NASA CR 65937

Third Quarterly Report

Phase C

THIN-FILM PERSONAL COMMUNICATIONS AND TELEMETRY SYSTEM (TFPCTS)

For the period of September 24, 1967 to December 24, 1967

Contract No. NAS 9-3924

Submitted to

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

January 1968

Submitted by

Melpar, Inc.
7700 Arlington Boulevard
Falls Church, Virginia 22046

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1. INTRODUCTION

This report for the third quarter of Phase C is submitted in compliance with Contract NAS 9-3924 between NASA-Houston and Melpar, Inc. The objective of this contract is to design and construct a thin-film personal communication and telemetry system. During Phase C, the objective is to package two transceivers using the modules developed in Phase B of the program.

All of the thin-film modules required by Phase B have now been delivered. The final modules, which were delivered during the last quarter, were the "IF Amplifier No. 2" and the "Voice-Operated Switch" (VOX).

The primary problem during the third quarter has been the assembly and development of the RF portions of the transmitter and receiver. This has resulted from component failure during assembly and from dissimilarities between the thin-film circuits and the conventional circuits contained in the breadboard models. The thin-film modules have insufficient voltage gain and this is believed to result from improper impedance matching between stages at radio frequencies.

Assembly yield is expected to be improved through new lead bonding and assembly techniques and the gain should be increased to acceptable levels through modification of circuit impedances.

2. TECHNICAL DISCUSSION

2.1 Bonding Techniques

2.1.1 Old Techniques

The original plan for this program was to use copper over chromium films for all terminals, conductors, and capacitor plates. This would have permitted the use of solder joints (60/40 lead-tin) which are considered to be the strongest, lowest resistance, and most reliable type of bond for thin-film circuits. The use of copper plates resulted in poor capacitors, however, and it became necessary to switch to aluminum.

Attempts were then made to solder to Al-Cr terminals, but a satisfactory solder or solder/flux combination could not be found at that time. Copper or gold films deposited over the aluminum (at the terminals only) also did not result in good bonds, apparently due to too much alloying with the aluminum.

Bonds were then formed using a conductive, silver epoxy, reinforced with a stronger nonconductive epoxy. Initially, the bonds appeared to be satisfactory, but after a period of time, the resistance of some of the joints increased to an intolerable level.

The reliability of the joints was improved by split-tip, resistance welding of 5-mil-diameter gold wire between large copper or phosphor-bronze leads and the corresponding thin-film terminals and by welding 5-mil gold wire over the 1-mil gold leads from the transistor chips at the proper thin-film pads. These joints were reinforced with both conductive and nonconductive epoxy.

It later became necessary to omit the epoxies at discrete component leads so that they could be replaced for circuit development purposes. Without the redundancy of both welded and conductive epoxied joints, it became apparent that the reliability of welded joints is unsatisfactory. This is caused primarily by an occasional fracturing of the glass around the weld, probably resulting from thermal shock. The joint may be adequate initially, but a crack encircling the joint may form later, causing a high resistance or open circuit. This can occur even though the wire appears to be mechanically well bonded to the substrate.

Thermocompression and ultrasonic bonding have also been tried and, although the bonds appeared to be satisfactory, the bonding equipment available is limited to a maximum wire size of 1-mil diameter. This size wire is so easily broken that its use has been avoided except for transistor chips which cannot accommodate larger wire.

A bonding method for RF circuits, used during the last quarter, consisted of "tinning" the Al-Cr terminals with an 80% gold/20% tin alloy. This was accomplished by heating the substrate on a hot plate with preforms of the alloy positioned on the terminals. When the upper, film surface of the substrate reaches a temperature of about 380° C (lower surface about 50° C hotter), the preforms melt and flow over the terminal surface. It is then possible to form satisfactory bonds on the "tinned" pads using 60/40 lead tin solder and a small soldering iron. Pull strength is 2.0 to 2.5 pounds for a 0.040 x 0.100 inch joint, when the wire is pulled normal to the film. Transistor chips can also be electrically and mechanically joined to thin-film gate terminals, during the substrate heating, by placing preforms between the gate side of the chips and the films.

Disadvantages of this method are:

a. Heating of the 1 x 0.5 x 0.020 inch glass substrates on a hot plate results in large temperature gradients, causing stresses in the substrate and thin films which, in turn, may result in immediate or eventual capacitor failures. (Uniform temperatures could be achieved by heating in an oven, but this would result in difficulty in maintaining the preforms and chips in their proper positions.)

b. High temperature increases the chance of capacitor failure. This may be due to crystallization or grain growth in the aluminum plates.

c. The preform alloy tends to flow freely over the entire Al films. In some cases, it has flowed to the edges of capacitors, causing failure.

2.1.2 Present Technique

Very recently, a new type of solder was investigated and found to be satisfactory for bonding copper, phosphor-bronze, or gold wires to Al-Cr films using a small soldering iron. The solder, which was developed at Melpar for another program, consists of 65% tin, 25% bismuth, and 10% silver. It has a melting point of 138° C.

The thin-film terminals and wires (excluding gold wires) are first "tinned." The surface oxide must be removed from non-gold wires before tinning. This may be done by dipping the leads in nitric acid followed by a water rinse. Resin flux may not be used. This is probably an advantage, since flux may cause damage through chemical reactions, especially if it happens to contact thin-film capacitors. The thin-film pads must be cleaned with acetone before tinning. The wire is then soldered to the pad. Soldering temperature is 260°C.

The joints, although not as good as Cu-Cr films soldered with lead-tin solder, are satisfactory. A typical joint of 0.040 x 0.040 inch has a pull strength of 0.8 to 2.4 pounds normal to the substrate surface and a resistance of less than 0.1 ohm. Leads have been unsoldered and resoldered up to 12 times without joint failure. In addition, joints have been heated in air at 125°C for 120 hours without any measurable change in resistance.

The present technique does not require epoxy reinforcement except at the circuit pins, which are subject to relatively large stresses. This is another advantage, since it facilitates replacement of discrete components and reduces the chances of coating capacitors with epoxy, which may cause failure due to stresses resulting from shrinkage during curing of the epoxy cement.

2.2 Assembly Techniques

Some of the problems associated with assembly, excluding lead bonding problems, are scratches and punctures which cause capacitor shorts and broken leads from chip transistors (1-mil-diameter gold wire).

Another problem is discrete component failure. When this occurs, attempts are made to replace the component by cutting through the epoxy cement used to fasten the component to the substrate. This sometimes causes the substrate to break. In addition, it is suspected that coating of capacitors with epoxy cement may cause failure due to shrinkage of the epoxy.

Progress in assembling the RF portions of the transmitter and receiver has been particularly slow. Suspected reasons for this are:

a. The gold/tin preform method of bonding with epoxy reinforcement has been used. The disadvantages of this technique were discussed in paragraph 2.1.1.

b. There is a great deal more handling of the RF circuits than occurs during assembly of any other circuit. Seven to eight RF circuits are mounted in a brass case with brass partitions between substrates to provide RF shielding. The signal leads between circuits are soldered after the substrates are placed in the case and then the partitions are installed and spot-welded to the case. A typical circuit contains a relatively large discrete coil and variable capacitor, and either a canned or chip transistor which are connected prior to assembly in the case. The performance of each circuit is checked immediately before and after assembly in the case. The chance of scratching a capacitor or breaking a transistor lead with the soldering iron or test probes is higher than with the other, lower frequency circuits because of the small working space available. In addition, when a failure occurs, all of the circuits in the case generally have to be probed to locate the failure, and then the malfunctioned substrate frequently must be replaced. (Sometimes a shorted capacitor can be opened by applying a small voltage pulse so that replacement of the substrate is not always necessary.) If a substrate must be replaced, unsoldering and resoldering of signal leads must be performed. This is particularly difficult after the brass partitions have been spot-welded to the case. The troubleshooting and repair work is very time-consuming and has resulted in very slow progress in completing the receiver and transmitter.

Approximately 57% of the RF circuits assembled in the receiver and transmitter have had to be replaced. The % loss of circuits for various reasons is listed below:

a. Shorted capacitors - 29%

b. Discrete component failure leading to broken substrates - 11%

c. Poor solder joints - 11%

d. Broken chip transistor leads - 6%

2.2.1 Circuit Assembly Procedure

In view of the above problems, the following assembly procedure was recently put into effect: (Note: All soldering is to be done in accordance with paragraph 2.1.2)

a. Cover all capacitors with a protective coating consisting of 2000Å of vacuum-deposited borosilicate dielectric or with Humiseal 1H35 applied by spraying through an aperture mask.

b. Scribe and dice the substrates into individual circuits, as required.

c. Trim all capacitors and certain resistors to specified values. For RF circuits, all resistors are trimmed to their final values at this point.

d. Blow off glass chips with a gentle flow of clean, dry gas.

e. Tin all solder pads, pins, and non-gold leads of discrete components.

f. Solder circuit pins using a jig to hold the pins in their proper positions. (All pins consist of 0.020 inch diameter x 0.500 inch long phosphor-bronze and are soldered to 0.040 inch wide x 0.125 inch long thin-film terminals located on 0.075 inch centers along one edge of the substrate.)

g. Fasten discrete components and reinforce pins using nonconducting epoxy cement. Prevent epoxy from coating capacitors, solder pads, or ends of leads. Cure epoxy in oven at 60° C for 30 minutes.

h. Solder all discrete component leads.

i. Test circuit and adjust as required. For most circuits, several of the resistors are trimmed to obtain specified voltages in this step. For RF circuits, the variable discrete capacitor is adjusted to obtain peak voltage gain.

j. Store circuits in clean, dry container.

2.2.2 Transistor Chip Preparation

Chip transistors are used for all circuits except for some of the RF circuits for which transistors are available in cans only. Chip size is 20 mils x 30 mils x approximately 3 mils thick. The chips are prepared as follows:

a. Spot-weld a 20-mil-diameter x 5-mil-thick gold plated kovar disk to a TO 5 transistor header.

b. Place a transistor chip on the above disk with two 15-mil-diameter x 1-mil-thick gold-silicon preforms (manufactured by Coining Corp. of America) sandwiched between the chip and disk. The gate side of the chip must face the preform.

c. Heat the header on a hot plate (containing an access hole for the header leads) at 410° to 420° C for about 5 minutes. This melts the preform and bonds the chip to the disk.

d. Fasten 1-mil-diameter gold wires between the source and drain terminals of the chip and the source and drain pins of the header, using thermocompression, ball bonding.

e. Fasten a 5-mil-diameter gold lead between the disk and the gate pin of the header using a split-tip resistance welder.

f. Test the device on a curve tracer. Approximately 15% of the transistors are rejected at this point.

g. Remove the device from the header. This is done by breaking the spot-weld between the kovar disk and the header and by cutting the leads at the header pins using a small knife.

h. Store in a clean, dry container.

2.3 Circuit Deposition

All thin-film circuits used in the systems will have been fabricated in accordance with the latest vacuum deposition procedures, which were finalized during October. There are now sufficient quantities of all circuits to complete the program except for the "Operational Amplifier and Mixer" and the "Audio Amplifier and Transmitter." Deposition of these should be completed by the end of January.

A universal vacuum processing procedure, applicable to all of the circuits in the program except the RF circuits, will be included in the final report. Because the procedure for the RF circuits is somewhat unique, a separate procedure for RF circuits will be contained in the final report.

2.4 System Assembly and Development

2.4.1 RF Circuits

In addition to the problems associated with catastrophic component failures described in paragraph 2.2, the RF portions of the transmitter and receiver do not operate as well as the breadboard models.

Although the entire RF portion of a thin-film receiver (consisting of an oscillator, tripler, two amplifiers, and a mixer operating at approximately 259 MHz) has been assembled, the voltage gain from the diplexer (antenna) input to the mixer output is only 0.6. The voltage gain should be at least 2 in order to supply sufficient voltage to drive the IF amplifiers. The gain in the breadboard model is 30.

The RF portion of the transmitter, excluding the two power amplifiers, has been assembled. This includes the crystal oscillator, tripler, modulator, and three amplifiers. The voltage output of the assembled portion is about 5 volts, peak-to-peak. This must be increased to at least 8 volts peak-to-peak in order to drive the power amplifiers, which operate in the class C mode for maximum efficiency and, therefore, minimum temperature. (The breadboard model provides 11 volts peak-to-peak to the power amplifiers.)

When a typical single-stage thin-film RF amplifier is tested with resistive source and load impedances of 3300 and 1000 ohms, respectively, the voltage gain is an acceptable 2.8 to 3.2 volts/volt. The gain is reduced when the amplifier is coupled to its neighboring thin-film circuits. The gain reduction appears to result from improper impedance matching. The impedances in the thin-film circuits, resulting from lead inductance, stray capacitance, and "skin effect" at high frequencies, is evidently quite different from the impedances in the breadboard model, which is fabricated from conventional discrete components and conductors having much larger cross sections.

For example, the voltage gain of the RF portion of the thin-film receiver can be increased from 0.6 to 4.0 by substituting a resistor of 10K to 56K ohms for the LC tank circuit and by removal of the bypass capacitor at the output end of the "antenna signal amplifier." This tank circuit is believed to be necessary, however, in order to attenuate signals at frequencies different from the desired radio frequency.

Efforts are being made to modify the impedances sufficiently to obtain adequate gain in both the transmitter and receiver.

2.4.2 Audio and IF Circuits

Assembly of the remaining circuits, including the telemetry subsystem, is progressing satisfactorily. Assembly yield is high and no problems are anticipated other than meeting the schedule. The most time-consuming task remaining is the fine trimming of the VCO resistors. Efforts are being made to obtain an additional trimming apparatus so that this portion of the work can be accelerated.

2.5 Redesign of the Transmit-Receive Diplexer:

Redesign of the transmit-receive diplexer was necessary because prior work with the thin-film version revealed certain practical limitations. In particular, narrow-band networks of this type invariably require reversible, nonincremental adjustment after placement in the shielding enclosure; therefore, present thin-film trimming techniques are not applicable. In addition, present deposition methods produce films of insufficient thickness relative to the skin depth at 300 MHz, resulting in excessive loss at these frequencies.

In view of the availability of extremely compact discrete trimmer capacitors, the approach chosen involves the use of these capacitors in conjunction with fixed strip-line inductors. Since 1/16-inch-thick double-clad board is used, the copper is left intact on one surface to provide a ground plane for the circuit etched on the opposite surface. The entire unit can be quite thin, although reasonable clearance must be left between the circuit side of the board and the shielding enclosure. (Close shielding tends to reduce the stripline impedance so that final trimming must be done through tuning holes with the shield in place.)

In order to utilize only one type of tuned circuit, overall electrical design was based upon the highpass-lowpass combination of Figure 1. Appropriate rejection poles were introduced by the modification shown in Figure 2. Thus, only parallel-tuned circuits are required and the high input impedance at each reject frequency automatically decouples that particular filter from the remainder of the circuit.

In stripline, a pure (neglecting losses) inductance to ground can be realized by means of a strip which is grounded at the far end. Likewise, a pure capacitance to ground results when the far end is left open-circuited. However, a pure floating inductance (such as that required for a parallel-tuned circuit) cannot exist, because proximity of the ground plane introduces a large distributed capacitance. Consequently, the stripline equivalent of a parallel-tuned circuit must be analyzed on the basis of more detailed transmission line theory.

With reference to Figure 3, the parallel resonant circuit equivalent consists simply of a stripline loop bridged by a tuning capacitor which has the reactance magnitude of A ohms. By adding a voltage source E and load resistor R, the input impedance Z_{in} was found to be given by

$$Z_{in} = \frac{AZ_o \sin\theta + jR\,(Z_o \sin\theta - A\cos\theta)}{R\left(2\cos\theta - 2 + \frac{A}{Z_o}\sin\theta\right) + j\,(Z_o \sin\theta - A\cos\theta)}$$

where θ is the electrical length around the loop and Z_o is the characteristic impedance of the stripline.

The reject (equivalent parallel resonant) frequency occurs when Z_{in} is a pure reactance. Solution for this condition resulted in

$$\sin\theta = \frac{A}{Z_o}$$

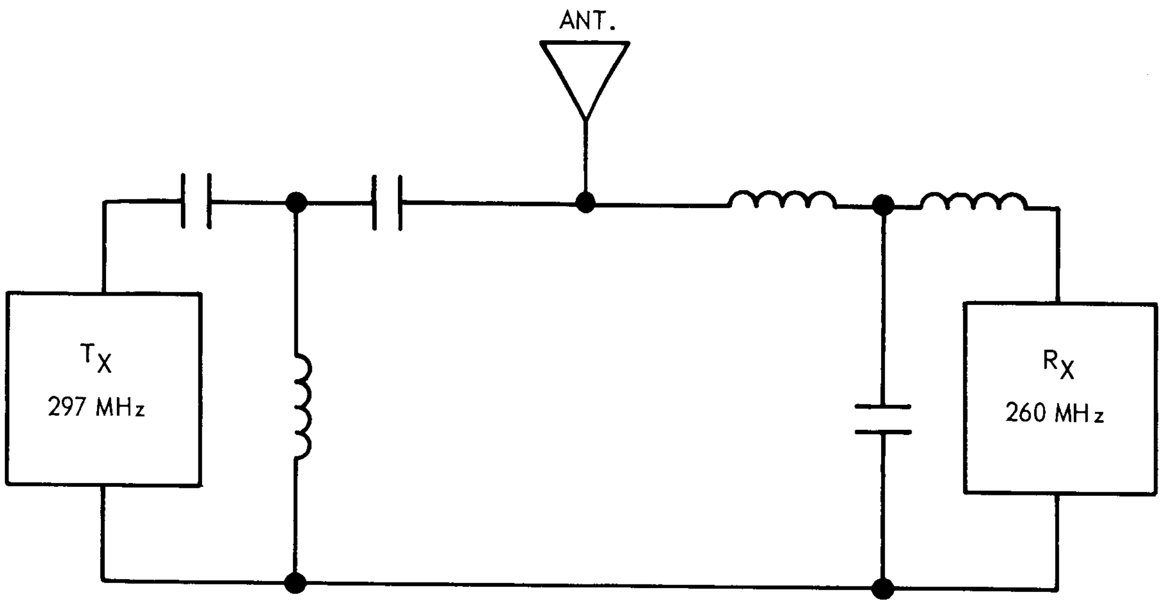


Figure 1. Highpass-Lowpass Diplexer

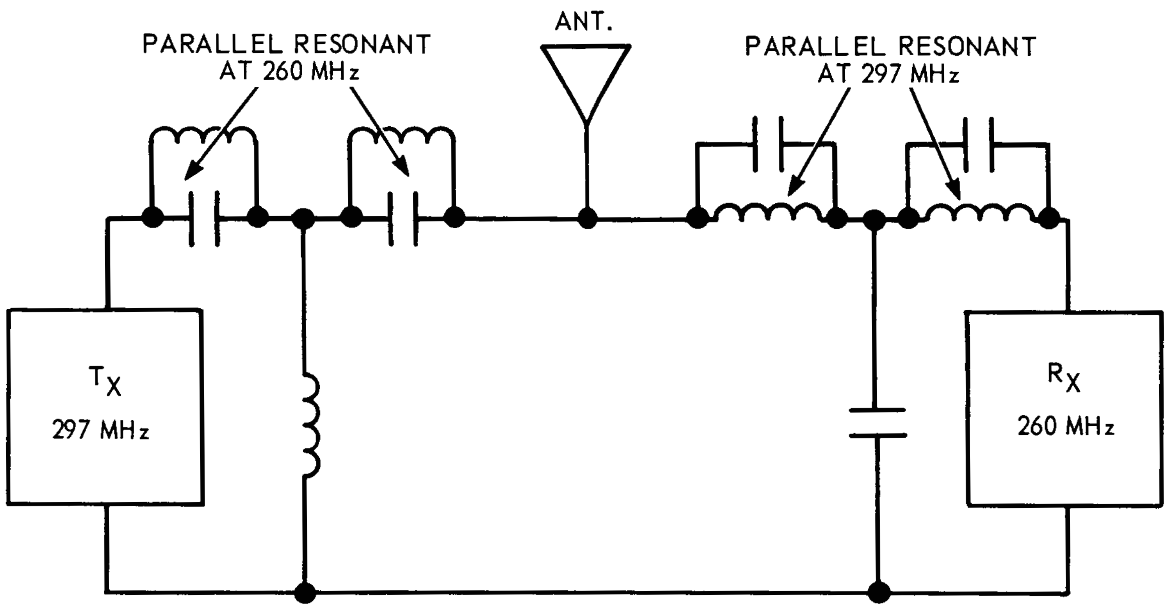


Figure 2. Modified Highpass-Lowpass Diplexer

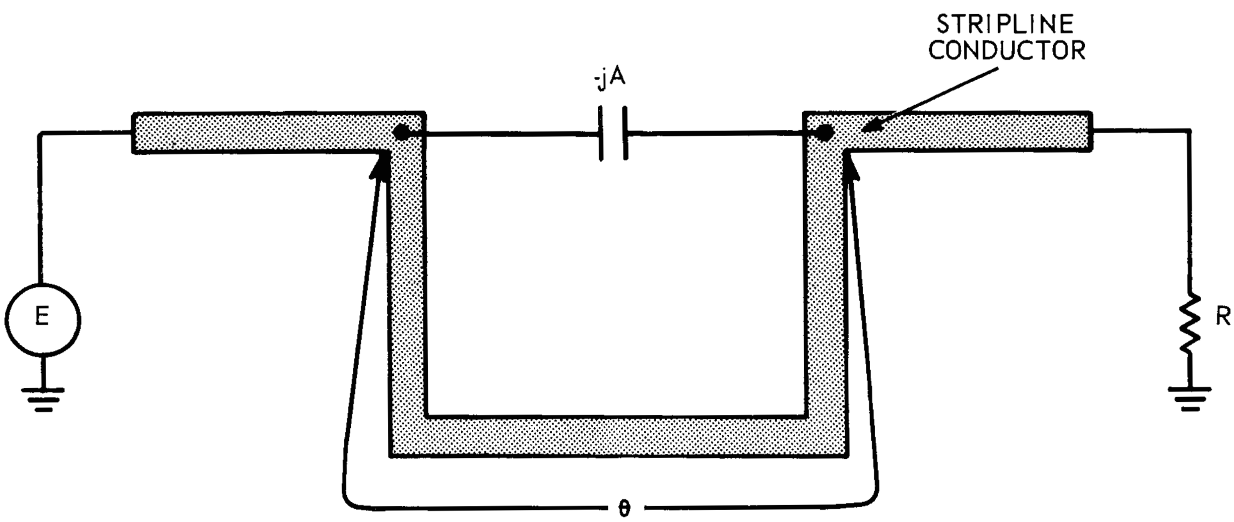


Figure 3. Equivalent Stripline Parallel Resonant Circuit

while the reject input impedance turned out to be

$$\frac{-jA}{(1 - \cos\theta)}$$

ohms. This, of course, differs from the infinite impedance associated with a parallel resonant circuit and agrees with the intuitive observation that the floating inductor has a large distributed capacitance. Furthermore, it is seen that this capacitance becomes less as the loop becomes electrically (and physically) shorter.

Further inspection of the general expression for Z_{in} revealed that the bridged loop acts as an impedance inverter when

$$\tan\theta = \frac{A}{Z_o} .$$

Consequently, a pair (or any even number) of loops may be connected in series to form a pass network for the frequency which satisfies the preceeding equation. It follows that a series-connected pair of bridged loops will act as a specialized pass-reject network.

Noting that θ and A are, respectively, proportional and inversely proportional to frequency, the pass and reject relations were rearranged in the form

$$\tan\theta_p = K \sin(K\theta_p)$$

where θ_p is the electrical line length at the pass frequency and K is given by

$$K = \frac{\text{(reject frequency)}}{\text{(pass frequency)}}$$

For θ_p less than 90°, the nature of the trigonometric functions requires that K be greater than unity. Consequently, the network is a low-pass high-reject type directly applicable to the receiver side of the diplexer.

Design of the receiver network on this basis was quite straightforward in that loop length is uniquely determined by the pass and reject frequencies. The final receiver circuit is diagrammed in Figure 4, where the loop length is approximately 2.7 inches and the tuning capacitors are approximately 10 pF. The neutralizing tap shown was found necessary to offset coupling due to physical proximity of the loops and thereby improve the rejection. Measured rejection at 297 MHz was greater than 60 dB, while the insertion loss at 260 MHz was approximately 1 dB. Design of the less critical transmitter network has also been completed and an integrated breadboard of the diplexer will be tested shortly.

A parallel investigation necessary to realization of the diplexer circuits involved careful measurement of the stripline characteristic impedance and velocity factor. This was accomplished by making up different lengths of shorted line and resonating each length with a standard capacitor. The resonant frequencies were determined by means of a sweeper, a frequency standard, and a coupling loop. For the 1/16-inch-thick epoxy-fiberglass board and 1/16-inch conductor width employed, the characteristic impedance and velocity factor turned out to be, respectively, 74 ohms and 0.56.

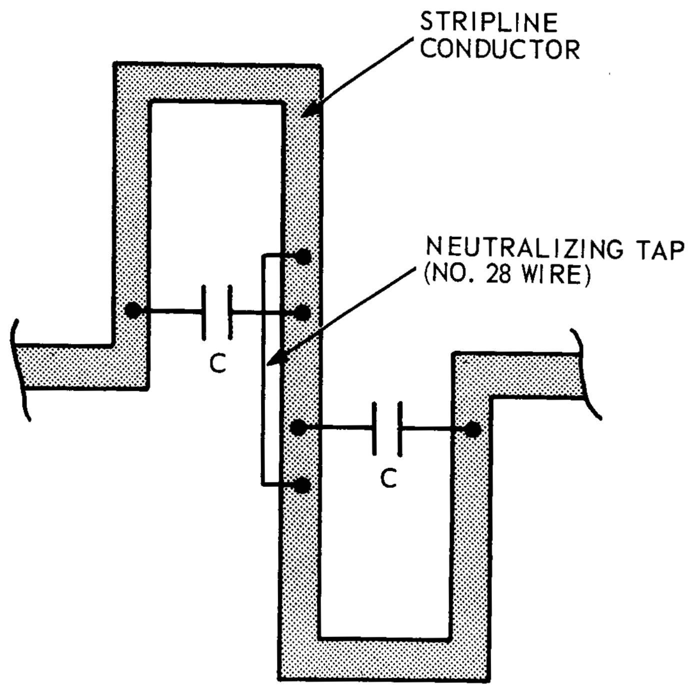


Figure 4. Diagram of Receiver Circuit

2.6 DC Power Supplies

After careful evaluation, it has been concluded that the use of thin-film circuits in the power supplies is impractical. The supplies will require some large value capacitors and transformers in order to be reasonably efficient. These cannot be fabricated with thin films at the present state of the art. The supplies will also require some transistors of relatively large power and size, as well as several normal size transistors and diodes. It is doubtful that there would be any space saving and there would be very little weight saved by substituting thin-film resistors and smaller value capacitors for their discrete counterparts, when compared to the weight and space required by the discrete components that must be used.

In view of this, it has been decided that the power supplies will be purchased and will consist entirely of discrete components.

Several supplies are presently under consideration. The size, weight, and shape will be decided by the end of January, so that the final package design can be started. The order will be placed as soon as the optimum voltages are determined. This will be accomplished after the first transmitter and receiver and the telemetry subsystem have been completed and have been tested together in both the simplex and duplex modes. This is scheduled for the third week of February.

2.7 Purchased Parts

All of the necessary purchased components and modules have been procured except the dc power supplies, coax (relay) switch, mode switch, antenna connector, and a multiple pin connector for dc and audio frequency signals. The multiple pin connector will be used for power input from the battery, the seven telemetry input signals, and the microphone and headset audio frequency signals.

All purchased parts should be available by the end of February except the coax switches and power supplies which are not expected until the middle of March. The coax switches have been ordered and should be received within 60 days. The dc supplies will be ordered after initial system tests, scheduled for the second week of February; delivery is expected to be within 30 days. Most of the system testing, however, can be performed before the coax switches and power supplies arrive.

2.8 Final Package Design

Final design of the printed circuit (mother) board to which the modules will be connected and the case for the transceiver and telemetry system is scheduled to start at the end of January.

The final configurations of the metallic containers used to house the RF portions of the receiver and transmitter for shielding purposes must be determined before the final package can be designed. The same applies to the power supply modules, switches, and connectors. Design and fabrication of boards and cases is estimated to require one month.

2.9 Integrated Thin-Film Audio Amplifier

A completely thin-film "5006-11 audio amplifier - transmitter" was constructed in order to test the operation and stability of the CdSe TFT in the audio circuit. Recently, under a contract with the Naval Air Systems Command,[1] techniques were developed for stabilizing the TFT for operation up to approximately 40° C. The TFT's used in the circuit were first stabilized according to the process described in the Third Quarterly Report of that contract and then attached to the circuit substrate with a silicone compound (Humiseal 1H34). After the circuit resistors were trimmed to their appropriate values, the entire circuit was coated in Humiseal 1H34 and pre-aged (unoperating) in air at 125° C for 8 hours. The performance of the circuit was unaffected by the aging period indicating an allowable storage temperature of up to 125° C.

The circuit is operated at room temperature with a drain and bias supply of +12 V and +2 V, respectively. The frequency response curve is shown in Figure 5. The input signal is maintained at 15 millivolts peak-to-peak for a maximum linear output signal of approximately 6 V peak-to-peak and a maximum voltage gain of 400. The operating frequency range is from 250 Hz to 30 kHz.

Each stage of the amplifier has a midfrequency voltage gain of about 10. A total gain for the 3 stages of about 1000 is not realized, however, due to the coupling

1. Third Quarterly Report on Thin-Film Monotronics, submitted to U. S. Dept. of the Navy, Naval Air Systems Command, Washington, D. C., Contract No. N00019-67-C-0405.

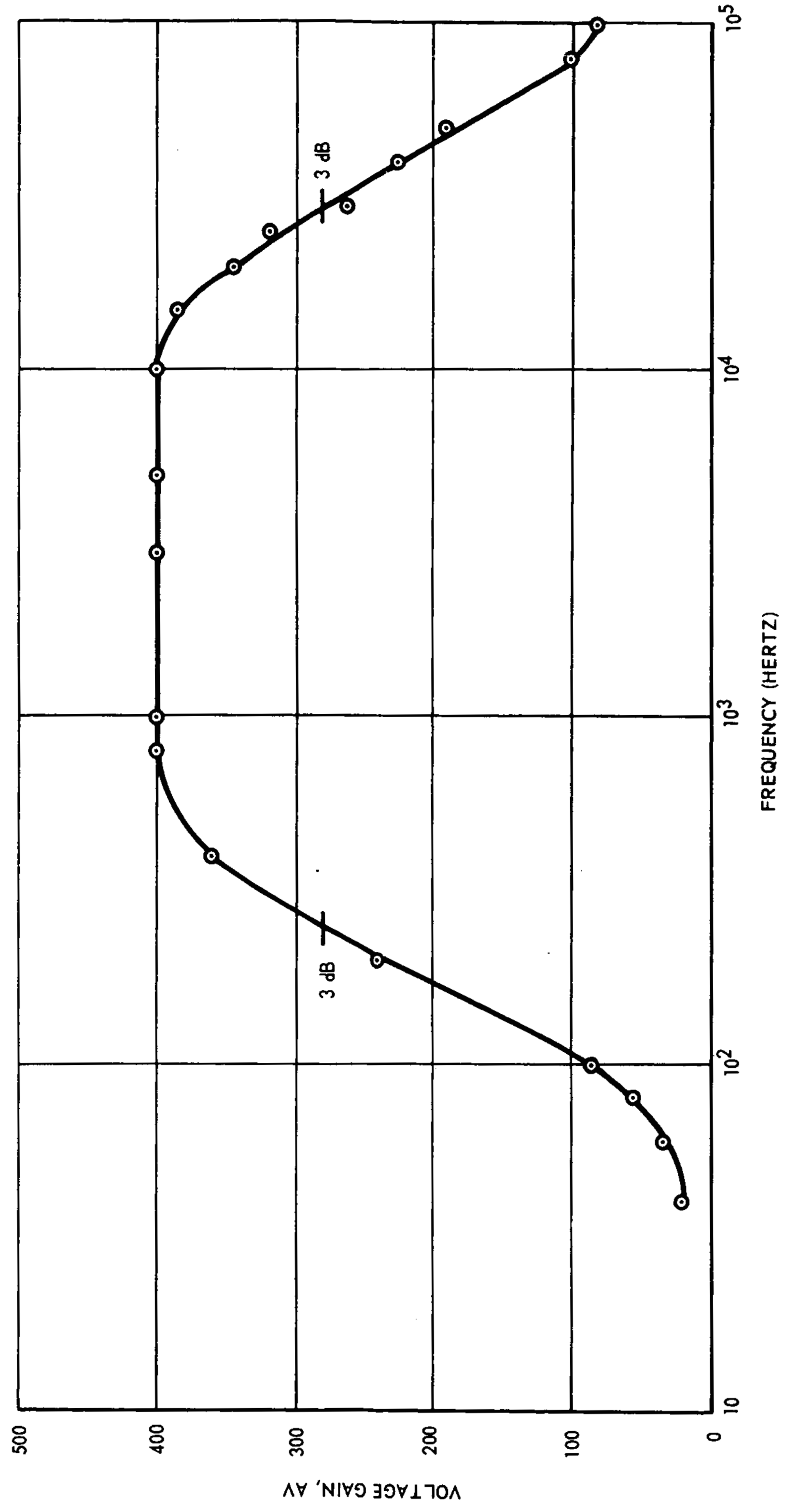


Figure 5. Frequency Response Curve of an Integrated Thin-Film Audio Amplifier

attenuation caused by the Miller capacitance of the TFT. No precaution was taken to reduce the gate-to-drain capacitance, C_{gd}, since these TFT's were fabricated for stabilization studies rather than circuit application. C_{gd} generally ranged from 25 to 30 pf giving a coupling attenuation per stage of about 0.8. Hence for the three stages, there is a total attenuation of about 0.5. The total midfrequency gain could therefore not exceed 500. With a reduction in C_{gd} an amplifier with a midfrequency gain of about 1000 can be constructed.

The circuit is being operated continuously at room temperature with the same bias and signal voltages used for the frequency response measurement. The input signal is maintained at 3 kHz. At present, the amplifier has undergone 1500 hours of continuous operation testing with no change in its characteristics. After 1000 hours, the amplifier was turned off for 48 hours and turned on again with no appreciable change.

3. SCHEDULE

The schedule for the remainder of the program is shown in figure 6. This schedule, although possible, is optimistic. It depends upon completion of development of the RF portions of the receiver and transmitter by the end of January, a high yield of modules during assembly, receipt of purchased parts within the suppliers' stated delivery times, and no unforeseen problems in the design and fabrication of the final package, including the "mother" printed circuit board and case. Delivery of the final system could be as much as two months late. Every effort is being made to meet the original hardware delivery date of 24 March 1968.

			QTY. REQ'D. FOR 2 SYSTEMS	JAN.	FEB.	MAR.
MODULE ASSEMBLY	RECEIVER	RF PORTION	4			
		IF AMPLIFIER NO. 1	4	HAVE 1		
		IF AMPLIFIER NO. 2	4	HAVE 1		
	TRANS-MITTER	RF PORTION	4			
		AUDIO AMPLIFIER	4			
		MODULATOR AND FILTER	4			
	TELEMETRY AND VOX	VOLTAGE-CONTROLLED OSCILLATOR	14			
		TWIN-T-FILTER	6	HAVE 3		
		SUMMING RESISTORS, SOURCE FOLLOWERS, AND COUPLING CAP.	2			
		OPERATIONAL AMP. AND MIXER	2			
		VOICE-OPERATED SWITCH	2			
DIPLEXER DESIGN AND FABRICATION		PROTOTYPE	2			
		FINAL	4			
PRELIMINARY SYSTEM TESTS		SIMPLEX				
		DUPLEX				
PROCURE PURCHASED PARTS:		1. DISCRETE COMPONENTS FOR MODULES		HAVE ENOUGH		
		2. COAX RELAY SWITCH	2			
		3. MODE SWITCH	2			
		4. ANTENNA CONNECTOR	2			
		5. MULTIPLE PIN CONNECTOR	2			
		6. DC POWER SUPPLIES	6			
DESIGN AND FABRICATE MOTHER BOARD AND CASE			2			
ASSEMBLE, TEST, AND DELIVER SYSTEMS			2			

NOTE: ARROWHEADS IN "MODULE ASSEMBLY" PORTION OF SCHEDULE INDICATE COMPLETION DATES OF INDIVIDUAL MODULES.

Figure 6. Schedule

4. PROGRAM PERSONNEL

Listed below are the key personnel involved in this program:

Project Leader:	F. J. Hemmer
Senior Engineers:	V. Grohmann
	W. Gutierrez
	A. Y. Lee
Engineers:	J. J. Giuliani
	W. E. Johnson, Jr.
	S. Muzidal

APPENDIX A

Deposition Masks for Individual Circuits

Universal Amplifier:	Figure A-1
IF Amplifier No. 2:	Figure A-2
Voice-Operated Switch:	Figure A-3

Note: The actual aperture masks used provide for deposition of a batch of several circuits at a time. The number of circuits per batch are:

Universal RF Amplifier:	28
IF Amplifier No. 2:	4
Voice-Operated Switch:	15

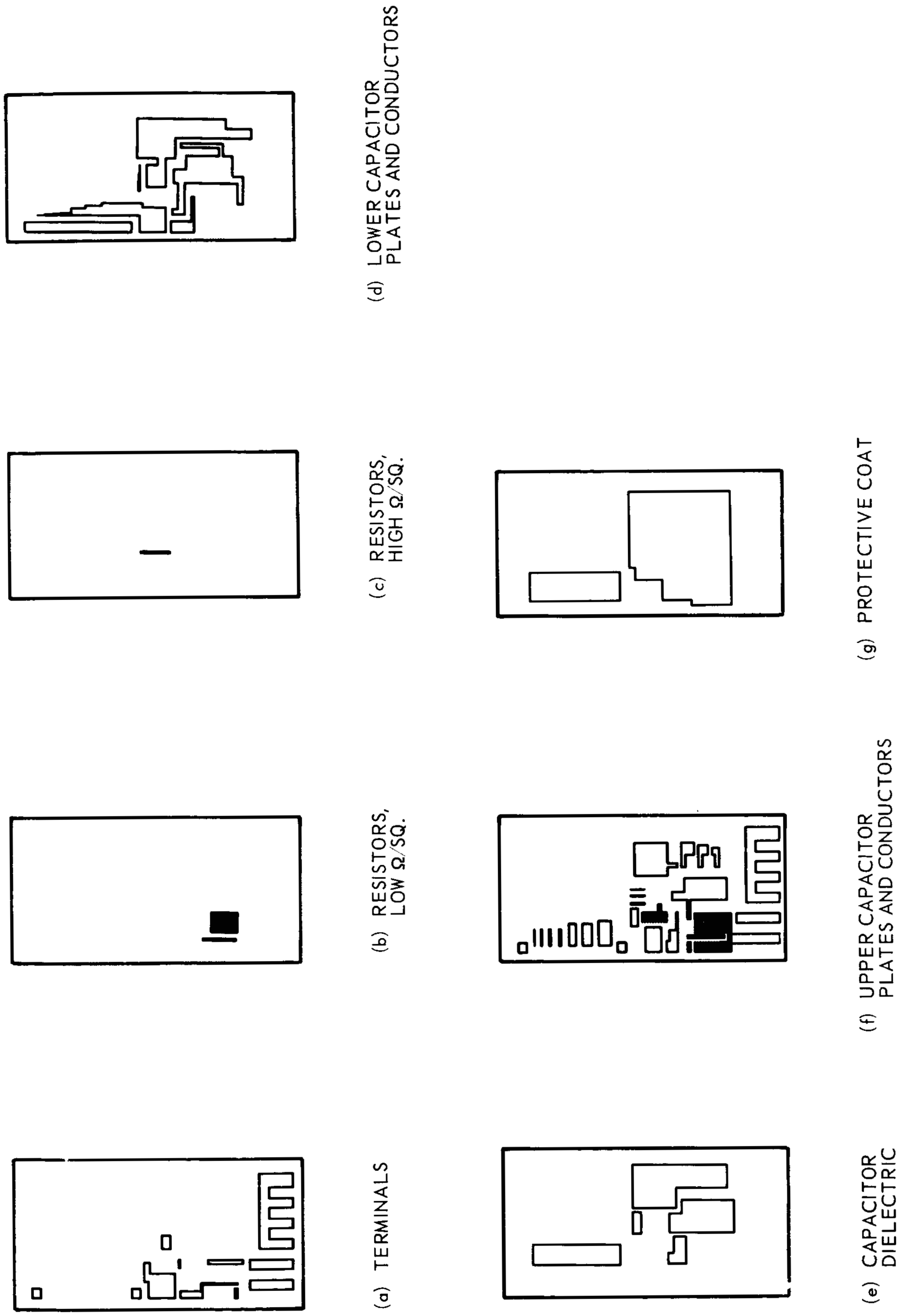
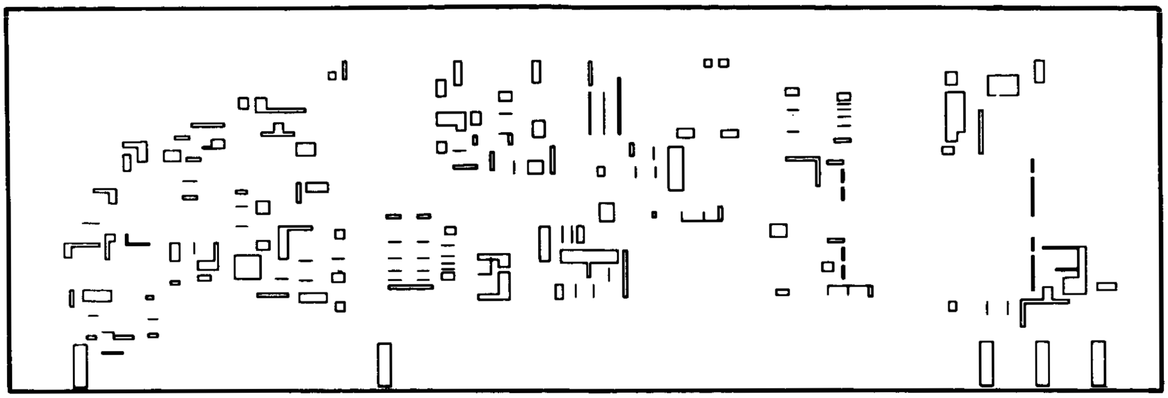
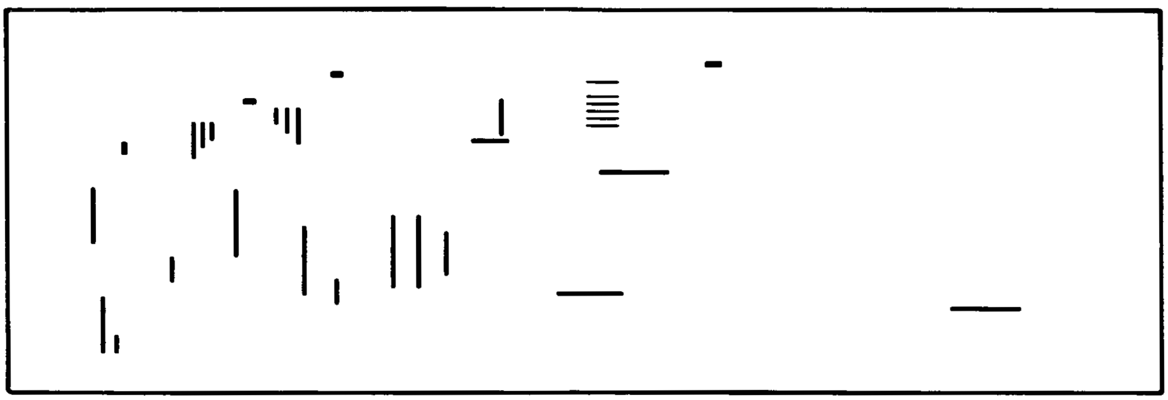


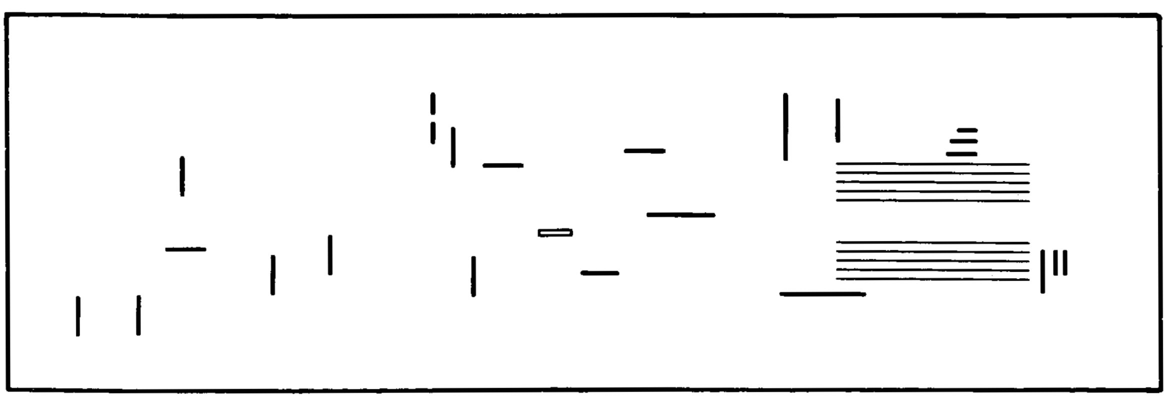
Figure A-1. Deposition Masks, 5006-14 Universal RF Circuit (1" x 0.5")



(a) TERMINALS AND TRIM BARS

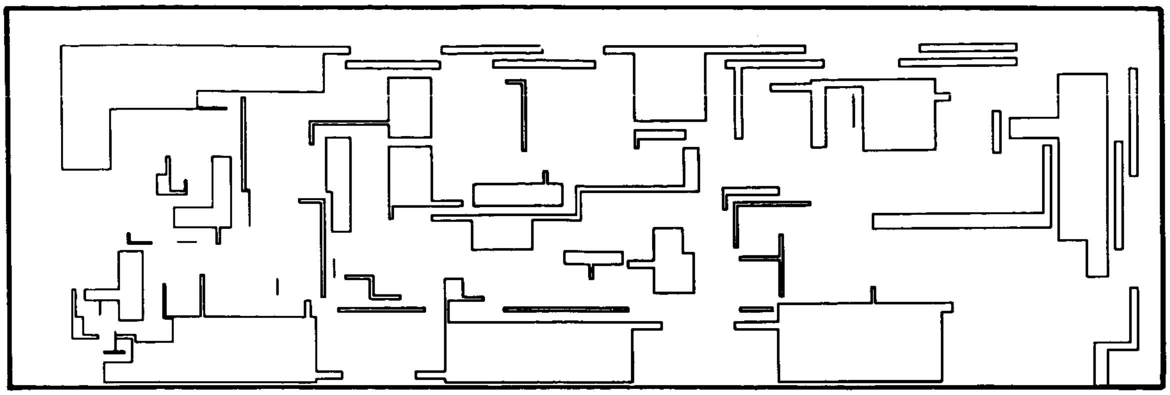


(b) RESISTORS, LOW Ω/SQ.

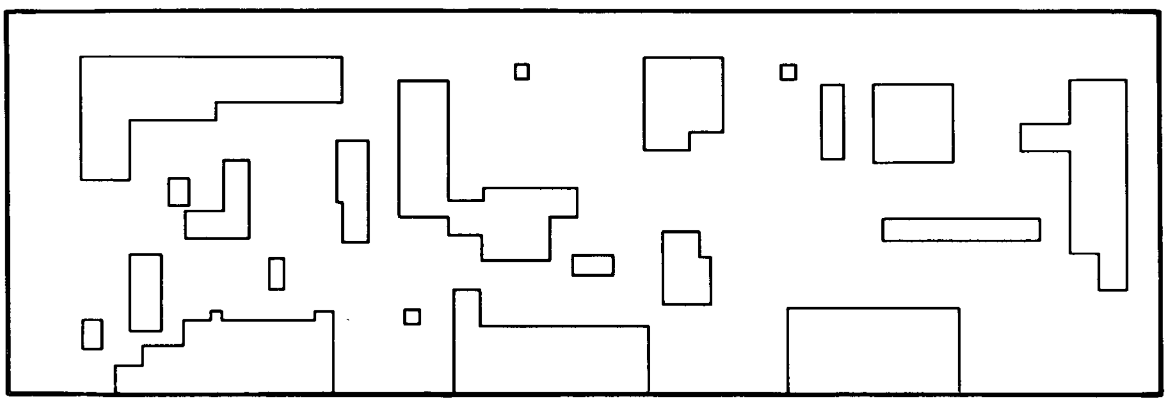


(c) RESISTORS, HIGH Ω/SQ.

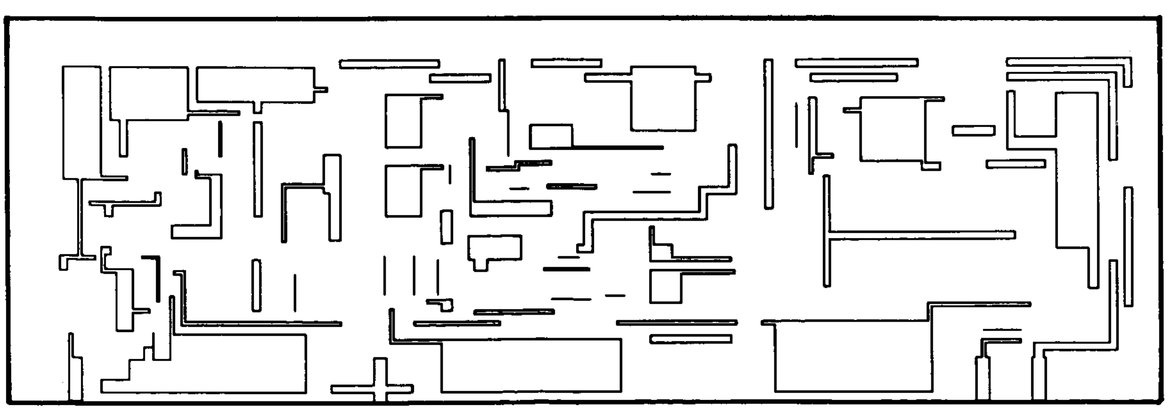
Figure A-2. Deposition Masks, 5006-15 IF Amplifier No. 2 (1" x 3") (Sheet 1 of 3)



(d) LOWER CAPACITOR
PLATES AND CONDUCTORS

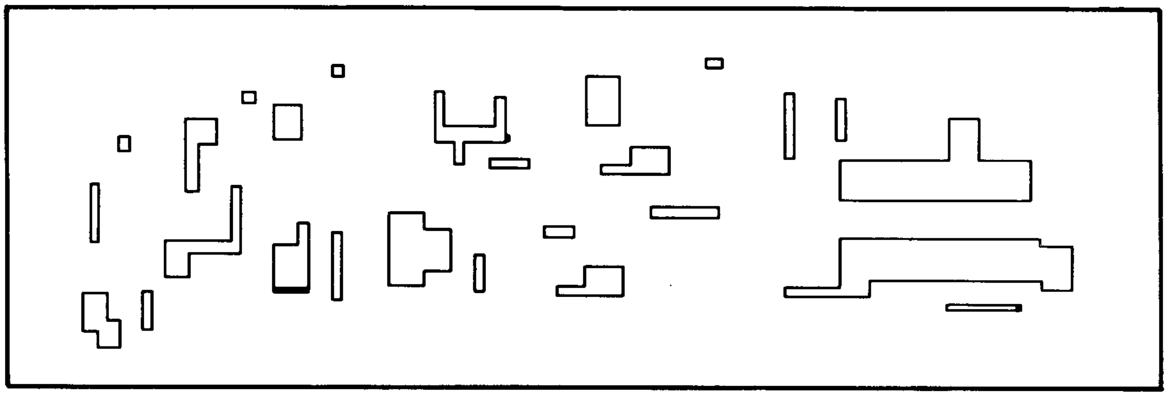


(e) CAPACITOR AND
CROSSOVER DIELECTRIC



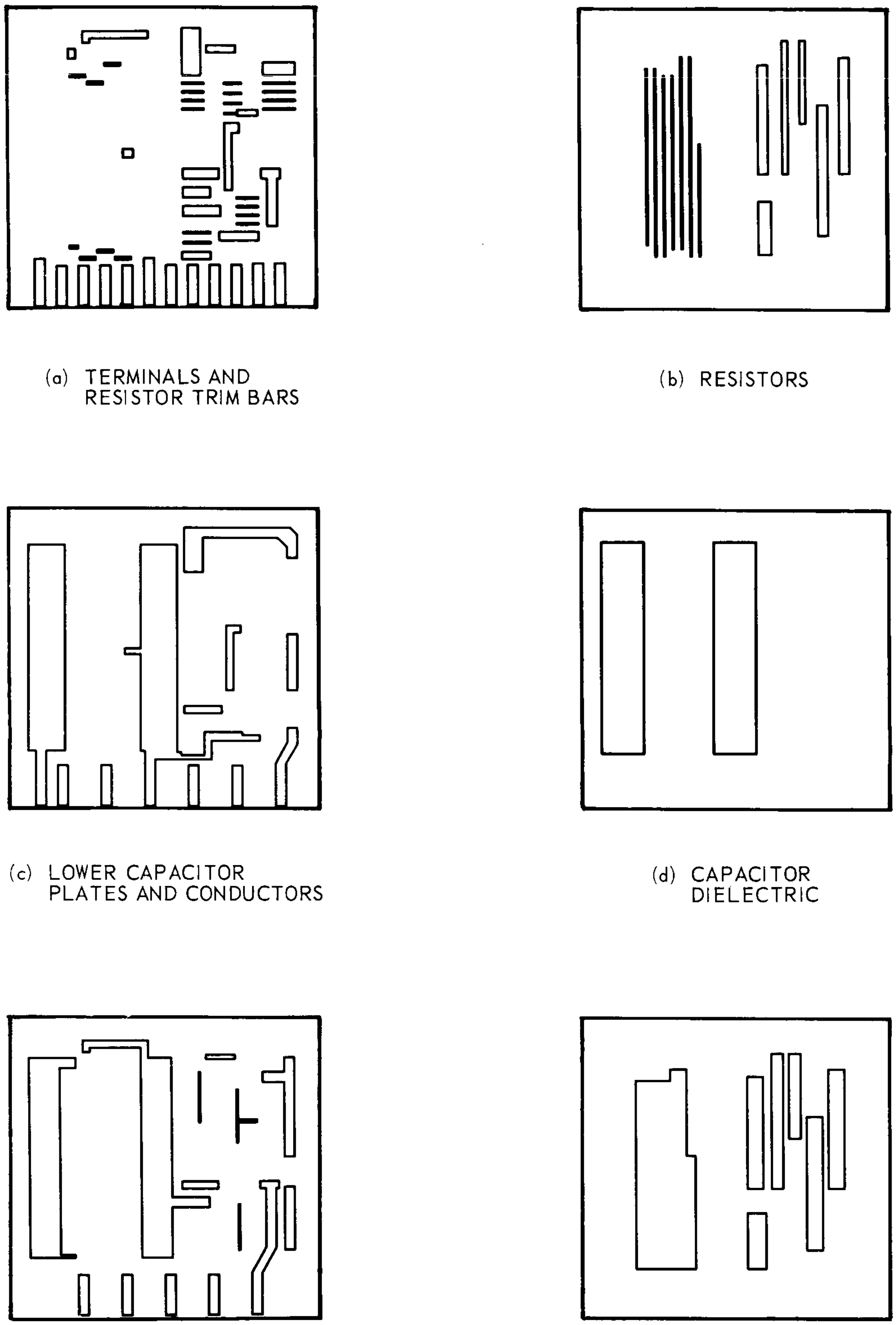
(f) UPPER CAPACITOR
PLATES AND CONDUCTORS

Figure A-2. Deposition Masks, 5006-15 IF Amplifier No. 2 (1" x 3")
(Sheet 2 of 3)



(g) RESISTOR PROTECTIVE FILM

Figure A-2. Deposition Masks, 5006-15 IF Amplifier No. 2 (1" x 3")
(Sheet 3 of 3)



(a) TERMINALS AND RESISTOR TRIM BARS

(b) RESISTORS

(c) LOWER CAPACITOR PLATES AND CONDUCTORS

(d) CAPACITOR DIELECTRIC

(e) UPPER CAPACITOR PLATES AND CONDUCTORS

(f) RESISTOR PROTECTIVE COAT

Figure A-3. Deposition Masks, 5006-16 Voice-Operated Switch (1" x 1")