade box R = ____________ Ohms

REV.

P/N 360014- 4 Coil L ____

WORK SHEET
(L1, L3)

Ref. Para.			
3.3.2.2	Measure	Voltage at peak	= ____ V (V1)
		Upper 3 db Frequency	= ____ KHz (f1)
		Lower 3 db Frequency	= ____ KHz (f2)
3.3.2.3	Calculate	$\left[(f1 - f2)/(1.69\ \text{KHz})\right](V1)$	= ____ V (V2)
	Set	Output meter to V2 volts by selecting resistor.	
	Set	Voltage across coil to 0.5V RMS.	
3.3.2.4	Measure	Upper 3 dB frequency	= ____ KHz (f3)
		Lower 3 dB frequency	= ____ KHz (f4)
	Calculate	$f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$	= ____ KHz (f5)
3.3.2.5	Add 2 turns to coil in + direction.		
	Measure	Upper 3 dB frequency	= ____ KHz (f6)
		Lower 3 dB frequency	= ____ KHz (f7)
	Calculate	$f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$	= ____ KHz (f8)
3.3.2.6	Calculate	$\left[2(f8)(f5 - 18.96\ \text{kHz})\right] / \left[(18.96\ \text{KHz})(f5 - f8)\right]$	= ____ turns (T)
	Add (T-2) turns in + direction if f5 > 18.96 KHz		
	Add (T-2) turns in - direction if f5 < 18.96 KHz		
3.3.2.7	Select resistor for lower 3 dB frequency = 18.134 KHz		
3.3.2.8	Check that upper 3 dB frequency = 19.725 to 19.923 KHz		
	Read decade box	R = ____ Ohms	

0

REV.

P/N 360014- 5 Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)
Upper 3 db Frequency = ____________ KHz (f1)
Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right](V1) =$ ____________ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 23.70\text{KHz})\right] / \left[(23.70\ \text{kHz})(f5 - f8)\right] =$ ________ turns (T)
Add (T-2) turns in + direction if f5 > 23.70 KHz
Add (T-2) turns in - direction if f5 < 23.70 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 22.87 KHz

3.3.2.8 Check that upper 3 dB frequency = 24.437 to 24.683 KHz
Read decade box R = ____________ Ohms

REV.

P/N 360014- 6 Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db Frequency = ____________ KHz (f1)

Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]\ (V1) =$ ____________ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 28.44\text{KHz})\right]\ /\ \left[(28.44\text{KHz})(f5 - f8)\right] =$ ________ turns (T)

Add (T-2) turns in + direction if f5 > 28.44 KHz

Add (T-2) turns in - direction if f5 < 28.44 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 27.608 KHz

3.3.2.8 Check that upper 3 dB frequency = 29.151 to 29.444 KHz

Read decade box R = ____________ Ohms

REV.

P/N 360014- 7 Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)
Upper 3 db Frequency = ____________ KHz (f1)
Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]$ (V1) = ____________ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f7)
Calculate $f7 + (f6 \div f7)/2 - (f6 - f7)^2/(8f7)$ = ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - \underline{33.18\ \text{KHz}})\right] / \left[(\underline{33.18\ \text{KHz}})(f5 - f8)\right]$ = ________ turns (T)
Add (T-2) turns in + direction if f5 > 33.18 KHz
Add (T-2) turns in - direction if f5 < 33.18 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 32.346 KHz

3.3.2.8 Check that upper 3 dB frequency = 33.866 to 34.206 KHz
Read decade box R = ____________ Ohms

V.

P/N 360014- 8 ________ Coil L ________

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)
Upper 3 db Frequency = ____________ KHz (f1)
Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) \;/(1.69 \text{ KHz})\right] (V1) =$ ____________ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 37.92\text{KHz})\right] / \left[(37.92\text{KHz})(f5 - f8)\right] =$ ________ turns (T)
Add (T-2) turns in + direction if f5 > 37.92KHz
Add (T-2) turns in - direction if f5 < 37.92KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 37.084 KHz

3.3.2.8 Check that upper 3 dB frequency = 38.581 to 38.968 KHz
Read decade box R = ____________ Ohms

REV.

P/N 360014- 9______ C L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ________ V (V1)

Upper 3 db Frequency = ________ KHz (f1)

Lower 3 db Frequency = ________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]$ (V1) = ________ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ________ KHz (f3)

Lower 3 dB frequency = ________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ________ KHz (f6)

Lower 3 dB frequency = ________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 42.66\text{KHz})\right] / \left[(42.66\text{KHz})(f5 - f8)\right]$ = ________ turns (T)

Add (T-2) turns in + direction if f5 > 42.66 KHz

Add (T-2) turns in - direction if f5 < 42.66 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 41.823 KHz

3.3.2.8 Check that upper 3 dB frequency = 43.296 to 43.731 KHz

Read decade box R = ________ Ohms

P/N 360014- 10 ______ Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db Frequency = ____________ KHz (f1)

Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right] (V1) =$ ____________ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 47.40\ \text{KHz})\right] / \left[(47.40\ \text{KHz})(f5 - f8)\right] =$ ________ turns (T)

Add (T-2) turns in + direction if f5 > 47.40 KHz

Add (T-2) turns in - direction if f5 < 47.40 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 46.563 KHz

3.3.2.8 Check that upper 3 dB frequency = 48.011 to 48.494 KHz

Read decade box R = ____________ Ohms

P/N 360014- 11______ Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)

Upper 3 db Frequency = ______ KHz (f1)

Lower 3 db Frequency = ______ KHz (f2)

3.3.2 3 Calculate $\left[(f1 - f2) / (1.69\ \text{KHz})\right] (V1)$ = ______ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)

Lower 3 dB frequency = ______ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ______ KHz (f6)

Lower 3 dB frequency = ______ KHz (f7)

Calculate $f7 + (f6 \div f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 52.14\text{KHz})\right] / \left[(52.14\text{KHz})(f5 - f8)\right]$ = ______ turns (T)

Add (T-2) turns in + direction if f5 > 52.14KHz

Add (T-2) turns in - direction if f5 < 52.14KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 51.302 KHz

3.3.2.8 Check that upper 3 dB frequency = 52.727 to 53.257 KHz

Read decade box R = ______ Ohms

P/N 360014- 12 ____ Coil L ____

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____ V (V1)
Upper 3 db Frequency = ____ KHz (f1)
Lower 3 db Frequency = ____ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]\ (V1)$ = ____ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____ KHz (f3)
Lower 3 dB frequency = ____ KHz (f4)
Calculate $f4 + (f3 - f4)/2\ - (f3 - f4)^2/(8f4)$ = ____ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____ KHz (f6)
Lower 3 dB frequency = ____ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 56.88\text{KHz})\right]\ /\ \left[(56.88\text{ KHz})(f5 - f8)\right]$ = ____ turns (T)
Add (T-2) turns in + direction if f5 > 56.88 KHz
Add (T-2) turns in - direction if f5 < 56.88 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 56.041 KHz

3.3.2.8 Check that upper 3 dB frequency = 57.443 to 58.020 KHz
Read decade box R = ____ Ohms

REV.

P/N 360014- 13 Coil L ____

WORK SHEET
(L1, L3)

Ref. Para.		
3.3.2.2	Measure	Voltage at peak = ________ V (V1)
		Upper 3 db Frequency = ________ KHz (f1)
		Lower 3 db Frequency = ________ KHz (f2)
3.3.2.3	Calculate	$\left[(f1 - f2) / (1.69 \text{ KHz})\right] (V1) =$ ________ V (v2)
	Set	Output meter to V2 volts by selecting resistor.
	Set	Voltage across coil to 0.5V RMS.
3.3.2.4	Measure	Upper 3 dB frequency = ________ KHz (f3)
		Lower 3 dB frequency = ________ KHz (f4)
	Calculate	$f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)
3.3.2.5	Add 2 turns to coil in + direction.	
	Measure	Upper 3 dB frequency = ________ KHz (f6)
		Lower 3 dB frequency = ________ KHz (f7)
	Calculate	$f7 + (f6 \div f7)/2 - (f6 - f7)^2/(8f7) =$ ________ KHz (f8)
3.3.2.6	Calculate	$\left[2(f8)(f5 - 61.62 \text{ KHz})\right] / \left[(61.62 \text{ KHz})(f5 - f8)\right] =$ ________ turns (T)
	Add (T-2) turns in + direction if f5 > 61.62 KHz	
	Add (T-2) turns in - direction if f5 < 51.62 KHz	
3.3.2.7	Select resistor for lower 3 dB frequency = 60.781 KHz	
3.3.2.8	Check that upper 3 dB frequency = 62.158 to 62.783 KHz	
	Read decade box	R = ________ Ohms

P/N 360014- 14 Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)
Upper 3 db Frequency = ______ KHz (f1)
Lower 3 db Frequency = ______ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) /(1.69\ \text{KHz})\right] (V1)$ = ______ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)
Lower 3 dB frequency = ______ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ______ KHz (f6)
Lower 3 dB frequency = ______ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 66.36\,\text{KHz})\right] / \left[(66.36\,\text{KHz})(f5 - f8)\right]$ = ______ turns (T)
Add (T-2) turns in + direction if f5 > 66.36 KHz
Add (T-2) turns in - direction if f5 < 66.36 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 65.520 KHz

3.3.2.8 Check that upper 3 dB frequency = 66.974 to 67.546 KHz
Read decade box R = ______ Ohms

P/N 360014- 15 ____ Coil L ____

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____ V (V1)

Upper 3 db Frequency = ____ KHz (f1)

Lower 3 db Frequency = ____ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) / (1.69\ \mathrm{KHz})\right] (V1)$ = ____ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____ KHz (f3)

Lower 3 dB frequency = ____ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____ KHz (f6)

Lower 3 dB frequency = ____ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 71.10\ \mathrm{KHz})\right] / \left[(71.10\ \mathrm{KHz})(f5 - f8)\right]$ = ____ turns (T)

Add (T-2) turns in + direction if f5 > 71.10 KHz

Add (T-2) turns in - direction if f5 < 71.10 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 70.260 KHz

3.3.2.8 Check that upper 3 dB frequency = 71.590 to 72.310 KHz

Read decade box R = ____ Ohms

REV.

P/N 360014- 16 ______ Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)
Upper 3 db Frequency = ______ KHz (f1)
Lower 3 db Frequency = ______ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) / (1.69 \text{ KHz})\right] (V1)$ = ______ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)
Lower 3 dB frequency = ______ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ______ KHz (f6)
Lower 3 dB frequency = ______ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 85.32 \text{ KHz})\right] / \left[(85.32 \text{ KHz})(f5 - f8)\right]$ = ______ turns (T)
Add (T-2) turns in + direction if f5 > 85.32 KHz
Add (T-2) turns in - direction if f5 < 85.32 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 84.479 KHz

3.3.2.8 Check that upper 3 dB frequency = 85.738 to 86.600 KHz
Read decade box R = ______ Ohms

P/N 360014- 17 Coil L ____

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ________ V (V1)

Upper 3 db Frequency = ________ KHz (f1)

Lower 3 db Frequency = ________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) / (1.69\ \text{KHz})\right] (V1)$ = ________ V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ________ KHz (f3)

Lower 3 dB frequency = ________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ________ KHz (f6)

Lower 3 dB frequency = ________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 90.06\ \text{KHz})\right] / \left[(90.06\ \text{KHz})(f5 - f8)\right]$ = ________ turns (T)

Add (T-2) turns in + direction if f5 > 90.06 KHz

Add (T-2) turns in - direction if f5 < 90.06 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 89.219 KHz

3.3.2.8 Check that upper 3 dB frequency = 90.454 to 91.364 KHz

Read decade box R = ________ Ohms

REV.

P/N 360014- 18 Coil L ________

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)
Upper 3 db Frequency = ____________ KHz (f1)
Lower 3 db Frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]$ (V1) = ____________ V (v2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - \underline{94.80\text{KHz}})\right] / \left[(\underline{94.80\text{KHz}})(f5 - f8)\right]$ = ________ turns (T)
Add (T-2) turns in + direction if f5 > 94.80 KHz
Add (T-2) turns in - direction if f5 < 94.80 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 93.959 KHz

3.3.2.8 Check that upper 3 dB frequency = 95.171 to 96.127 KHz
Read decade box R = ____________ Ohms

REV.

P/N 360014- 19 Coil L ______

WORK SHEET
(L1, L3)

Ref. Para.

3.3.2.2 **Measure** Voltage at peak = __________V (V1)

Upper 3 db Frequency = __________KHz (f1)

Lower 3 db Frequency = __________KHz (f2)

3.3.2.3 **Calculate** $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]$ (V1) = __________V (v2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 **Measure** Upper 3 dB frequency = __________KHz (f3)

Lower 3 dB frequency = __________KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = __________KHz (f6)

Lower 3 dB frequency = __________KHz (f7)

Calculate $f7 + (f6 \div f7)/2 - (f6 - f7)^2/(8f7)$ = __________KHz (f8)

3.3.2.6 **Calculate** $\left[2(f8)(f5 - 99.54\ \text{KHz})\right]\ /\ \left[(99.54\ \text{KHz})(f5 - f8)\right]$ = __________ turns (T)

Add (T-2) turns in + direction if f5 > 99.54 KHz

Add (T-2) turns in - direction if f5 < 99.54 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 98.699 KHz

3.3.2.8 Check that upper 3 dB frequency = 99.887 to 100.891 KHz

Read decade box R = __________ Ohms

P/N 360014- 2 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______________ V (V1)
Upper 3 db frequency = ______________ KHz (f1)
Lower 3 db frequency = ______________ KHz (f2)

3.3.2.3 Calculate [(f1 - f2) /(1.69 KHz)] (V1) = ____________ V (V2)
Set Output meter to V2 volts by select ng resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 = (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ___________ KHz (f8)

3.3.2.6 Calculate [2(f8)(f5 - 9.48 KHz)] / [(9.48 KHz)(f5 - f8)] = _________ turns (T)
Add (T-2) turns in + direction if f5 > 9.48 KHz
Add (T-2) turns in - direction if f5 < 9.48 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 8.693 KHz

3.3.2.8 Check that upper 3 dB frequency = 10.311 to 10.414 KHz
Read decade box R = ______________ Ohms

3.3.4.3 Calculate R3 =

$$\frac{(R)(13.01\,K) + (8.93\,M)}{(7.00K) - R}$$

REV.

P/N 360014- 3 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)
Upper 3 db frequency = ______ KHz (f1)
Lower 3 db frequency = ______ KHz (f2)

3.3.2.3 Calculate [(f1 - f2) /(1.69 KHz)] (V1) = ______ V (V2)
Set Output meter to V2 volts by select ng resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)
Lower 3 dB frequency = ______ KHz (f4)
Calculate $f4 = (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ______ KHz (f6)
Lower 3 dB frequency = ______ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ______ KHz (f8)

3.3.2.6 Calculate [2(f8)(f5 - 14.22 KHz)] / [(14.22 KHz)(f5 - f8)] = ______ turns (T)
Add (T-2) turns in + direction if f5 > 14.22 KHz
Add (T-2) turns in - direction if f5 < 14.22 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 13.400 KHz

3.3.2.8 Check that upper 3 dB frequency = 15.015 to 15.166 KHz
Read decade box R = ______ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(11.33K) + (1.769M)}{(9.67K) - R}$

REV.

P/N 360014- 4 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)
Upper 3 db frequency = ______ KHz (f1)
Lower 3 db frequency = ______ KHz (f2)

3.3.2.3 Calculate [(f1 - f2) /(1.69 KHz)] (V1) = ______ V (V2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)
Lower 3 dB frequency = ______ KHz (f4)
Calculate $f4 = (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ______ KHz (f6)
Lower 3 dB frequency = ______ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)

3.3.2.6 Calculate [2(f8)(f5 - 18.96 KHz)] / [(18.96 KHz)(f5 - f8)] = ______ turns (T)
Add (T-2) turns in + direction if f5 > 18.96 KHz
Add (T-2) turns in - direction if f5 < 18.96 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 18.134 KHz

3.3.2.8 Check that upper 3 dB frequency = 19.725 to 19.923 KHz
Read decade box R = ______ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.75K) + (562.5K)}{(9.25K) - R}$

REV.

P/N 360014- 5 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)
Upper 3 db frequency = ____________ KHz (f1)
Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2)/(1.69\ KHz)]\ (V1)$ = ____________ V (V2)
Set Output meter to V2 volts by select ng resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 = (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____________ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 23.70\ KHz)] / [(23.70\ KHz)(f5 - f8)]$ = ____________ turns (T)
Add (T-2) turns in = direction if f5 > 23.70 KHz
Add (T-2) turns in - direction if f5 < 23.70 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 22.87 KHz

3.3.2.8 Check that upper 3 dB frequency = 24.437 to 24.683 kHz
Read decade box R = ____________ Ohms

3.3.4.3 Calculate R3 = $\frac{(R)(10.58K) + (363.5K)}{(2.421K) - R}$

P/N 360014- 6 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 **Measure** Voltage at peak = ______________ V (V1)
Upper 3 db frequency = ______________ KHz (f1)
Lower 3 db frequency = ______________ KHz (f2)

3.3.2.3 **Calculate** $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]\ (V1)$ = ____________ V (V2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 **Measure** Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7)$ = ____________ KHz (f8)

3.3.2.6 **Calculate** $\left[2(f8)(f5 - 28.44\ \text{KHz})\right] / \left[(28.44\ \text{KHz})(f5 - f8)\right]$ = ________ turns (T)
Add (T-2) turns in + direction if f5 > 28.44 KHz
Add (T-2) turns in - direction if f5 < 28.44 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 27.608 KHz

3.3.2.8 Check that upper 3 dB frequency = 29.151 to 29.444 KHz
Read decade box R = ______________ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.40K) + (161.6K)}{(9.598K) - R}$

P/N 360014- 7 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ________ V (V1)
Upper 3 db frequency = ________ KHz (f1)
Lower 3 db frequency = ________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2) / (1.69\text{ KHz})\right] (V1) =$ ________ V (V2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ________ KHz (f3)
Lower 3 dB frequency = ________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ________ KHz (f6)
Lower 3 dB frequency = ________ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7) =$ ________ KHz (f)

3.3.2.6 Calculate $\left[2(f8)(f5 - 33.18\text{ KHz})\right] / \left[(33.18\text{ KHz})(f5 - f8)\right] =$ ________ turns (T)
Add (T-2) turns in + direction if f5 > 33.18 KHz
Add (T-2) turns in - direction if f5 < 33.18 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 32.346 KHz

3.3.2.8 Check that upper 3 dB frequency = 33.866 to 34.206 KHz
Read decade box R = ________ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.29K) + (96.73K)}{(9.705K) - R}$

P/N 360014- 8 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db frequency = ____________ KHz (f1)

Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]\ (V1) =$ ____________ V (V2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ____________ KHz (f)

3.3.2.6 Calculate $\left[2(f8)(f5 - 37.92\ \text{KHz})\right]\ /\ \left[(37.92\ \text{KHz})(f5 - f8)\right] =$ ____________ turns (T)

Add (T-2) turns in = direction if f5 > 37.92 KHz

Add (T-2) turns in - direction if f5 < 37.92 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 37.084 KHz

3.3.2.8 Check that upper 3 dB frequency = 38.591 to 38.968 KHz

Read decade box R = ____________ Ohms

3.3.4 3 Calculate R3 =

$$R3 = \frac{(R)(10.51K) + (271.6K)}{(2.488K) - R}$$

P/N 360014- 9 Coil L 5

WORK SHEET

Ref. Para.		
3.3.2.2	Measure	Voltage at peak = __________ V (V1)
		Upper 3 db frequency = __________ KHz (f1)
		Lower 3 db frequency = __________ KHz (f2)
3.3.2.3	Calculate	$\left[(f1 - f2)\ /(1.69\ \text{KHz})\right](V1) =$ __________ V (V2)
	Set	Output meter to V2 volts by selecting resistor.
	Set	Voltage across coil to 0.5V RMS.
3.3.2.4	Measure	Upper 3 dB frequency = __________ KHz (f3)
		Lower 3 dB frequency = __________ KHz (f4)
	Calculate	$f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)
3.3.2.5	Add 2 turns to coil in + direction.	
	Measure	Upper 3 dB frequency = __________ KHz (f6)
		Lower 3 dB frequency = __________ KHz (f)
	Calculate	$f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ __________ KHz (f8)
3.3.2.6	Calculate $\left[2(f8)(f5 - 42.66\ \text{KHz})\right] / \left[(42.66\ \text{KHz})(f5 - f8)\right] =$ __________ turns (	
	Add (T-2) turns in + direction if f5 > 42.66 KHz	
	Add (T-2) turns in - direction if f5 < 42.66 KHz	
3.3.2.7	Select resistor for lower 3 dB frequency = 41.823 KHz	
3.3.2.8	Check that upper 3 dB frequency = 43.296 to 43.731	
	Read decade box . R = __________ Ohms	
3.3.4.3	Calculate R3 = $\dfrac{(R)(10.40K) + (192.8K)}{(9.595K) - R}$	

REV.

P/N 360014- 10 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 **Measure** Voltage at peak = ______________ V (V1)

Upper 3 db frequency = ______________ KHz (f1)

Lower 3 db frequency = ______________ KHz (f2)

3.3.2.3 **Calculate** $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]\ (V1) =$ ______________ V (V2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 **Measure** Upper 3 dB frequency = ______________ KHz (f3)

Lower 3 dB frequency = ______________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ______________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ______________ KHz (f6)

Lower 3 dB frequency = ______________ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ______________ KHz (f8)

3.3.2.6 **Calculate** $\left[2(f8)(f5 - 47.40\ \text{KHz})\right]\ /\ \left[(47.40\ \text{KHz})(f5 - f8)\right] =$ ______________ turns (T)

Add (T-2) turns in = direction if f5 > 47.40 KHz

Add (T-2) turns in - direction if f5 < 47.40 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 46.563 KHz

3.3.2.8 Check that upper 3 dB frequency = 48.011 to 48.494 KHz

Read decade box R = ______________ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.75K) + (637.8K)}{(9.243K) - R}$

P/N 360014- 11 Coil L 5

WORK SHEET

Ref. Para.			
3.3.2.2	Measure	Voltage at peak	= ______ V (V1)
		Upper 3 db frequency	= ______ KHz (f1)
		Lower 3 db frequency	= ______ KHz (f2)
3.3.2.3	Calculate	[(f1 - f2) /(1.69 KHz)] (V1) = ______ V (V2)	
	Set	Output meter to V2 volts by selecting resistor.	
	Set	Voltage across coil to 0.5V RMS.	
3.3.2.4	Measure	Upper 3 dB frequency	= ______ KHz (f3)
		Lower 3 dB frequency	= ______ KHz (f4)
	Calculate	$f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)	
3.3.2.5	Add 2 turns to coil in + direction.		
	Measure	Upper 3 dB frequency	= ______ KHz (f6)
		Lower 3 dB frequency	= ______ KHz (f)
	Calculate	$f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f)	
3.3.2.6	Calculate	[2(f8)(f5 - 52.14 KHz)] / [(52.14 KHz)(f5 - f8)] = ______ turns (T)	
	Add (T-2) turns in + direction if f5 > 52.14 KHz		
	Add (T-2) turns in - direction if f5 < 52.14 KHz		
3.3.2.7	Select resistor for lower 3 dB frequency = 51.302 KHz		
3.3.2.8	Check that upper 3 dB frequency = 52.727 to 53.257 KHz		
	Read decade box	R = ______ Ohms	
3.3.4.3	Calculate R3 =	$\frac{(R)(10.62K) + (446.9K)}{(937.5K) - R}$	

P/N 360014- 12 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)
Upper 3 db frequency = ______ KHz (f1)
Lower 3 db frequency = ______ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2) / (1.69 \text{ KHz})] (V1)$ = ______ V (V2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)
Lower 3 dB frequency = ______ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ______ KHz (f6)
Lower 3 dB frequency = ______ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 56.88 \text{ KHz})] / [(56.88 \text{ KHz})(f5 - f8)]$ = ______ turns (T)
Add (T-2) turns in = direction if f5 > 56.88 KHz
Add (T-2) turns in - direction if f5 < 56.88 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 56.041 KHz

3.3.2.8 Check that upper 3 dB frequency = 57.443 to 58.020 KHz
Read decade box R = ______ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.52K) + (305.1K)}{(9.474K) - R}$

REV.

P/N 360014- 13 Coil L 5

WORK SHEET

Ref. Para.		
3.3.2.2	Measure	Voltage at peak = ______ V (V1)
		Upper 3 db frequency = ______ KHz (f1)
		Lower 3 db frequency = ______ KHz (f2)
3.3.2.3	Calculate	[(f1 - f2) /(1.69 KHz)] (V1) = ______ V (V2)
	Set	Output meter to V2 volts by selecting resistor.
	Set	Voltage across coil to 0.5V RMS.
3.3.2.4	Measure	Upper 3 dB frequency = ______ KHz (f3)
		Lower 3 dB frequency = ______ KHz (f4)
	Calculate	$f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ______ KHz (f5)
3.3.2.5	Add 2 turns to coil in + direction.	
	Measure	Upper 3 dB frequency = ______ KHz (f6)
		Lower 3 dB frequency = ______ KHz (f)
	Calculate	$f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ______ KHz (f8)
3.3.2.6	Calculate [2(f8)(f5 - 61.62 KHz)] / [(61.62 KHz)(f5 - f8)] = ______ turns (T	
	Add (T-2) turns in - direction if f5 > 61.62 KHz	
	Add (T-2) turns in - direction if f5 < 61.62 KHz	
3.3.2.7	Select resistor for lower 3 dB frequency = 60.781 KHz	
3.3.2.8	Check that upper 3 dB frequency = 62.158 to 62.783 KHz	
	Read decade box	R = ______ Ohms
3.3.4.3	Calculate R3 =	$\frac{(R)(10.58K) + (39.52K)}{(9.418K) - R}$

P/N 360014- 14 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db Frequency = ____________ KHz (f1)

Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2) / (1.69\ KHz)]\ (V1)$ = ____________ V (V2)

Set Output meter to V2 volts by select ng resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____________ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 66.36\ KHz)] / [(66.36\ KHz)(f5 - f8)]$ = ____________ turns (T)

Add (T-2) turns in = direction if f5 > 66.36 KHz

Add (T-2) turns in - direction if f5 < 66.36 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 65.520 KHz

3.3.2.8 Check that upper 3 dB frequency = 66.874 to 67.546 KHz

Read decade box R = ____________ Ohms

3.3.4.3 Calculate R3 = $\frac{(R)(10.50K) + (280.5K)}{(9.498K) - R}$

P/N 360014- 15 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ______ V (V1)

Upper 3 db frequency = ______ KHz (f1)

Lower 3 db frequency = ______ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2)/(1.69\ \text{KHz})]\ (V1) =$ ______ V (V2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ______ KHz (f3)

Lower 3 dB frequency = ______ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ______ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ______ KHz (f6)

Lower 3 dB frequency = ______ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7) =$ ______ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 71.10\ \text{KHz})] / [(71.10\ \text{KHz})(f5 - f8)] =$ ______ turns (T)

Add (T-2) turns in + direction if f5 > 71.10 KHz

Add (T-2) turns in - direction if f5 < 71.10 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 70.260 KHz

3.3.2.8 Check that upper 3 dB frequency = 71.590 to 72.310 KHz

Read decade box R = ______ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.59K) + (284.6K)}{(9.416K) - R}$

REV.

P/N 360014- 16 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db frequency = ____________ KHz (f1)

Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $\left[(f1 - f2)\ /(1.69\ \text{KHz})\right]$ (V1) = ____________ V (V2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____________ KHz (f8)

3.3.2.6 Calculate $\left[2(f8)(f5 - 85.32\ \text{KHz})\right] / \left[(85.32\ \text{KHz})(f5 - f8)\right]$ = ____________ turns (T

Add (T-2) turns in + direction if f5 > 85.32 KHz

Add (T-2) turns in - direction if f5 < 85.32 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 84.479 KHz

3.3.2.8 Check that upper 3 dB frequency = 85.738 to 86.600 KHz

Read decade box R = ____________ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.40K) + (192.8K)}{(9.595K) - R}$

P/N 360014- 17 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db frequency = ____________ KHz (f1)

Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2)/(1.69\text{ KHz})](V1)$ = ____________ V (V2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____________ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 90.06\text{ KHz})] / [(90.06\text{ KHz})(f5 - f8)]$ = ____________ turns (T)

Add (T-2) turns in + direction if f5 > 90.06 KHz

Add (T-2) turns in - direction if f5 < 90.06 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 89.219 KHz

3.3.2.8 Check that upper 3 dB frequency = 90.454 to 91.364 KHz

Read decade box R = ____________ Ohms

3.3.4.3 Calculate R3 = $\dfrac{(R)(10.37K) + (122.9K)}{(9.636K) - R}$

P/N 360014- 17 ________ Coil L 5 ________

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)

Upper 3 db frequency = ____________ KHz (f1)

Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2) / (1.69\ \text{KHz})]\ (V1)$ = ____________ V (V2)

Set Output meter to V2 volts by selecting resistor.

Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)

Lower 3 dB frequency = ____________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____________ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 90.06\ \text{KHz})] / [(90.06\ \text{KHz})(f5 - f8)]$ = ____________ turns (T)

Add (T-2) turns in + direction if f5 > 90.06 KHz

Add (T-2) turns in - direction if f5 < 90.06 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 89.219 KHz

3.3.2.8 Check that upper 3 dB frequency = 90.454 to 91.364 KHz

Read decade box R = ____________ Ohms

3.3.4.3 Calculate R3 =

$$\frac{(R)(10.37K) + (122.9K)}{(9.636K) - R}$$

REV.

P/N 360014- 18 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ____________ V (V1)
Upper 3 db frequency = ____________ KHz (f1)
Lower 3 db frequency = ____________ KHz (f2)

3.3.2.3 Calculate $[(f1 - f2) / (1.69 \text{ KHz})] (V1)$ = ____________ V (V2)
Set Output meter to V2 volts by selecting resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ____________ KHz (f3)
Lower 3 dB frequency = ____________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ____________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ____________ KHz (f8)

3.3.2.6 Calculate $[2(f8)(f5 - 94.80 \text{ KHz})] / [(94.80 \text{ KHz})(f5 - f8)]$ = ____________ turns (T)
Add (T-2) turns in + direction if f5 > 94.80 KHz
Add (T-2) turns in - direction if f5 < 94.80 KHz

3.3.2.7 Select resistor for lower 3 dB frequency = 93.959 KHz

3.3.2.8 Check that upper 3 dB frequency = 95.171 to 96.127
Read decade box R = ____________ Ohms

3.3.4.3 Calculate $R3 = \dfrac{(R)(10.32K) + (146.3K)}{(9.672K) - R}$

P/N 360014- 19 Coil L 5

WORK SHEET

Ref. Para.

3.3.2.2 Measure Voltage at peak = ________ V (V1)
Upper 3 db frequency = ________ KHz (f1)
Lower 3 db frequency = ________ KHz (f2)

3.3.2.3 Calculate [(f1 - f2) /(1.69 KHz)] (V1) = ________ V (V2)
Set Output meter to V2 volts by select ng resistor.
Set Voltage across coil to 0.5V RMS.

3.3.2.4 Measure Upper 3 dB frequency = ________ KHz (f3)
Lower 3 dB frequency = ________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = ________ KHz (f5)

3.3.2.5 Add 2 turns to coil in + direction.
Measure Upper 3 dB frequency = ________ KHz (f6)
Lower 3 dB frequency = ________ KHz (f)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ = ________ KHz (f8)

3.3.2.6 Calculate [2(f8)(f5 - 99.54 KHz)] / [(99.54 KHz)(f5 - f8)] = ________ turns (T)
Add (T-2) turns in + direction if f5 > 99.54 KHz
Add (T-2) turns in - direction if f5 < 99.54

3.3.2.7 Select resistor for lower 3 dB frequency = 98.699 KHz

3.3.2.8 Check that upper 3 dB frequency = 99.887 to 100.891
Read decade box R = ________ Ohms

3.3.4.3 Calculate R3 =

$$\frac{(R)(10.30K) + (59.7K)}{(9.702K) - R}$$

REV.

WORK SHEET
(L2, L4)

P/N 360014- 2 ______ Coil L ______

Ref. Para.		
3.3.6.1	Measure	Voltage at lead 4 ____________ V (V1) Voltage at T.P. 4 ____________ V (V2)
3.3.6.2	Measure	Upper 3 dB frequency = __________ KHz (f1) Lower 3 dB frequency = __________ KHz (f2)
3.3.6.3	Calculate	(10.0K Ohms) / $1 + \frac{V1}{V2}\left(\frac{1.69\text{ KHz}}{f1 - f2} - 1\right) =$ ________ K Ohms (R_B)
	Set	Decade box to R_B
3.3.6.4	Measure	Upper 3 db frequency = __________ KHz (f3) Lower 3 db frequency = __________ KHz (f4)
	Calculate	$f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)
3.3.6.5	Add two turns in the positive direction.	
	Measure	Upper 3 dB frequency = __________ KHz (f6) Lower 3 dB frequency = __________ KHz (f7)
	Calculate	$f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________ KHz (f8)
3.3.6.6	Calculate	[2(f8)(f5 - 9.48KHz] / [(9.48KHz)(f5 - f8)] + ______ Turns (T)
	Add (T-2) turns in + direction if f5 > 9.48KHz	
	Add (T-2) turns in - direction if f5 < 9.48KHz	
3.3.6.7	Select resistor for lower 3 dB frequency = 8.693 KHz	
	Check that upper 3 dB frequency = 10.311 to 10.414KHz	
3.3.6.9	Read Decade box	R = ________ K Ohms

REV.

WORK SHEET
(L2, L4)

P/N 360014-3 Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)

Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)

Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}\left(\frac{1.62\ \text{KHz}}{f1 - f2} - 1\right)$ = ________ K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)

Lower 3 db frequency = __________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = ____________ KHz (f6)

Lower 3 dB frequency = ____________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________ KHz (f8)

3.3.6.6 Calculate $\left[2(f8)(f5 - 14.22\text{KHz})\right] / \left[(14.22\text{KHz})(f5 - f8)\right]$ + ______ Turns (T

Add (T-2) turns in + direction if f5 > 14.22 KHz

Add (T-2) turns in - direction if f5 < 14.22 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 13.400 KHz

Check that upper 3 dB frequency = 15.015 to 15.166 KHz

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-4 Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 __________V (V1)
Voltage at T.P. 4 __________V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________KHz (f1)
Lower 3 dB frequency = __________KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}\left(\frac{1.60\ \text{KHz}}{f1 - f2} - 1\right)$ = __________K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________KHz (f3)
Lower 3 db frequency = __________KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = __________KHz (f6)
Lower 3 dB frequency = __________KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7)$ __________KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 18.96\text{KHz})] / [(18.96\text{KHz})(f5 - f8)] +$ ______Turns (T)
Add (T-2) turns in + direction if f5 > 18.96 KHz
Add (T-2) turns in - direction if f5 < 18.96 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 18.134 KHz
Check that upper 3 dB frequency = 19.725 to 19.923 KHz

3.3.6.9 Read Decade box R = __________K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-5 Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)
Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)
Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / 1 + \frac{V1}{V2}(\frac{1.69\text{ KHz}}{f1 - f2} - 1) =$ ________ K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)
Lower 3 db frequency = __________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = ____________ KHz (f6)
Lower 3 dB frequency = ____________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________ KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 23.70\text{ KHz})] / [(23.70\text{ KHz})(f5 - f8)] +$ ______ Turns (T)
Add (T-2) turns in + direction if f5 > 23.70 KHz
Add (T-2) turns in - direction if f5 < 23.70 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 22.87 KHz
Check that upper 3 dB frequency = 24.437 to 24.685

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

WORK SHEET
(L2, L4)

P/N 360014-6 Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)
Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)
Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / \ 1 + \frac{V1}{V2}\left(\frac{1.69\text{ KHz}}{f1 - f2} - 1\right) =$ ________ K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)
Lower 3 db frequency = __________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = ___________ KHz (f6)
Lower 3 dB frequency = ___________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________ KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 28.44\text{KHz})] / [(28.44\text{KHz})(f5 - f8)] +$ ______ Turns (T)
Add (T-2) turns in + direction if f5 > 28.44 KHz
Add (T-2) turns in - direction if f5 < 28.44 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 27.608 KHz
Check that upper 3 dB frequency = 29.151 to 29.444 KHz

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-7____ Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ________ V (V1)

Voltage at T.P. 4 ________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = ________ KHz (f1)

Lower 3 dB frequency = ________ KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / \left(1 + \frac{V1}{V2}\left(\frac{1.69\text{ KHz}}{f1 - f2}\right) - 1\right) =$ ________ K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = ________ KHz (f3)

Lower 3 db frequency = ________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = ________ KHz (f6)

Lower 3 dB frequency = ________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ ________ KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 33.18\text{kHz})] / [(33.18\text{KHz})(f5 - f8)] +$ ____ Turns (T)

Add (T-2) turns in + direction if f5 > 33.18

Add (T-2) turns in - direction if f5 < 33.18

3.3.6.7 Select resistor for lower 3 dB frequency = 32.346 KHz

Check that upper 3 dB frequency = 33.866 to 34.206

3.3.6.9 Read Decade box R = ________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-B ________ Coil L ________

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ________ V (V1)
Voltage at T.P. 4 ________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = ________ KHz (f1)
Lower 3 dB frequency = ________ KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / 1 + \frac{V1}{V2}(\frac{1.69\text{ KHz}}{f1 - f2} - 1) =$ ________ K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = ________ KHz (f3)
Lower 3 db frequency = ________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = ________ KHz (f6)
Lower 3 dB frequency = ________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ ________ KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 37.92\text{ KHz})] / [(37.92\text{ KHz})(f5 - f8)] +$ ________ Turns (T)
Add (T-2) turns in + direction if f5 > 37.92 KHz
Add (T-2) turns in - direction if f5 < 37.92 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 37.084 KHz
Check that upper 3 dB frequency = 38.581 to 38.968 KHz

3.3.6.9 Read Decade box R = ________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-9______ Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 __________V (V1)
Voltage at T.P. 4 __________V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________KHz (f1)
Lower 3 dB frequency = __________KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}\left(\frac{1.60\ KHz}{f1 - f2} - 1\right)$ = ________K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________KHz (f3)
Lower 3 db frequency = __________KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = __________KHz (f6)
Lower 3 dB frequency = __________KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 42.65\ KHz)] / [(42.66\ KHz)(f5 - f8)] +$ ______Turns (T)
Add (T-2) turns in + direction if f5 > 42.66 KHz
Add (T-2) turns in - direction if f5 < 42.66 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 41.823 KHz
Check that upper 3 dB frequency = 43.296 to 43.731

3.3.6.9 Read Decade box R = __________K Ohms

REV.

WORK SHEET
(1.2, 1.4)

P/N 360014-*10*________ Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________V (V1)
Voltage at T.P. 4 ____________V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________KHz (f1)
Lower 3 dB frequency = __________KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}(\frac{1.60\ KHz}{f1 - f2} - 1)$ = ________K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________KHz (f3)
Lower 3 db frequency = __________KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(3f4)$ = __________KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = __________KHz (f6)
Lower 3 dB frequency = __________KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7)$ __________KHz (f8)

3.3.6.6 Calculate [2(f8)(f5 - *47.40 KHz*)] / [(*47.40 KHz*)(f5 - f8)] + ______Turns (T
Add (T-2) turns in + direction if f5 > *47.40 KHz*
Add (T-2) turns in - direction if f5 < *47.40 KHz*

3.3.6.7 Select resistor for lower 3 dB frequency = *46.563* KHz
Check that upper 3 dB frequency = *48.011 to 48.494 KHz*

3.3.6.9 Read Decade box R = __________K Ohms

REV.

WORK SHEET (L2,L4) P/N 360014-*11* Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)
Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz ($f1$)
Lower 3 dB frequency = __________ KHz ($f2$)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}(\frac{1.60\text{ KHz}}{f1 - f2} - 1)$ = ________ K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz ($f3$)
Lower 3 db frequency = __________ KHz ($f4$)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(3f4)$ = __________ KHz ($f5$)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = __________ KHz ($f6$)
Lower 3 dB frequency = __________ KHz ($f7$)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7)$ __________ KHz ($f8$)

3.3.6.6 Calculate $[2(f5)(f5 - 52.14\text{KHz})] / [(52.14\text{KHz})(f5 - f8)] +$ ______ Turns (T
Add (T-2) turns in + direction if f5 > *52.14 KHz*
Add (T-2) turns in - direction if f5 < *52.14 KHz*

3.3.6.7 Select resistor for lower 3 dB frequency = *51.302* KHz
Check that upper 3 dB frequency = *52.727 to 53.257 KHz*

3.3.6.8 Read Decade box R' = __________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-12____ Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 __________ V (V1)
Voltage at T.P. 4 __________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)
Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / 1 + \frac{V1}{V2}\left(\frac{1.69\text{ KHz}}{f1 - f2} - 1\right) =$ ________ K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)
Lower 3 db frequency = __________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = __________ KHz (f6)
Lower 3 dB frequency = __________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7)$ __________ KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 56.88\text{kHz})] / [(56.88\text{KHz})(f5 - f8)] +$ _____ Turns (T
Add (T-2) turns in + direction if f5 > 56.86 KHz
Add (T-2) turns in - direction if f5 < 56.88 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 56.041 KHz
Check that upper 3 dB frequency = 57.443 to 58.020 KHz

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

WORK SHEET
(L2, L4)

P/N 360014-*13* ______ Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)

Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)

Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / \left(1 + \frac{V1}{V2}\left(\frac{1.69\text{ KHz}}{f1 - f2} - 1\right)\right) =$ ________ K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)

Lower 3 db frequency = __________ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = __________ KHz (f6)

Lower 3 dB frequency = __________ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________ KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 61.62\text{ KHz})] / [(61.62\text{ KHz})(f5 - f8)] +$ ______ Turns (T)

Add (T-2) turns in + direction if f5 > *61.62 KHz*

Add (T-2) turns in - direction if f5 < *61.62 KHz*

3.3.6.7 Select resistor for lower 3 dB frequency = *60.781* KHz

Check that upper 3 dB frequency = *62.158 to 62.783 KHz*

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-14 Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________V (V1)
Voltage at T.P. 4 ____________V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________KHz (f1)
Lower 3 dB frequency = __________KHz (f2)

3.3.6.3 Calculate $(10.0\text{K Ohms}) / 1 + \frac{V1}{V2}(\frac{1.69\text{ KHz}}{f1 - f2} - 1) =$ ________K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = ___________KHz (f3)
Lower 3 db frequency = ___________KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ __________KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = ___________KHz (f6)
Lower 3 dB frequency = ___________KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________KHz (f8)

3.3.6.6 Calculate $[2(f8)(f5 - 66.36\text{KHz})] / [(66.36\text{KHz})(f5 - f8)] +$ _____Turns (T)
Add (T-2) turns in + direction if f5 > 66.36 KHz
Add (T-2) turns in - direction if f5 < 66.36 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 65.520 KHz
Check that upper 3 dB frequency = 65.874 to 67.546 KHz

3.3.6.9 Read Decade box R = __________K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-15 Coil L ______

Ref. Para.

3.3.6.1 **Measure** Voltage at lead 4 ______ V (V1)

Voltage at T.P. 4 ______ V (V2)

3.3.6.2 **Measure** Upper 3 dB frequency = ______ KHz (f1)

Lower 3 dB frequency = ______ KHz (f2)

3.3.6.3 **Calculate** $(10.0\text{K Ohms}) / 1 + \frac{V1}{V2}(\frac{1.60\text{ KHz}}{f1 - f2} - 1) =$ ______ K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 **Measure** Upper 3 db frequency = ______ KHz (f3)

Lower 3 db frequency = ______ KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4) =$ ______ KHz (f5)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = ______ KHz (f6)

Lower 3 dB frequency = ______ KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(3f7)$ ______ KHz (f8)

3.3.6.6 **Calculate** $[2(f8)(f5 - 71.10\text{KHz})] / [(71.10\text{KHz})(f5 - f8)] +$ ______ Turns (T)

Add (T-2) turns in + direction if f5 > 71.10 KHz

Add (T-2) turns in - direction if f5 < 71.10 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 70.260 KHz

Check that upper 3 dB frequency = 71.590 to 72.310 KHz

3.3.6.9 Read Decade box R = ______ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-*16* Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)
Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)
Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}(\frac{1.69\ \text{KHz}}{f1 - f2} - 1)$ = ________ K Ohms (R_B)
Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)
Lower 3 db frequency = __________ KHz (f4)
Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.
Measure Upper 3 dB frequency = __________ KHz (f6)
Lower 3 dB frequency = __________ KHz (f7)
Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________ KHz (f8)

3.3.6.6 Calculate [2(f8)(f5 -*85.32KHz*)] / [(*85.32kHz*)(f5 - f8)] + ______ Turns (T)
Add (T-2) turns in + direction if f5 > *85.32 KHz*
Add (T-2) turns in - direction if f5 < *85.32 KHz*

3.3.6.7 Select resistor for lower 3 dB frequency = *84.479* KHz
Check that upper 3 dB frequency = *85.738 to 86.600 KHz*

3.3.6.9 Read Decade box R = __________ K Ohms

WORK SHEET
(L2,L4)

P/N 360014-17 Coil L ____

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 __________V (V1)

Voltage at T.P. 4 __________V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________KHz (f1)

Lower 3 dB frequency = __________KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / $1 + \frac{V1}{V2}\left(\frac{1.69\ \text{KHz}}{f1 - f2} - 1\right)$ = ________K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________KHz (f3)

Lower 3 db frequency = __________KHz (f4)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/(8f4)$ = __________KHz (f5)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = __________KHz (f6)

Lower 3 dB frequency = __________KHz (f7)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/(8f7)$ __________KHz (f8)

3.3.6.6 Calculate [2(f8)(f5 -90.06KHz)] / [(90.06KHz)(f5 - f8)] + ______Turns (T)

Add (T-2) turns in + direction if f5 > 90.06 KHz

Add (T-2) turns in - direction if f5 < 90.06 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 89.219 KHz

Check that upper 3 dB frequency = 90.454 to 91.364 KHz

3.3.6.9 Read Decade box R = __________K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-18 ______ Coil L ______

Ref. Para.

3.3.6.1 Measure Voltage at lead 4 ____________ V (V1)

Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 Measure Upper 3 dB frequency = __________ KHz (f1)

Lower 3 dB frequency = __________ KHz (f2)

3.3.6.3 Calculate (10.0K Ohms) / 1 + $\frac{V1}{V2}(\frac{1.67\ KHz}{f1 - f2}$ - 1) = ________ K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 Measure Upper 3 db frequency = __________ KHz (f3)

Lower 3 db frequency = __________ KHz (f4)

Calculate f4 + (f3 - f4)/2 - $(f3 - f4)^2$/(9f4) = __________ KHz (f5)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = __________ KHz (f6)

Lower 3 dB frequency = __________ KHz (f7)

Calculate f7 + (f6 - f7)/2 - $(f6 - f7)^2$/(-f7) __________ KHz (f[illegible])

3.3.6.6 Calculate [2(f8)(f5 - 94.80kHz] / [(94.80kHz)(f5 - f3)] + ______ Turns (T)

Add (T-2) turns in + direction if f5 > 94.80 KHz

Add (T-2) turns in - direction if f5 < 94.80 kHz

3.3.6.7 Select resistor for lower 3 dB frequency = 93.959 KHz

Check that upper 3 dB frequency = 95.171 to 96.127 KHz

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

WORK SHEET
(L2,L4)

P/N 360014-19 Coil L ____

Ref. Para.

3.3.6.1 **Measure** Voltage at lead 4 ____________ V (V1)

Voltage at T.P. 4 ____________ V (V2)

3.3.6.2 **Measure** Upper 3 dB frequency = __________ KHz ($f1$)

Lower 3 dB frequency = __________ KHz ($f2$)

3.3.6.3 **Calculate** $(10.0\text{K Ohms}) / 1 + \frac{V1}{V2}\left(\frac{1.69\text{ KHz}}{f1 - f2} - 1\right) =$ ________ K Ohms (R_B)

Set Decade box to R_B

3.3.6.4 **Measure** Upper 3 db frequency = __________ KHz ($f3$)

Lower 3 db frequency = __________ KHz ($f4$)

Calculate $f4 + (f3 - f4)/2 - (f3 - f4)^2/($[illegible]$f4) =$ __________ KHz ($f5$)

3.3.6.5 Add two turns in the positive direction.

Measure Upper 3 dB frequency = ____________ KHz ($f6$)

Lower 3 dB frequency = ____________ KHz ($f7$)

Calculate $f7 + (f6 - f7)/2 - (f6 - f7)^2/($[illegible]$f7)$ __________ KHz (f)

3.3.6.6 **Calculate** $\left[2(f8)(f5 - 99.54\text{kHz})\right] / \left[(99.54\text{KHz})(f5 - f8)\right] +$ ______ Turns (T)

Add (T-2) turns in + direction if $f5 >$ 99.54 KHz

Add (T-2) turns in - direction if $f5 <$ 99.54 KHz

3.3.6.7 Select resistor for lower 3 dB frequency = 98.699 KHz

Check that upper 3 dB frequency = 99.887 to 100.691 KHz

3.3.6.9 Read Decade box R = __________ K Ohms

REV.

P/N 360014-________ Coil 2
Tap 2

WORK SHEET

Ref. Para.

3.4.2.2 Measure

Upper peak frequency = ________KHz (f1)

Lower peak frequency = ________KHz (f2)

Calculate frequency difference: f1 - f2 = ________KHz (f3)

Add turns in + direction if f3< 8.2036 KHz

Add turns in - direction if f3> 8.2036 KHz

P/N 360014-________ Coil 2
Tap 3

WORK SHEET

Ref. Para.

3.4.2.2 Measure

Upper peak frequency = ________KHz (f1)

Lower peak frequency = ________KHz (f2)

Calculate frequency difference: f1 - f2 = ________KHz (f3)

Add turns in + direction if f3< 4.7710 KHz

Add turns in - direction if f3> 4.7710 KHz

P/N 360014-________ Coil 4
Tap 2

WORK SHEET

Ref. Para.

3.4.2.2 Measure Upper peak frequency = ________KHz (f1)
Lower peak frequency = ________KHz (f2)
Calculate frequency difference: f1 - f2 = ________KHz (f3)
Add turns in + direction if f3< 5.4402 KHz
Add turns in - direction if f3> 5.4402 KHz

REV.

P/N 360014-______ Coil 4
Tap 3

WORK SHEET

Ref. Para.

3.4.2.2 Measure

Upper peak frequency = ______KHz (f1)

Lower peak frequency = ______KHz (f2)

Calculate frequency difference: f1 - f2 = ______KHz (f3)

Add turns in + direction if f3< 9.2267 KHz

Add turns in - direction if f3> 9.2267 KHz

REV.	ISSUE DATE	PAGE	PARA.	DESCRIPTION OF CHANGE	AUTHORIZATION
A		5	3.3.3.3	Change wording in third sentence to read as follows: "Move the test lead from lead 2 of L3 to test point E."	Typographical error.
A		9	3.4.1	Change Lead 2 to Lead 3	Typographical error.
A		3	3.3.2.3	Add "at the peak frequency."	Clarification
A		10	3.4.4	Change T.P. 2 to T.P. 3	Typographical error.

APPENDIX C

FORM 821-E

AVCO ELECTRONICS DIVISION
CINCINNATI, OHIO 45241
CODE IDENT. NO. 80045

NO. E S 150.002
REV.
PAGE NO. 1 OF

REV. FOR ISSUE DATE, SUPERSEDED ISSUE DATES AND CHANGE NOTICE NUMBERS, SEE THE REVISION RECORD PAGE.

PROTOTYPE
TEST PROCEDURE
FOR
SS/DSB MULTIPLEXER

AED No. 360000

DATA RECORD ES 150.003

Prepared by________________________ __________

Reviewed by________________________ __________

Approved by________________________ __________

TABLE OF CONTENTS

REV.

1.0 Introduction

The purpose of this document is to define tests to be conducted on the prototype unit to demonstrate the degree to which the SS/DSB Multiplexer conforms to NASA Specification 110114A.

Sections 1.0 thru 7.0 define these tests and refer to Data Sheet ES 150.003 for recording the results. Section 8.0 diagrams the location of the test points.

2.0 Power Supply

2.1.1 Purpose - To verify that the power supply is functioning in the system.

2.1.2 Test Equipment Required

(a) Multiplexer with all cards inserted.

(b) Power supply 28 Vdc/4 A.

(c) Voltmeter

(d) Oscilloscope

2.1.3 Bench Setup

See Figure 1.

2.1.4 Test

(a) Apply 28 Vdc to the Multiplexer. With the VTVM measure the voltage between the testpoints shown on the chart below. If the readings are not as shown adjust R16 for +5.0V, and thereafter R13 and R15 for ±13.0V.

TP9 to TP10 = +5.0V
TP8 to TP11 = +13.0V
TP7 to TP11 = -13.0V

(b) Adjust the input voltage to 23.8 Vdc and record the voltage at the same test points.

(c) Adjust the input voltage to 32.2 Vdc and record the voltage at the same test points.

(d) Measure and record the peak-to-peak value of the ripple and the spikes with the oscilloscope.

2.2.0 System Isolation

2.2.1 Purpose - To insure mutual isolation between system ground, chassis, power return and calibration return.

2.2.2 Equipment Required

(a) Nulling Voltmeter (Fluke)

(b) Power supply (50VDC)

(c) Multiplexer (all PC cards installed)

(d) Resistor, 100K ± 1%

2.2.3 Bench Setup

(a) Connect the equipment as shown in Figure 2.

2.2.4 Test

(a) Read and record the three voltmeter readings.

(b) The values read on the VTVM shall not exceed 0.1 Vdc.

2.3.0 Power Drain

2.3.1 Purpose - To verify that the Multiplexer operates within the input current limits.

2.3.2 Test Equipment

(a) 28 Vdc supply

(b) Multiplexer (All cards inserted)

(c) DC ammeter (2 amp)

2.3.3 Bench Setup

(a) Connect the equipment as shown in Figure 3.

(b) Set the power supply to 28 ± 1 Vdc.

2.3.4 Test

(a) Read and record the line current.

3.0 Carrier Generation Modules

3.1 Purpose - To check and adjust the phase between sub-carriers generated in different divider-chains.

3.2 Test Equipment

(a) Multiplexer

(b) Power-supply 28 Vdc

(c) Oscilloscope

3.3 Bench Setup

(a) See Figure 4.

(b) Connect one input of the scope to the reference signal, 12F in the T-CXO-counter, pin C on the connector for Module 8.

3.4 Test

(a) Connect the second scope input to 6F in the VCO-counter under test, Module 9, T.P. 2.

(b) Adjust C15 on the adjacent VCO-card (Module 3) until the time difference between the positive going edges of the two signals is less than 40 ns. Record the resultant time difference.

(c) Repeat (a) and (b) for the other two VCO-divider-chains. (Module 10, T.P. 2 and Module 11, T. P. 2)

4.0 Channel and IF Modules

4.1.0 Input Impedance and Back Current of Channel Units

4.1.1 Purpose - To verify the input impedance is 100K ohms and that the back current is not in excess of 1 microamp.

4.1.2 Test Equipment

(a) Differential VTVM

(b) VTVM H.P.

(c) Resistors, 100K ± .1%; 10K ± 5%

(d) Multiplexer with all cards inserted.

(e) Audio oscillator

(f) Power supply 28 Vdc

4.1.3 Bench Setup Input Impedance

See Figure 5.

4.1.4 Test

(a) Place the 100K resistor in series with the audio oscillator and the channel input under test.

(b) With the power on set the output of the audio oscillator at 1.5 ± .1 kHz and 2.0 Vrms. Measure and record the voltage across the 100K resistor.

(c) Measure the input at the channel card. The reading taken at this point shall be within ± .5% of that read in (b) above.

(d) Repeat (a) through (c) for each channel.

4.1.5 Bench Setup-Back Current

See Figure 6.

4.1.6 Test

(a) Apply 2.5 Vpp at 1.5 kHz to the 18 channel inputs not under test. Measure and record the AC and DC components across the 10K resistor across the input of the channel under test.

(b) Repeat (a) for all channels.

4.2.0 Data Source Faults

4.2.1 Purpose - To verify that each channel input shall accept a signal up to 5.0 Vpp and no data loss shall occur upon application of 15.0 Vpp.

4.2.2 Test Equipment

(a) Spectrum Analyzer

(b) Multiplexer (DSB-IF filters inserted)

(c) 28 Vdc power supply

(d) Resistors 3000 Ohm ± 1% 1500 Ohm ± 1%

4.2.3 Bench Setup

(a) Connect the equipment as shown in Figure 7.

(b) Set the audio oscillator output for 1.5 kHz, 15.0 Vpp using a H.P. 410 B or equivalent.

4.2.4 Test

(a) With the switch in the 5 volt position observe the spectrum of the system output.

(b) Put the switch in the 15 volt position for 20 seconds. Only one channel in the spectrum should be affected.

(c) Return the switch to the 5 volt position

(d) At 5 seconds after step (c) record that the output spectrum is identical to that of (a).

(e) Repeat (a) through (d) for all channels.

4.3.0 Amplitude Level Linearity

4.3.1 Purpose - To check the amplitude linearity and verify the sideband amplitude symmetry of each channel unit.

4.3.2 Test Equipment

(a) Multiplexer (One DSB-IF filter inserted)

(b) Power supply 28 Vdc.

(c) Audio osc.

(d) VTCM

(e) SSB-IF filter

(f) Wave-Analyzer

4.3.3 Bench Setup

(a) See Figure 8.

(b) Set audio osc. to 15oo Hz.

(c) Set the wave analyzer to a band-width of 200 Hz.

4.3.4 Test

(a) Read and record the level of both sidebands at the output of the channel unit under test with audio oscillator settings of .05, .1, .2, .4, .8, 1.6 Vrms. Calculate the gain and the average of the gain. Maximum divergence from this average shall be less than .1db.

(b) Replace the DSB-IF filter with an SSB-IF filter and make the same measurement.

(c) Repeat (a) and (b) for each channel.

4.4 Amplitude Spectral Linearity

4.4.1 Purpose - To verify that the channel ripple is less than .1 dB.

4.4.2 Test Equipment

(a) Wave analyzer

(b) Multiplexer (SSB-IF filters)

(c) Power supply 28 Vdc.

(d) Audio Oscillator

(e) VTVM

4.4.3 Bench Setup

(a) Connect the equipment as shown in Figure 9.

(b) Set the oscillator to 2.5 ± .01 Vpp and apply to the channel input under test.

4.4.4 Test

(a) With the wave analyzer (20 Hz bandwidth) read and record the channel output amplitude at the system output with audio oscillator setting of 10, 30, 2780 and 3000 Hz.

(b) Sweep the oscillator from 10 to 3000 Hz and with the wave analyzer (200 Hz bandwidth) read and record all the peaks and valleys at the system output.

(c) Remove all IF filters and insert one DSB-IF filter in the channel to be tested. Repeat (a) and (b), but sweep from DC to 3000 Hz.

4.5.0 Absolute and Relative Time Delay

4.5.1 Purpose - To test the time delay in each channel and the time-correlation from channel to channel.

4.5.2 Test Equipment

(a) Multiplexer (DSB-IF filters inserted)

(b) Power supply 28 Vdc.

(c) Audio oscillator

(d) Op. amp.

(e) Freq. compensating network for Op. amp.

(f) Oscilloscope (Dual Beam)

4.5.3 Bench Setup

(a) See Figure 10.

(b) Connect the output from the Schmitt trigger to the oscilloscope vertical input, which has a time base unit with a delayed trigger output. Connect it as well to the trigger input of this time base unit and set for external triggering. The oscilloscope delayed trigger output should be connected to the trigger input of the second time base unit. Connect the output of the channel under test to the other vertical input (B).

4.5.4 Test

(a) Set the oscillator to 1000 Hz, 2 Vpp and adjust the delayed trigger for coincident zero-crossovers of the two signals. Use the same time/cm. for both beam sweeps.

(b) Vary the input frequency and measure the maximum time difference between the two zero crossovers. It shall be less than 5 us.

(c) Repeat (a) and (b) for all channels.

(d) Repeat (a) for channel 19

(e) Without changing the delayed trigger, connect the other 18 channels, one at a time, and record the time difference between zero crossings on the scope. The time difference shall be less than 2.3 microseconds for each channel and no channel shall differ by more than 2.3 us from any other channel.

5.0 AGC Modules

5.1.0 Attack/Recovery Time and Input Range

5.1.1 Purpose - To measure the attack and recovery time of the AGC and the AGC-input range.

5.1.2 Test Equipment

(a) Oscillator, Audio

(b) Oscillator, Square Wave

(c) Power Supply, 28 Vdc.

(d) Multiplexer

(e) Test card (See Figure 11).

(f) Oscilloscope

5.1.3 Bench Setup Attack & Recovery Time

(a) Remove the calibration card (Module 7) and insert the test card

(b) Make the necessary connections as shown in Figure 11. Connect the square wave generator to the test card and set it to 100 Hz, 5 Vpp squarewave and set the Audio-Osc. to 1000 Hz., 5 Vpp sinewave.

5.1.4 Test

Read and record the attack and recovery time at 90% of the steady state level, as defined in Figure 11 b

5.1.5 Bench Setup - AGC-range

Disconnect the square wave generator and instead switch the input manually between 0 and +3V with a power-supply.

5.1.6 Test

Read and record the difference in output level. It shall be less than .4 db.

5.2. Relative Data Output Levels and Harmonics Suppression

5.2.1 Purpose - To verify the proper functioning of all channels and summing amplifiers, and the suppression of the harmonics.

5.2.2 Test Equipment

(a) Wave Analyzer

(b) Power supply, 28 Vdc

(c) Multiplexer (all cards inserted)

(d) Audio oscillator

(e) High Impedance Voltmeter

(f) Counter, electronic

5.2.3 Bench Setup

(a) See Figure 9. SSB-IF filters inserted.

(b) Set audio oscillator output at 2.5 ± .05 Vpp, 1000 ± 100 Hz and apply to all channel inputs.

5.2.4 Test

(a) Pilot amplitude - With the wave analyzer (200 Hz bandwidth) read and record the two pilot outputs. Use a counter to check the frequency. The amplitude of the lower frequency pilot tone (P1) shall be 6 ±0.5 dB greater than the high frequency pilot tone (P2).

(b) Relative channel level - With the wave analyzer (200 Hz bandwidth) read and record the output of each channel at the system output 1. Use a counter to check the frequency. The difference between the amplitude of each channel and P2 shall be less than 0.5 dB.

(c) Harmonics and spurious outputs - With the wave analyzer (200 Hz bandwidth) read and record the amplitude of the harmonics and spurious outputs. All these outputs shall be down 42 dB minimum with respect to the regular channel outputs measured in (b).

(d) Remove all IF filters and insert DSB-IF filters. Repeat (a) through (c).

5.3.0 AGC Tracking and Channel Intermodulation

5.3.1 Purpose - To check the AGC tracking of the pilot tone and to measure the intermodulation between channels.

5.3.2 Test Equipment

(a) Multiplexer (with SSB-IF filters inserted)
(b) Power Supply, 28 Vdc.
(c) Audio Oscillator
(d) Gausian, White Noise Generator
(e) VTVM
(f) Wave Analyzer

5.3.3 Bench Setup

See Figure 12.

5.3.4 Tests

(a) Set the audio oscillator to 1500 ± 100 Hz, 2.5 ± .1 Vpp sinewave and connect it to the input of the channel under test. Set the noise generator to 2.5 ± .1 Vpp, 0 to 3 kHz bandwidth and connect it to the remaining channels.

(b) With the wave-analyzer (200 Hz bandwidth) read and record the output of the channel under test and the amplitude of the pilot tone (75.84 kHz) at system output 1.

(c) Remove the noise from the other channels and repeat step (b).

(d) The change in difference between channel output amplitude and pilot tone amplitude as measured in steps (b) and (c) shall be less than .25 db.

(e) Reset the audio oscillator output to 5.0 ± 0.1 Vpp on the channel being measured and apply 2.5 ± 0.1 Vpp noise on all remaining channels.

(f) Tune the wave analyzer to cover the 3 kHz bandwidth directly above the channel carrier frequency. Record the channel output amplitude.

(g) Disconnect the audio oscillator. Read and record the channel output amplitude. The difference between reading of steps (f) and (g) shall be 45 db minimum.

(h) Repeat (a) through (g) for each channel.

(i) Remove the IF-filters. Insert DSB-IF filters for channels 1,3,5,7,9,11,15,17, and 19 only. Remove all other channel boards. Repeat (a) through (h). In (f) use a bandwidth of 6 kHz centered at the channel carrier frequency.

6.0 Auxiliary Modules

6.1.0 Special Service Channel

6.1.1 Purpose - To verify the response of the special service channel.

6.1.2 Test Equipment Required

(a) Audio oscillator
(b) Multiplexer
(c) Power supply 28 Vdc
(d) VTVM (H.P. 410 B)
(e) Counter
(f) Wave Analyzer

6.1.3 Bench Setup

(a) Figure 12.

6.1.4 Test

(a) With an input of 2.5 ± .05 Vpp at 1 kHz to the special service channel input, measure the system output at J2/E with the wave analyzer. It shall be attenuated less than 3 dB.

(b) With an input of 2.5 ± .05 Vpp sweep the frequency from 10 to 1000 Hz and measure the peaks and the valleys at the channel output. The differences in output shall not be more than 3 dB

6.2.0 Calibration and Signal Input Interruption

6.2.1 Purpose - To verify proper operation of calibration circuitry.

6.2.2 Test Equipment

(a) Square Wave Generator
(b) Power supply, 28 Vdc
(c) Voltmeter, High Impedance
(d) Wave analyzer
(e) Oscilloscope
(f) Multiplexer
(g) Frequency Counter

6.2.3 Bench Setup - Calibration Command

(a) Connect the equipment as shown in Figure 14.

(b) Set the square wave generator to 1 Hz and 28 Vpp.

6.2.4 Test

(a) Read and record the burst duration of the 400 Hz calibration signal at TP2 on cards 14/1-19. It shall be the same on each channel module.

(b) Read and record the peak-to-peak voltage of the command signal at which the calibration signal disappears, by decreasing the square wave amplitude. It shall be less than 14 V, more than 10 V.

6.2.5 Bench Setup

(a) Connect the equipment as shown in Figure 15.

6.2.6 Test

(a) Read and record amplitude and frequency of the calibration signal. If the amplitude is not .161 Vpp ± 1% adjust R7 on card Cd7. Read and record the second (800 Hz) and third (1200 Hz) harmonics. They should be at least 45 dB down compared to the fundamental (400 Hz).

7.0 Output Impedance and Output Amplitude

7.1 Purpose - To verify that the dynamic Multiplexer output impedance is 300 Ohms maximum with a channel input frequency of 1000 Hz, and that is possible to adjust the output amplitude from 250 to 350 mV rms, driving a load of 4K in parallel with .035 uf.

7.2 Test Equipment

(a) Audio oscillator
(b) Power supply, 28 Vdc
(c) VTVM
(d) Resistors; 300 Ohms ± 1%, 4K ± 5%.
(e) Multiplexer (all cards inserted, DSB-IF filters)
(f) Capacitor .035 uf ± 10%

7.3 Bench Setup

(a) Connect the equipment as shown in Figure 16. Ground the input to the special service channel.

(b) Set the audio oscillator to 2.5 Vpp, 1000 Hz and apply it in common to all channel inputs.

7.4 Test

(a) Record the output voltage (E_{nl}) with S1 and S2 open.

(b) Record the output voltage (E_1) with the load resistor R_1 (S_1 closed).

(c) Calculate the output impedance using the following formula:

$$Z_0 = \frac{R_1 \ (E_{n\,1} - E_1)}{E_1}$$

(d) Repeat (a) through (c) for output 2 (J2/c)

(e) Open switch S1 and close S2, Read and record the maximum and minimum output amplitude when varying R9 on Module 12. Set R9 for an output of 300 mVrms.

(f) Study the output on the scope. Disconnect the load. No appreciable difference shall be noticed.

(g) Repeat (e) and (f) for output 2, but use R27 instead of R9 for varying the output level.

8.0 Testing Diagrams

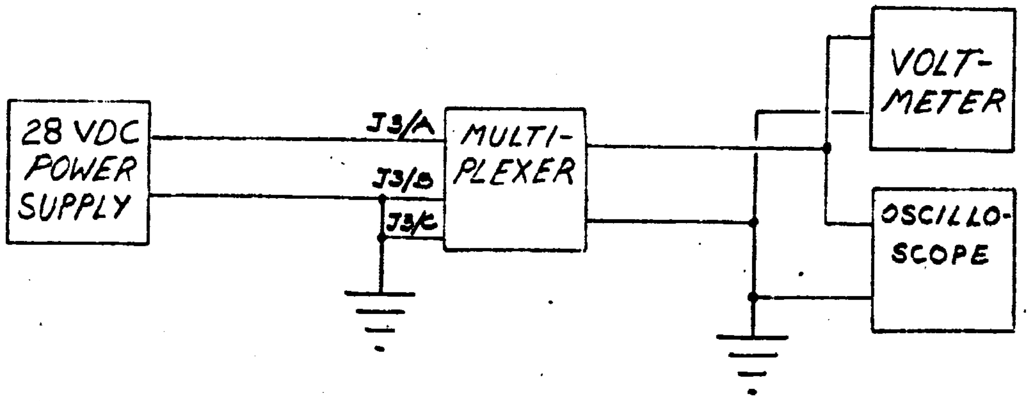


FIG. 1 POWER SUPPLY TEST

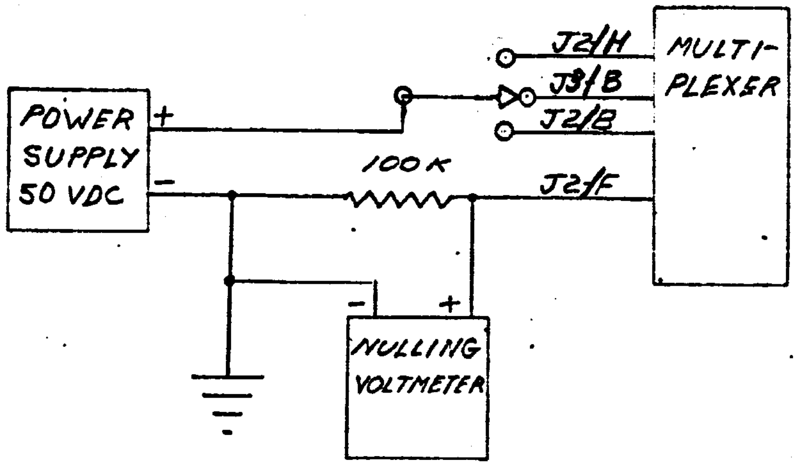


FIG. 2 CHASSIS ISOLATION

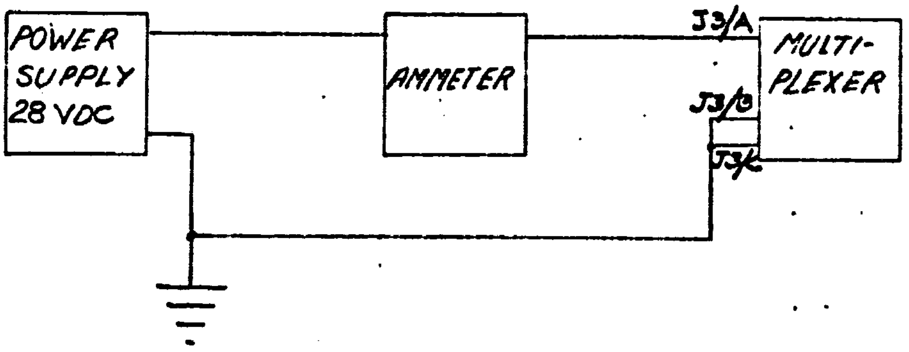


FIG. 3 POWER DRAIN

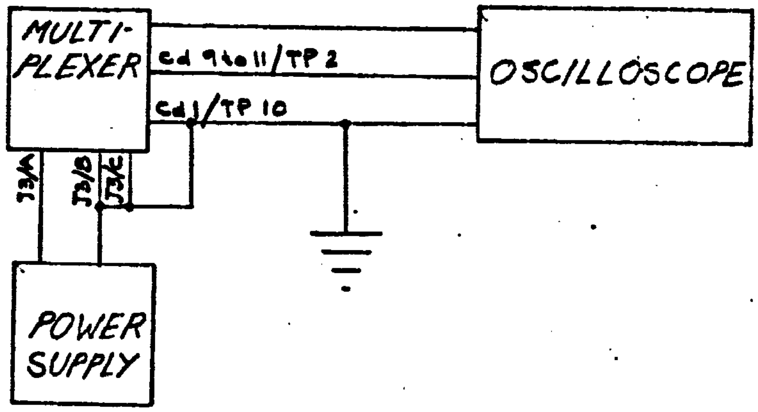


FIG. 4 SUB-CARRIER GENERATION

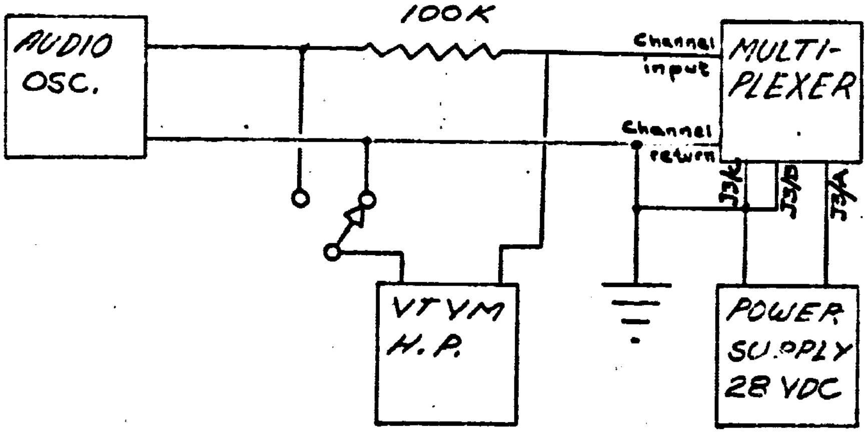


FIG. 5 INPUT IMPEDANCE

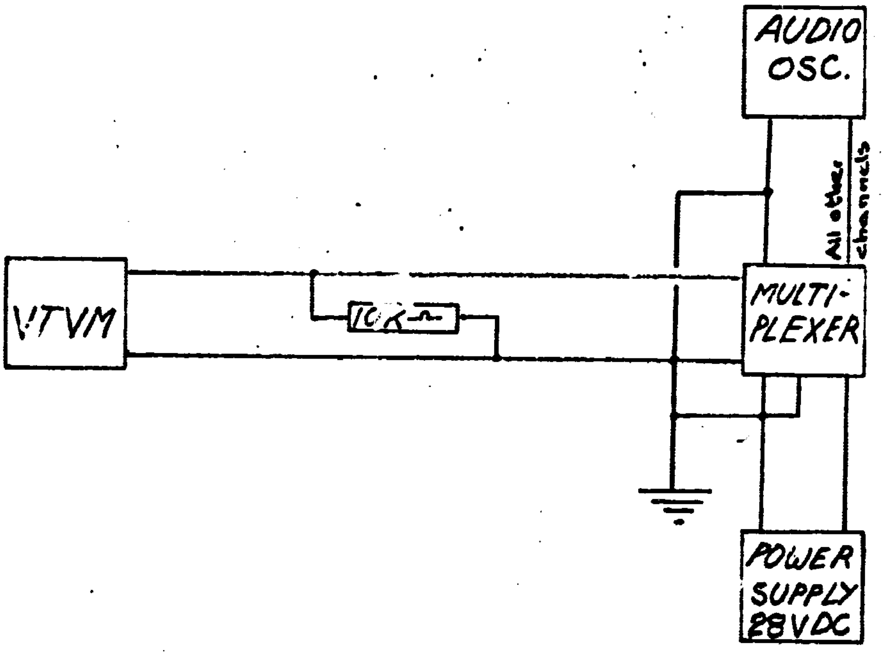


FIG. 6 BACK CURRENT

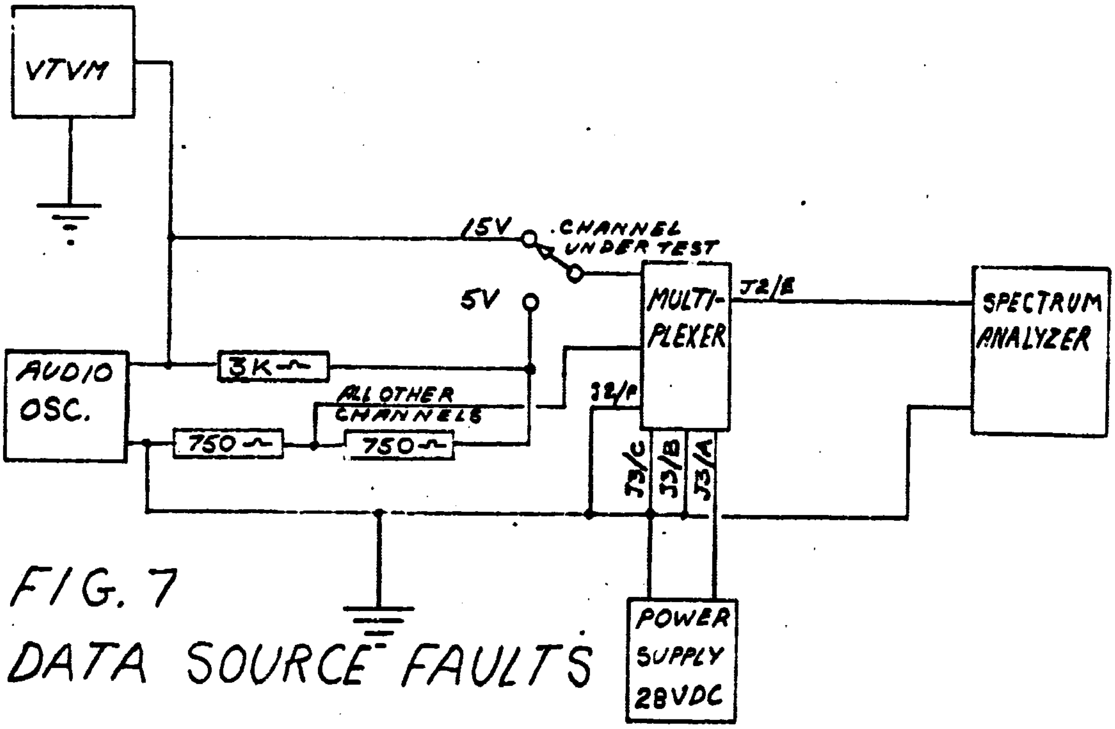


FIG. 7
DATA SOURCE FAULTS

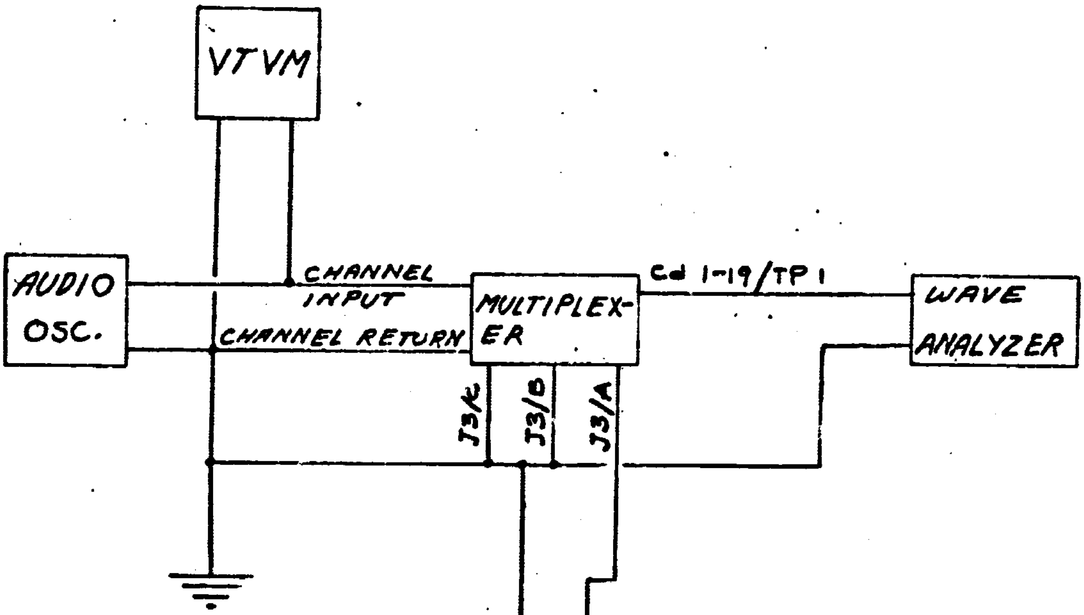


FIG. 8 LINEARITY

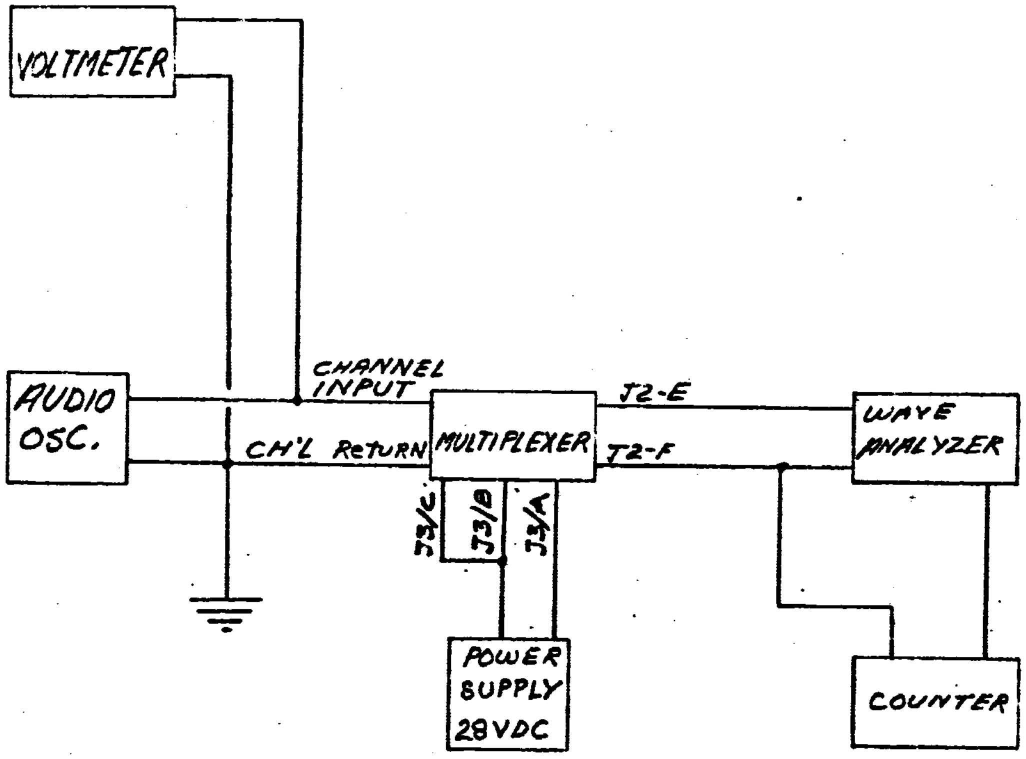


FIG. 9 AMPLITUDE SPECTRAL LINEARITY

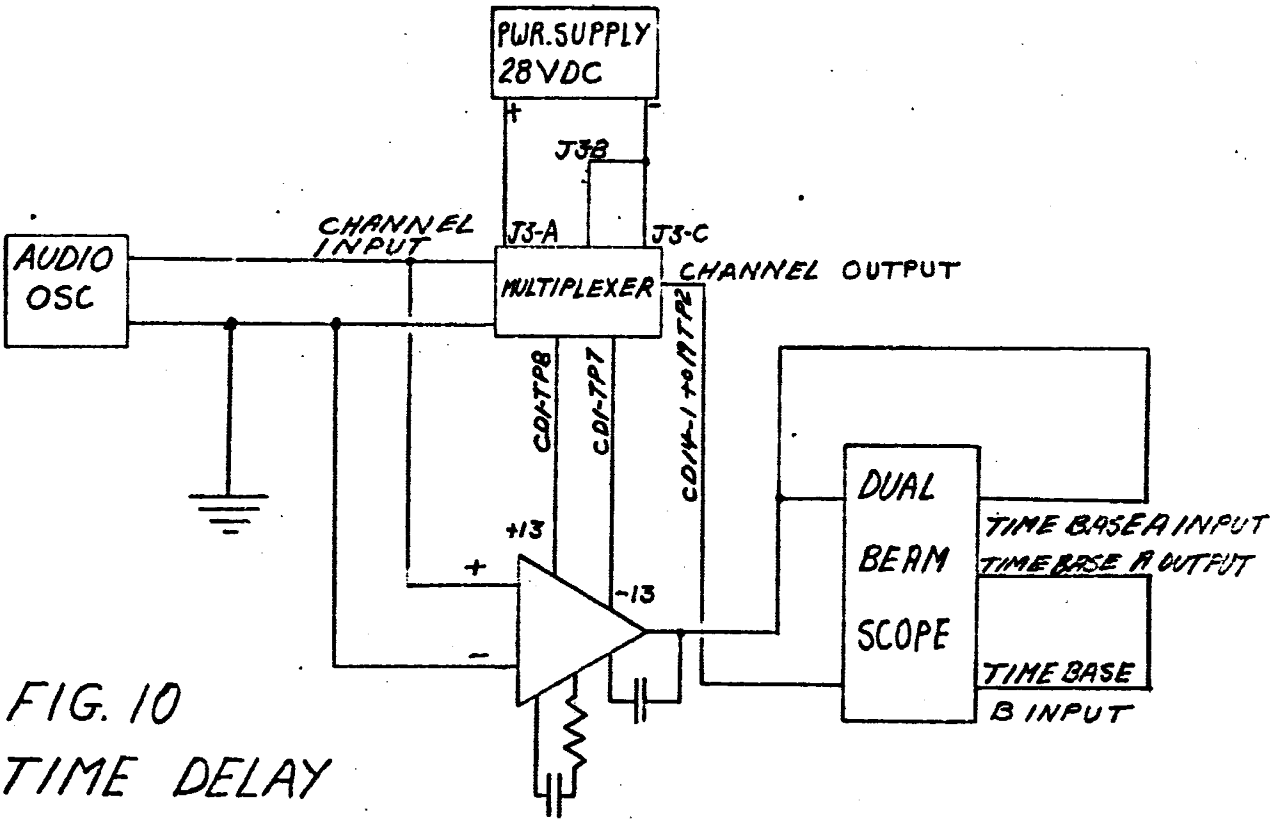


FIG. 10
TIME DELAY

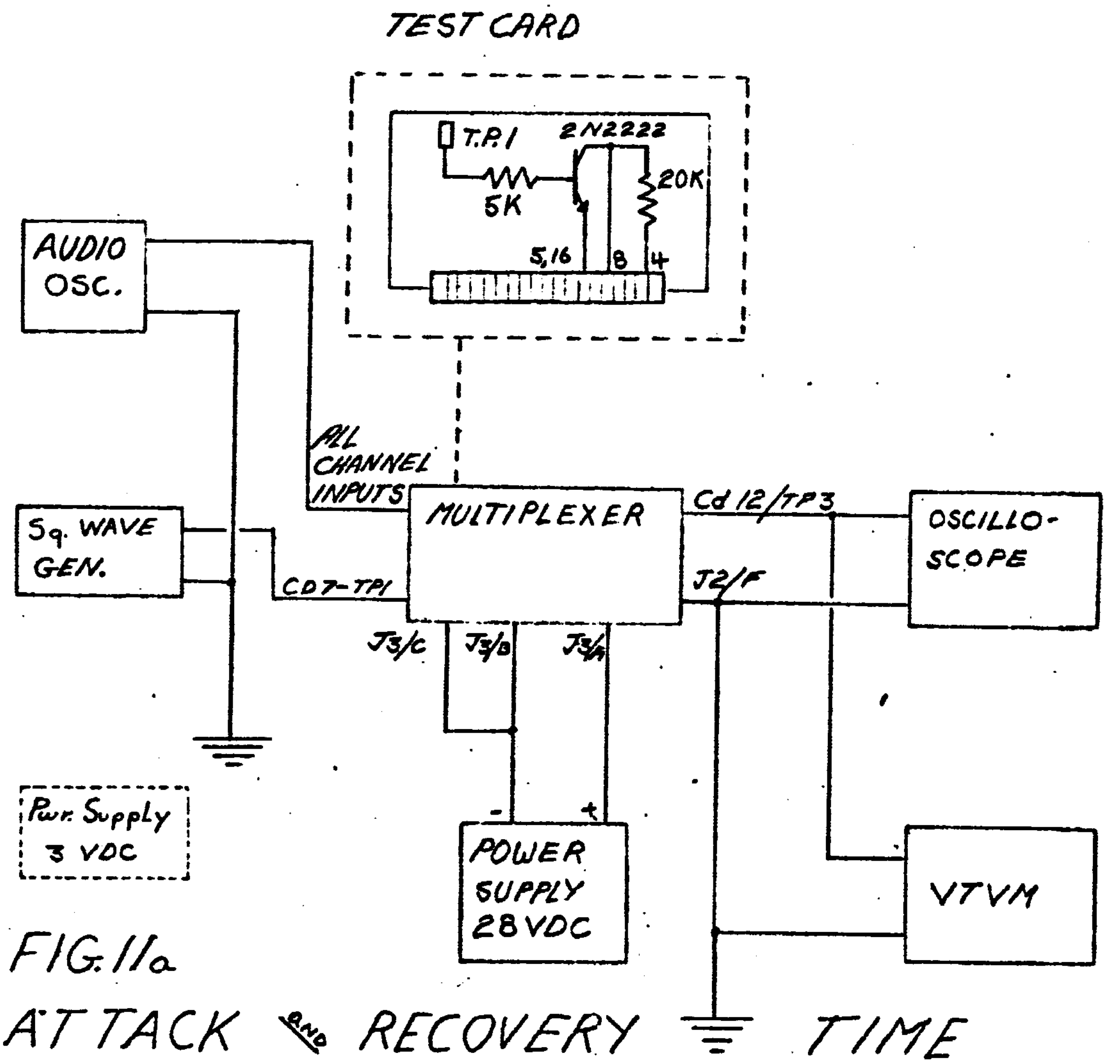


FIG. 11a

ATTACK and RECOVERY TIME

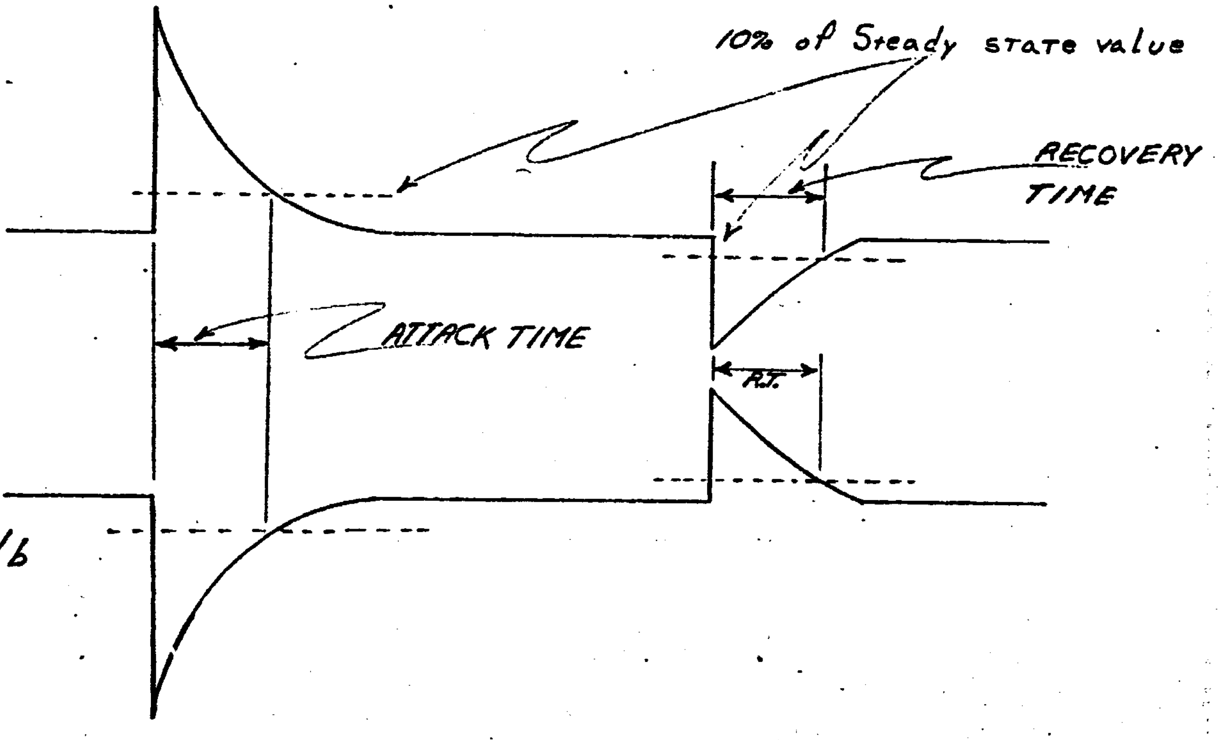


FIG. 11b

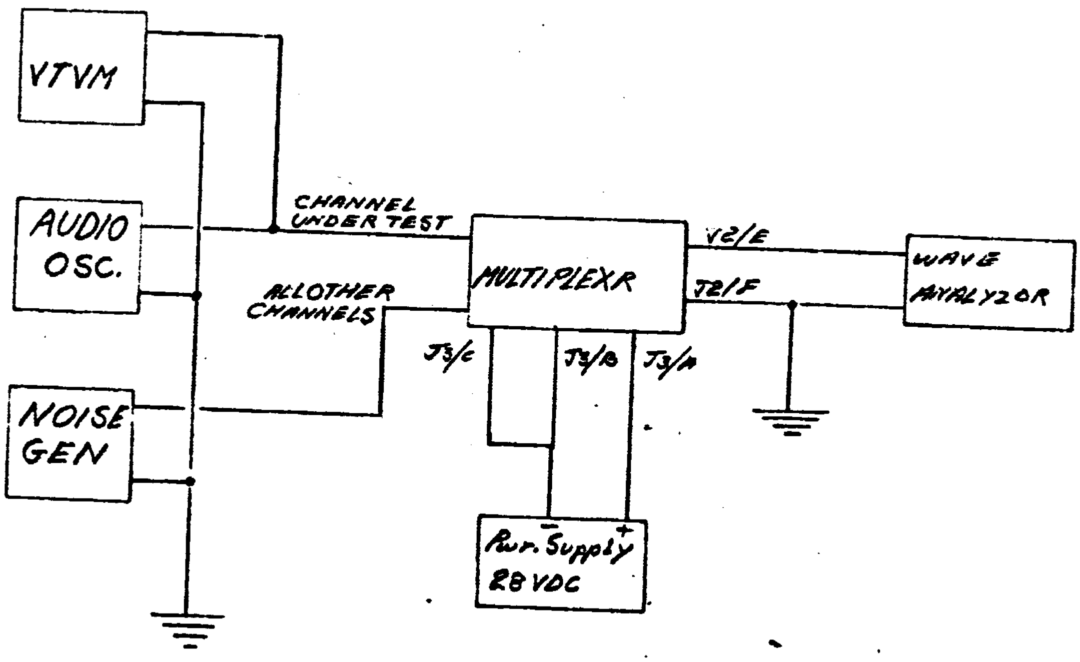


FIG. 12 AGC TRACKING

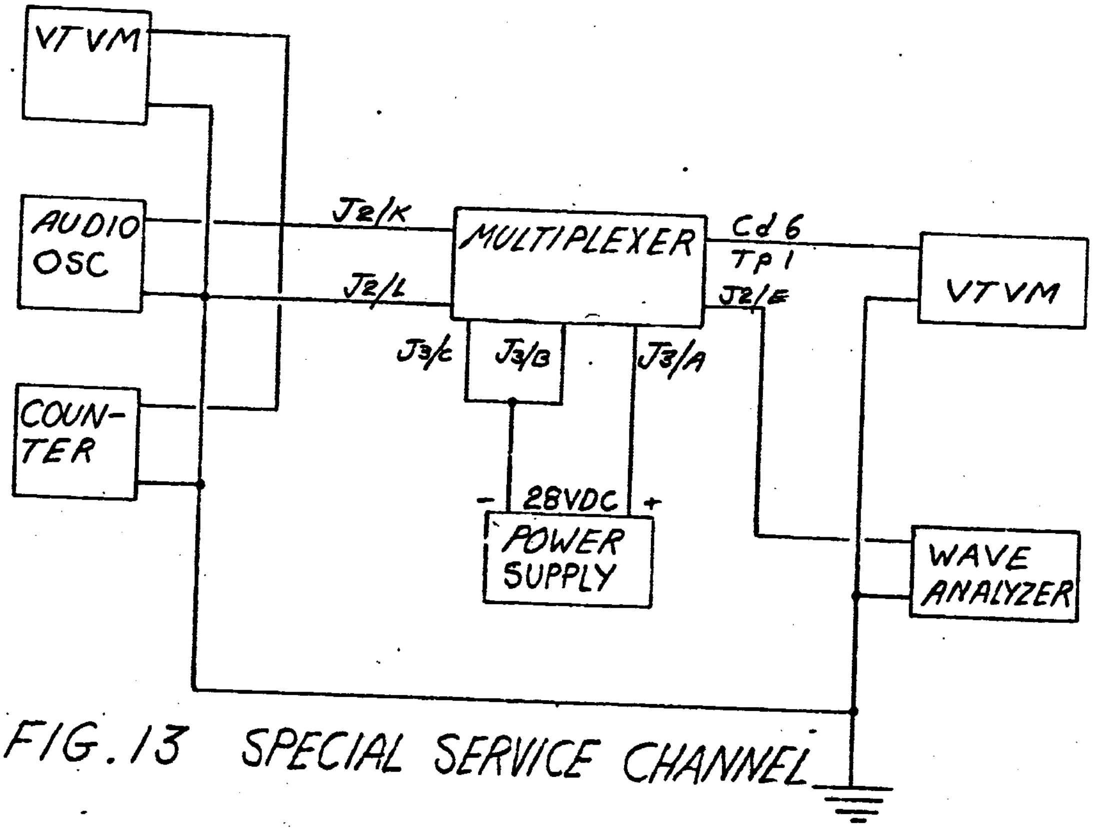


FIG. 13 SPECIAL SERVICE CHANNEL

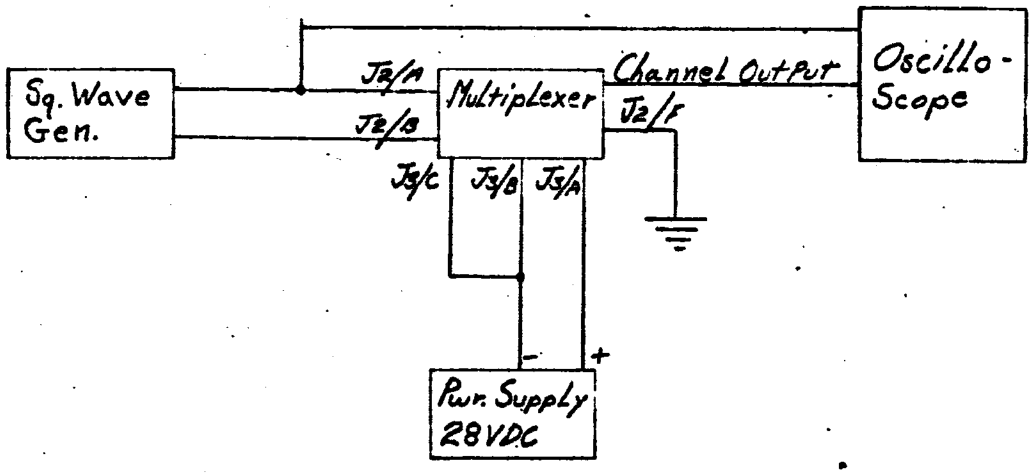


Fig. 14 Calibration Command

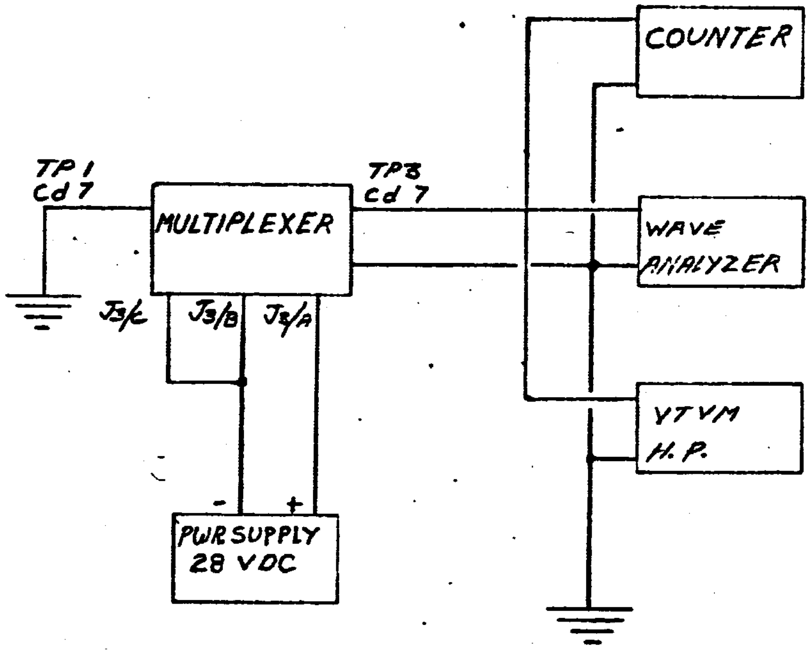


FIG. 15 CALIBRATION SIGNAL

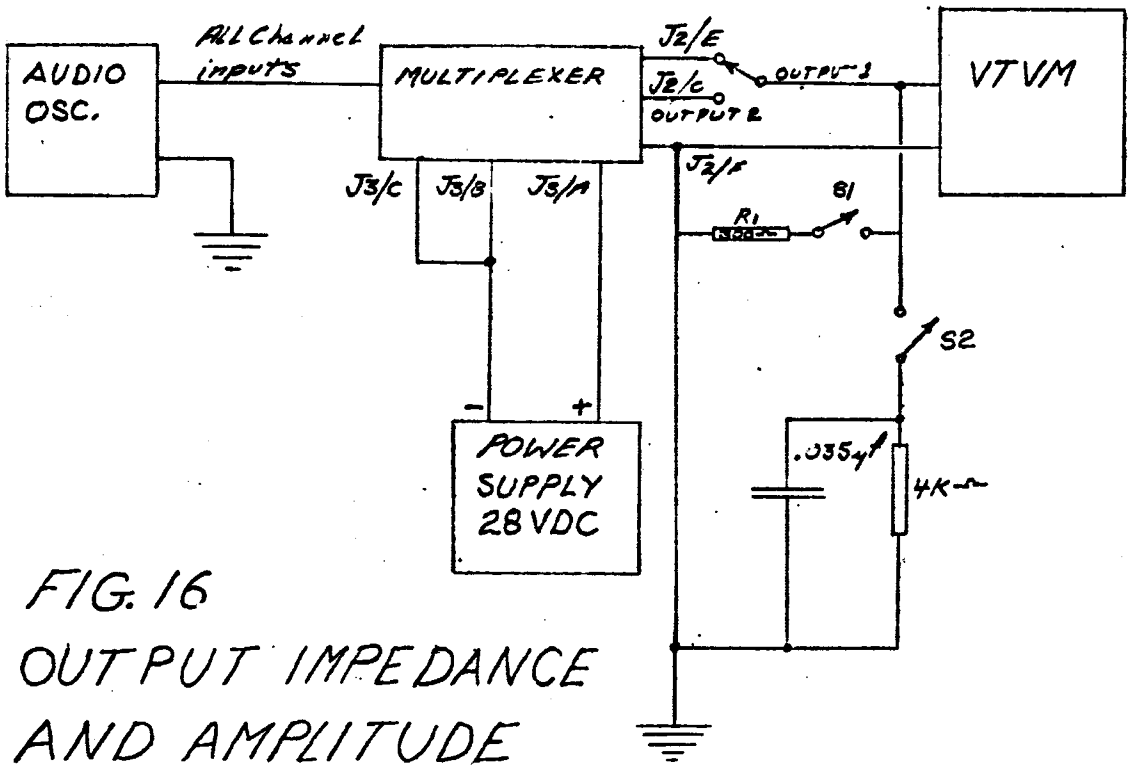
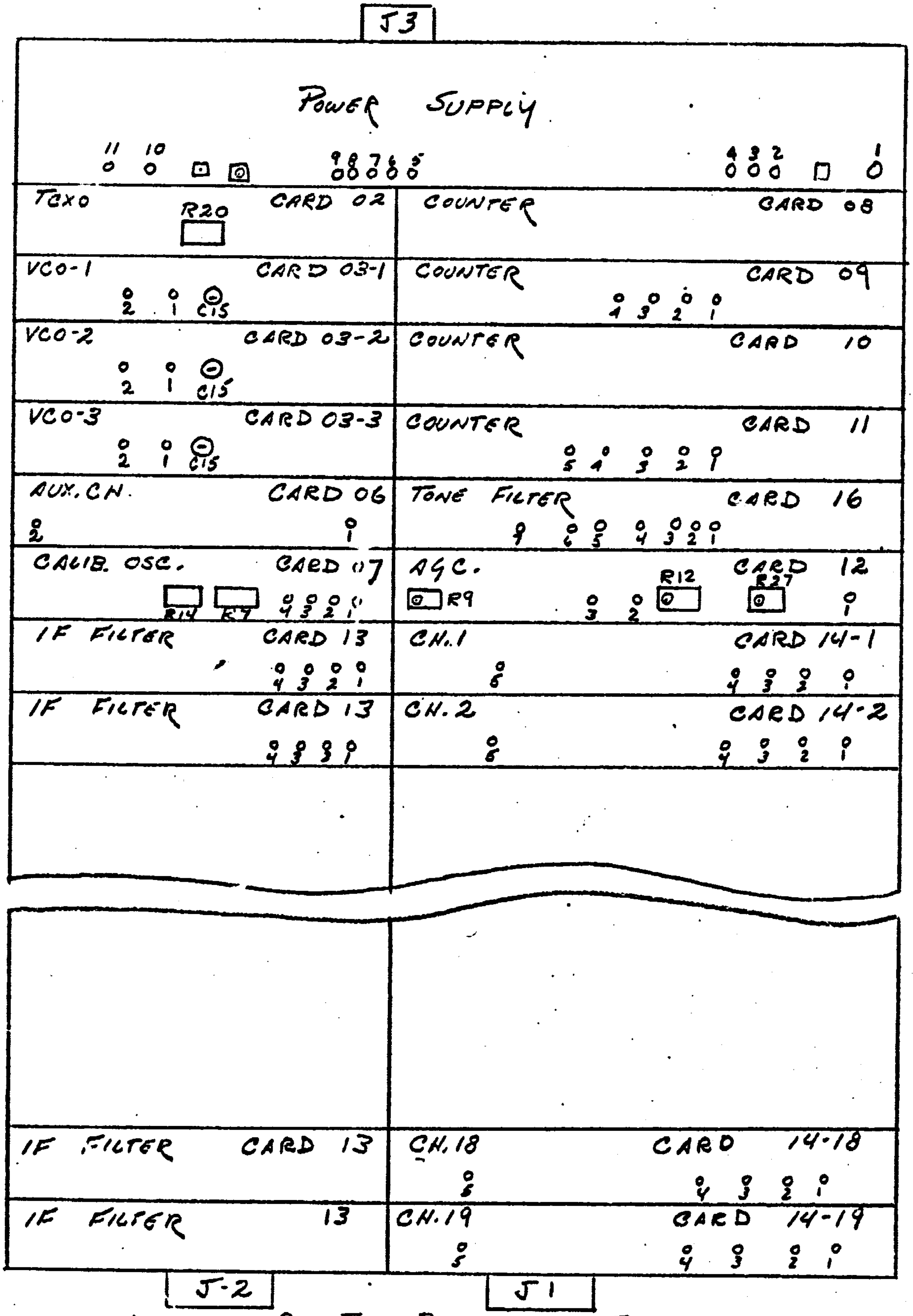


FIG. 16
OUTPUT IMPEDANCE AND AMPLITUDE



LOCATION OF TEST POINTS AND TRIMMERS

FIG. 17

APPENDIX D

FORM 821-E

AVCO ELECTRONICS DIVISION
CINCINNATI, OHIO 45241
CODE IDENT. NO. 80045

NO. E S 150.003
REV.
PAGE NO. 1 OF

REV. FOR ISSUE DATE, SUPERSEDED ISSUE DATES AND CHANGE NOTICE NUMBERS, SEE THE REVISION RECORD PAGE.

PROTOTYPE

DATA SHEET

SS/DSB MULTIPLEXER

AED Part No. 360000

Tested By____________________

Tested At____________________ Date__________

Prepared By____________________ Date__________

1.0 INTRODUCTION

This data sheet is intended as a record of the results of tests specified in ES-150.002. This data is used to test conformance of the SS/DSB Multiplexer (AED Part No. 360000) to MSFC Specification 110114A.

REV.

2.0 Power Supply

2.1 Power Supply Test

Input	Cd 1/TP 9	Cd 1/TP 8	Cd 1/TP 7	
28.0				
32.2				
28.8				
	Vp-p	Vp-p	Vp-p	
28				Ripple
28				Spikes

2.2 Isolation

Voltage across resistor : 1. (Chassis) ________Vdc

2. (Power return) ________Vdc

3. (Calibration) ________Vdc

2.3 Current drain

Line Current : ____________Adc

3.0 Carrier Generation

Module 9, TP2 Signal (lags)/(leads) reference by ______ ns.

Module 10, TP2 Signal (lags)/(leads) reference by ______ ns.

Module 11, TP2 Signal (lags)/(leads) reference by ______ ns.

4.0 Channel and IF Modules

4.1 Input impedance and back current

Channel No	Voltage across resistor (dB) *	Voltage across input (dB)*	Back current uA peak AC	Back current uA DC	Back current Total**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					

* The difference between these two readings shall be less than .1 dB

** This value not to exceed 1.0 microamp.

4.2 Data source faults

Channel		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Any noticeable difference between the two spectra	Yes																			
	No																			

4.3 <u>Channel linearity cont.</u>

Channel	Input	Output DSB					Output SSB		
No	V RMS	USB dB	Gain dB	LSB dB	Gain dB	Avg Gain dB	LSB dB	Gain dB	Avg Gain dB
"	.8								
"	1.6								
14	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
15	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
16	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
17	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
18	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
19	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								

4.3 Channel linearity cont.

Channel	Input	Output DSB					Output SSB		
No	V RMS	USB dB	Gain dB	LSB dB	Gain dB	Avg Gain dB	LSB dB	Gain dB	Avg Gain dB
7	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
8	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
9	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
10	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
11	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
12	.05								
"	.1								
"	.2								
"	.4								
"	.8								
"	1.6								
13	.05								
"	.1								
"	.2								
"	.4								

4.3 Channel linearity

	Channel	Input	Output DSB					Output SSB		
	No	V RMS	USB dB	Gain dB	LSB dB	Gain dB	Avg. Gain dB	LSB dB	Gain dB	Avg. Gain dB
	1	.05								
	"	.1								
	"	.2								
	"	.4								
	"	.8								
	"	1.6								
	2	.05								
	"	.1								
	"	.2								
	"	.4								
	"	.8								
	"	1.6								
	3	.05								
	"	.1								
	"	.2								
	"	.4								
	"	.8								
	"	1.6								
	4	.05								
	"	.1								
	"	.2								
	"	.4								
	"	.8								
	"	1.6								
	5	.05								
	"	.1								
	"	.2								
	"	.4								
	"	.8								
	"	1.6								
	6	.05								
	"	.1								
	"	.2								
	"	.4								
	"	.8								
	"	1.6								

4.4 Amplitude Spectral Linearity

A. SSB

Channel No.							Ripple dB
1	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
2	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
3	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
4	Freq. (Hz)	10	30		2780	3000	
	Amp. (db)						
5	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
6	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
7	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
8	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
9	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
10	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
11	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
12	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
13	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
14	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
15	Freq. (Hz)	10	30		3780	3000	
	Amp. (dB)						
16	Freq. (Hz)	10	30		3780	3000	
	Amp. (dB)						
17	Freq. (Hz)	10	30		3780	3000	
	Amp. (dB)						
18	Freq. (Hz)	10	30		3780	3000	
	Amp. (dB)						
19	Freq. (Hz)	10	30		3780	3000	
	Amp. (dB)						

4.4 Amplitude Spectral Linearity - (Continued)

B. DSB

Channel No.							Ripple dB
1 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
1 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
2 USB	Freq.(Hz)	10	30		2780	3000	
	Amp. (dB)						
2 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
3 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
3 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
4 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
4 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
5 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
5 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
6 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
6 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
7 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
7 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
8 USB	Freq.(Hz)	10	30		2780	3000	
	Amp. (dB)						
8 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
9 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
9 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						

REV.

4.4 Amplitude Spectral Linearity - (Continued)

B. DSB - (Continued)

Channel No.							Ripple dB
10 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
10 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
11 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
11 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
12 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
12 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
13 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
13 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
14 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
14 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
15 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
15 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
16 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
16 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
17 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
17 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
18 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
18 LSB	Freq (Hz)	10	30		2780	3000	
	Amp. (dB)						
19 USB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						
19 LSB	Freq. (Hz)	10	30		2780	3000	
	Amp. (dB)						

REV.

4.5 Time Delay

CHANNEL NO.	MAXIMUM TIME DIFFERENCE	
	VS. Frequency (us)	Referenced to Ch. 19 (us)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		

REV.

5.0 AGC Module

5.1 AGC Attack & Recovery Time and Range

Attack time : __________ms

Recovery time: __________ms

Difference in output level : __________dB

5.2 Relative Data Output Levels and Harmonics Suppression

(A) SSB

	Channel			Harmonics		Harmonics	
	No	Freq. kHz	Output Amplitude dB	Freq. kHz	Ampl. dB	Freq. kHz	Ampl. dB
	P1	75.83					
	P2	80.57					
	1	3.74					
	2	8.48					
	3	13.22					
	4	17.96					
	5	22.70					
	6	27.44					
	7	32.18					
	8	36.92					
	9	41.66					
	10	46.40					
	11	51.14					
	12	55.88					
	13	60.62					
	14	65.36					
	15	70.10					
	16	84.32					
	17	89.06					
	18	93.80					
	19	98.54					

5.2 Relative Data Output Levels and Harmonics Suppression Cont.

(B) DSP

Channel			Harmonics		Harmonics	
No	Freq. kHz	Output Amplitude dB	Freq. kHz.	Ampl. dB	Freq. kHz	Ampl. dB
P1	75.83					
P2	80.57					
1	3.74					
1	5.74					
2	8.48					
2	10.48					
3	13.22					
3	15.22					
4	17.96					
4	19.96					
5	22.70					
5	24.70					
6	27.44					
6	29.44					
7	32.18					
7	34.18					
8	36.92					
8	38.92					
9	41.66					
9	43.66					
10	46.40					
10	48.40					
11	51.14					
11	53.14					
12	55.88					
12	57.88					
13	60.62					
13	62.62					
14	65.36					
14	67.36					
15	70.10					
15	72.10					
16	84.32					
16	86.32					
17	89.06					
17	91.06					
18	93.80					
18	95.80					
19	98.54					
19	100.54					

REV.

5.3 AGC Tracking & Channel Intermodulation

Channel No.	With noise applied			Without noise applied			Channel output level		
	Output of Channel dB	Pilot Tone dB	Diff dB	Output of Channel dB	Pilot Tone dB	Diff dB	With Signal dB	Without Signal dB	Diff. dB
1 SSB									
1 DSB									
2 SSB									
3 SSB									
3 DSB									
4 SSB									
5 SSB									
5 DSB									
6 SSB									
7 SSB									
7 DSB									
8 SSB									
9 SSB									
9 DSB									
10 SSB									
11 SSB									
11 DSB									
12 SSB									
13 SSB									
13 DSB									
14 SSB									
15 SSB									
15 DSB									
16 SSB									
17 SSB									
17 DSB									
18 SSB									
19 SSB									
19 DSB									

6.0 Auxiliary Modules

6.1 Special Service Channel Response

		Peaks and Valleys ac Cd6/TP1									Ripple
Freq. (Hz)	1000										
Ampl. (dB)											

6.2 Calibration

Calibration duration : __________ms

Command Voltage min. : __________V

Cal. signal freq. : __________Hz

Cal. signal Ampl. : __________Vpp, ________dB

2nd Harmonic : __________dB

3rd Harmonic : __________dB

7.0 Output Impedance and Amplitude

Output No	En_1 (mV RMS)	E_1 (mV RMS)	Zo (Ohms)	Amplitude Max (mV RMS)	Amplitude Min (mV RMS)
1					
2					

APPENDIX E

TENTATIVE DATA SHEET

The SS/DSB Multiplexer frequency multiplexes 19 data channels, each with information up to 1.5 kHz or 3.0 kHz into a base band of approximately 100 kHz. Each channel can be SSB or DSB, suppressed carrier, multiplexed by using the appropriate IF filter module provided. The multiplexed mode as well as the information bandwidth (1.5 or 3.0 kHz) can be separately chosen for each channel except that a channel in the 3 kHz DSB mode must be used above an unused channel and a 3 kHz bandwidth channel may not be used below a 1.5 kHz, DSB Channel. The channel sub-carrier frequencies (suppressed) are at multiples of 4.74 kHz from 4.74 kHz to 71.10 kHz and from 85.32 kHz to 99.54 kHz. Two pilot tones (75.84 kHz and 80.58 kHz) are transmitted with the data for phase and frequency coherent sub-carrier regeneration and provide amplitude reference for the baseband data. AGC is applied to the output base band including the pilot tones. A 1 kHz auxiliary channel (amplitude preserved) is also available for transmitting time multiplex information and internal calibration of all channels is provided.

Channel Data:

Input Impedance = 100K ± 1%

Amplitude Linearity = 1% (3 kHz Input Bandwidth)

Phase Linearity = 1%

Channel Cross Talk = 60 dB maximum

Output = 250 to 350 Millivolts RMS, Independent of channel usage, (plus Special Service Channel)