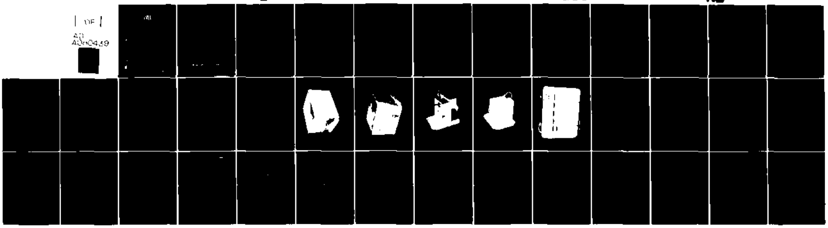
AD-A080 439 TRI-CON ASSOCIATES INC CAMBRIDGE MA F/G 4/1
THE DESIGN OF MASS SPECTROMETER ASSEMBLIES FOR SPACE SHUTTLE LA--ETC(U)
SEP 79 G P MURPHY F19628-78-C-0150
UNCLASSIFIED C-169 AFGL-TR-79-0233 NL

1 OF 1
AD
A080439



END
DATE
FILMED
3-80
DDC

LEVEL II

AFGL-TR-79-0233

THE DESIGN OF MASS SPECTROMETER ASSEMBLIES FOR SPACE SHUTTLE LAUNCHED SATELLITES

George P. Murphy

TRI-CON ASSOCIATES, INC.
765 Concord Avenue
Cambridge, Massachusetts 02138

September 1979

FINAL REPORT: Period Covered June 1978 to September 1979

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFGL-TR-79-0233
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): THE DESIGN OF MASS SPECTROMETER ASSEMBLIES FOR SPACE SHUTTLE LAUNCHED SATELLITES
5. TYPE OF REPORT & PERIOD COVERED: FINAL REPORT, June 1978 to September 1979
6. PERFORMING ORG. REPORT NUMBER: C-169
7. AUTHOR(s): George P. Murphy
8. CONTRACT OR GRANT NUMBER(s): F19628-78-C-0150
9. PERFORMING ORGANIZATION NAME AND ADDRESS: TRI-CON ASSOCIATES, INC., 765 Concord Avenue, Cambridge, Massachusetts 02138
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 61102F, 2310G3AK
11. CONTROLLING OFFICE NAME AND ADDRESS: Air Force Geophysics Laboratories, Hanscom Air Force Base, Massachusetts 01731, Contract Monitor: E. Trzcinski/LKD
12. REPORT DATE: 30 September 1979
13. NUMBER OF PAGES: 33
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report): Approved For Public Release, Distribution Unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): Space Shuttle Launched Satellites
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses the developement of instrumentation to be flown on satellites which will be launched from the space shuttle.

The instrument is a quadrupole Mass Spectrometer designed to measure preselected masses in the 1 AMU to 50 AMU region. A discussion of the various circuits will be included in this report along with a complete set of Schematics and Drawings.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF DRAWINGS

1. INTRODUCTION

The objective of this contract was to Design, Develop and Fabricate three mass spectrometer assemblies to be used for ion composition studies during the Space Shuttle Program.

This report discusses the operation of the electronic circuits, and the mechanical layout of what is referred to as the "LASSII" Mass Spectrometer Experiment.

There are two packages to each instrument, one referred to as the Electronics Package and the other referred to as the Sensor Package.

The Sensor Package does contain some of the electronics discussed in this report such as the electrometer amplifiers, RF Oscillator and High Voltage Power Supply.

2. INSTRUMENT DESCRIPTION

The electronic portion of a quadrupole mass spectrometer consists of the following sub-assemblies.

(1) Electrometer amplifiers for measuring the very small signal currents, derived from an electron multiplier.

(2) A programmer to select the masses to be measured and the order in which they are sampled.

(3) The DC amplifier and RF oscillator which supply the signals to the quadrupole rods that are necessary for mass focussing.

(4) The high voltage power supply for the electron multiplier biasing.

(5) The housekeeping and monitor circuits.

(6) The low voltage converter power suppiy.

(7) Test Console.

2.1 Electrometer Amplifiers

The schematic for the two logarithmic amplifiers used to measure the spectra data and aperture current is shown on Drawing D-873.

The amplifiers have a logarithmic transfer characteristic and provide an output voltage of from zero to five volts for an input current range of $5X10^{-11}$ amps to $5X10^{-6}$ amps. The transfer function of a typical logarithmic amplifier is plotted on 5 cycle Lin-Log paper as shown in Figure 2.

The amplifiers are designed around very high input impedance (10^{15}ohms) integrated operational amplifiers. This design uses Intersil ICH 8500A amplifiers and are designated U_1 and U_5 on Drawing D-873.

The logarithmic characteristic is obtained from the relationship between the collector current and the emitter base voltage of standard junction transistors.

The base emitter voltage changes approximately 58 millivolts for every decade change of input current at 25^oC. The 58 millivolts is amplified by use of a β network consisting of R_2, R_4, and S_1 so that the output presented to telemetry is 1 volt per decade.

The transistors Q_1 and Q_2 are dual NPN, PNP in the same TO-5 can. A dual transistor is used to compensate for the change in the base emitter voltage with temperature.

The compensation is accomplished by holding the collector current in the transistor on the right hand side (Q_1, Q_2) at a constant value. The change in VBE with temperature is approximately 2 millivolts per degree centigrade.

If the right hand side tracks the left hand side a $\frac{\Delta V}{\Delta T}$ change will appear at the common emitter point and not at the output.

To prevent latch up from opposite polarity inputs (spikes, transients etc.) each amplifier has a reverse polarity limiter.

For the spectra electronics Q_3 will conduct and prevent the amplifier from going into an "open loop" state in the event of a positive input current.

In the aperture electronics, diode CR_6 serves the same purpose for negative input current.

Each electrometer has a buffer amplifier for voltage level shifting into the telemetry range of 0 to 5 volts, and also to provide isolation from long lines.

2.2 Programmer

The LASSII Mass Spectrometer Programmer is designed to have five modes, any one of which can be selected by ground command. The contract work statement requested that the first four modes were to be sit modes while the fifth mode would scan up to 32 different masses. A design change was introduced into the programmer such that the four sit modes can also be used as mini-scan modes. A selection of from one to eight different masses can now be programmed in modes 1 through 1V.

The mode selection is accomplished through the ground control to spacecraft command link and stored in the experiment on latching relays K_1 to K_4 (Drawing D-1026.)

The relays in turn change the operation of the digital logic to produce the five different modes.

The digital logic and memory (Drawing D-1026) are used to control the voltage output of a 10 bit digital to analog converter U_9. A particular voltage output from U_9 can be related to a particular mass, and it is this parameter that is controlled in the process of mass selection.

For laboratory adjustments a ten bit binary counter U_8 is used to produce a linear sweep output from the digital to analog converter U_9.

When the programmer is in the mode selectable operation, the DAC is controlled by a pair of PROMS U_6 and U_7.

The PROMS U_6 and U_7 are in turn controlled or addressed by either the counter U_5 and U_6 or by another PROM U_3.

PROMS U_6 and U_7 have data stored in them which relates to the selected masses. The PROM can store up to 32 mass positions and will probably be programmed to generate the MODE V "All Masses of Interest" scan.

The mode V scan will be generated by the binary counter U_4 and U_5 sequencing through the 32 address of memories U_6 and U_7.

In modes I through IV the counter U_4 and U_5 is inhibited and the data presented at the jam inputs of U_4 and U_5, appears at the outputs. Therefore, the address of memories U_6 and U_7 can be stored as data in memory U_3. Memory U_3 is controlled by the command logic relays and a counter U_{15}. The counter allows for up to eight different masses in modes I through IV. If only one mass is desired then U_3 will be programmed with the same data at eight different positions.

Also included in the programmer is a ten bit staircase which is generated by U_{14} and U_{11}. This output can be superimposed on the mass selection analog voltage, at the rate of ten increments per unit mass scan.

The mass scan is stepped along at a rate of 10 ms per mass step, and the staircase at 1 increment per ms.

2.3.1 DC Amplifiers

The DC amplifiers (Drawing D-1028) supply equal but opposite polarity voltages to the quadrupole rods. The voltage amplitude depends on the particular mass to be focussed and must be maintained at a fixed ratio relative to the peak RF amplitude in order to obtain good mass resolution. The amplifiers are linear and are capable of sweeping from 0 to $\pm$ 60 volts relative to a fixed rod bias of

-15 volts. The circuit is designed around an integrated high voltage operational amplifier such as the Burr Brown type 3582J and are shown schematically as U_2 U_3 on Drawing D-1028.

The input to the DC amplifier is derived from the digital to analog converter which appears in program schematic Drawing D-1026. The output of the DC sweep is divided down by resistors R_{13} and R_{14} and supplied to telemetry in a 0 to 5 volt level by way of 1/4 of the quad operational amplifier U_1.

2.3.2 RF Oscillator

The RF oscillator (Drawing C-857) consists of two sections, the oscillator proper, and the control and monitor section.

The oscillator is a tuned secondary, Hartley oscillator with the frequency being determined by the inductance of the secondary winding and the rod capacitance. The secondary is split and capacitively coupled so that a $\pm$ DC voltage can also be applied to the rods.

The amplitude and power to the oscillator is controlled by the base drive of transistors Q_1 and Q_2. A servo loop consisting of amplifiers U_1, U_2 and U_3 maintain the peak RF amplitude at a fixed ratio relative to the DC. The output of a control winding is peak detected by U_3 and summed into the input of U_1 which in turn supplies the base drive of transistors Q_1 and Q_2. Ferrite beads are used in the oscillator base drive windings and in the control winding to suppress parasitic oscillations. The predominant parasitic is usually about twenty mega hertz for this particular layout.

The oscillator coil is wound on a one inch diameter hollow cylinder of polystyrene and has a turns ratio of 1,2,2,1 in the primary and a 104 turn center tap secondary. The frequency of oscillation is fixed at about 3.5 mega-hertz and the amplitude varied from 0 to 600 volts peak to peak. The oscillator coil is mounted in a shielded cavity and isolated from the rest of the circuits to minimize RF interference. Conductive interference is minimized by use of LC filters in the $\pm$ DC sweep lines, the +28 line and also on the $\pm$ 15 volt lines.

2.4 High Voltage Power Supply

The high voltage power supply is manufactured by Velonex, Inc. of Santa Clara, California.

The power supply is contained in a welded metal can with the dimensions of 1.25" by 1.75 by 1.75. The output is a nominal 3000 volts with a $\pm$ 500 volt adjustment.

The power supply is used to Bias a 20 stage Johnson Laboratory Electron Multiplier Model MM-1. The power supply and electron multiplier are mounted on a plate directly behind the quadrupole rods.

2.5 Monitor Circuits

The monitor circuits provide an insight to the performance of the instrument as a function of time and temperature.

An on board commutator is used to sample various power supply voltages, two temperature indicators and a mode indicator.

The commutator circuit is drawn on Schematic D-1028, and consists of a counter U_6 and a CMOS analog multiplexer U_5. The counter U_6 will be driven by a 1 pulse per second signal supplied by the spacecraft.

The power supply monitors are resistor dividers with operational amplifiers used where level shifting is required.

The temperature monitors were designed around a Fenwal Thermistor Type GA51J11, and are located in each package. The thermistors are purchased with a threaded screw type mount and are attached directly to the aluminum chassis.

A curve of output voltage versus temperature appears in Figure 1.

The mode monitor is a voltage staircase generated by relays K_1 to K_4 and is shown on Schematic D-1026.

2.6 Low Voltage Converter

A low voltage converter is necessary because of the range of the various biases required in the operation of a mass spectrometer.

The input regulator for the power supply (Drawing D-1023) was originally designed as a switching regulator using a Fairchild ua78S40.

Problems in the manufacturing of the ua78S40 resulted in delayed deliveries of the component, and a fixed voltage regulator of the ua78GKM type was installed to prevent delays in the testing of the instruments.

The input to the converter is protected from a reverse polarity being applied by the diodes CR_3 and CR_4. The filter C_1, L_1 and C_2 is used to reduce any conducted interference from the experiment and may be changed during EMI testing.

The transformer is wound on a toroid and potted in a heat conductive epoxie.

The frequency of oscillation for the transformer, with a 20 volt input is about five kilo-hertz.

Post regulators U_2, U_3 and U_4 are used to minimize drift in the low voltage analog circuits.

2.7 Test Console

A test console is supplied with the mass spectrometer experiment to allow for field tests without the need of a large number of test instruments.

The test console will supply the power and timing functions and display mode and data signals received from the experiment.

A photograph of the front panel appears in Figure 5.

Auxilliary jacks are available to allow for more precise measurements of each parameter.

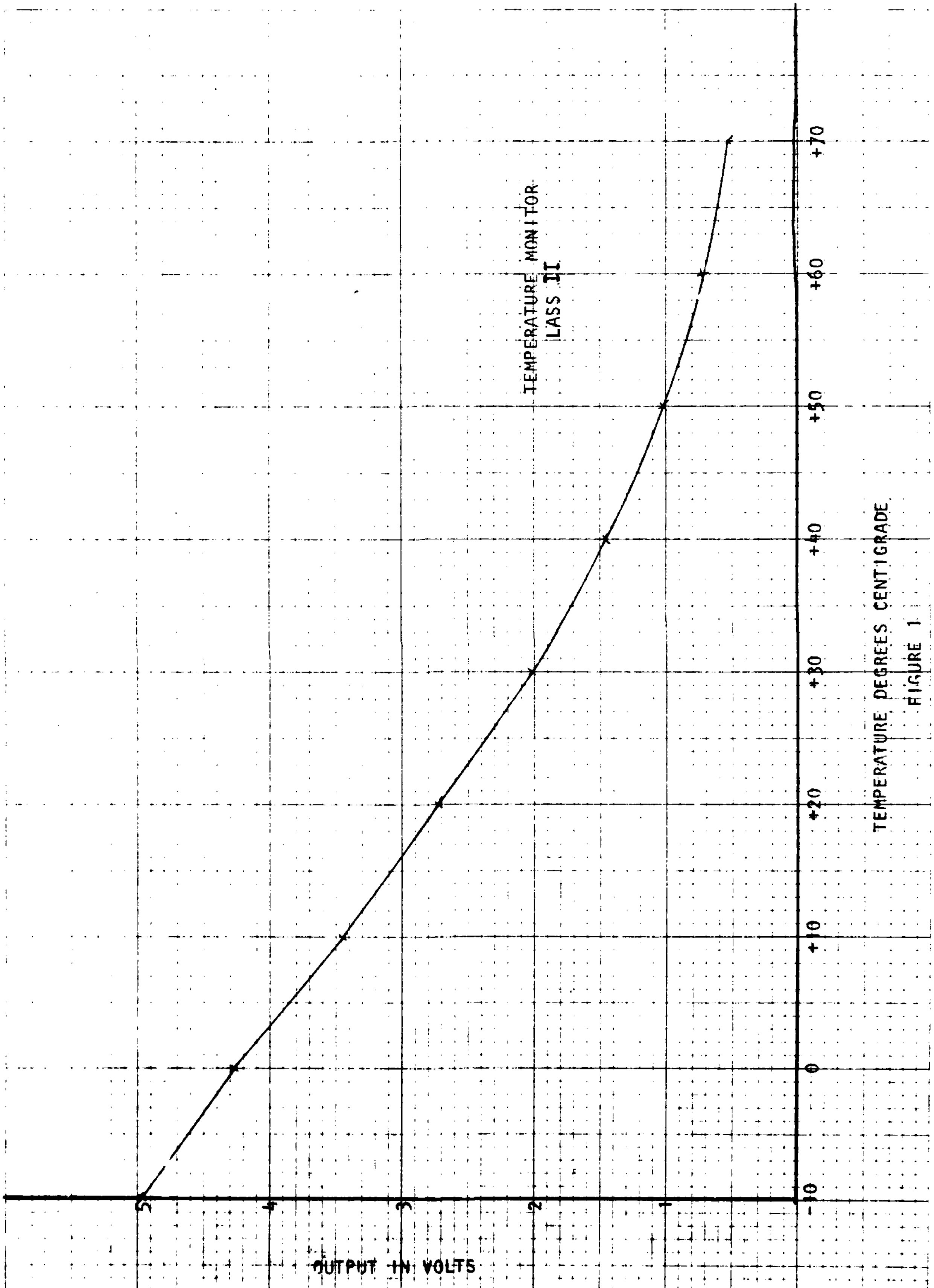

TEMPERATURE MONITOR
LASS II
TEMPERATURE DEGREES CENTIGRADE
-10
0
+10
+20
+30
+40
+50
+60
+70
OUTPUT IN VOLTS
1
2
3
4
5

FIGURE 1

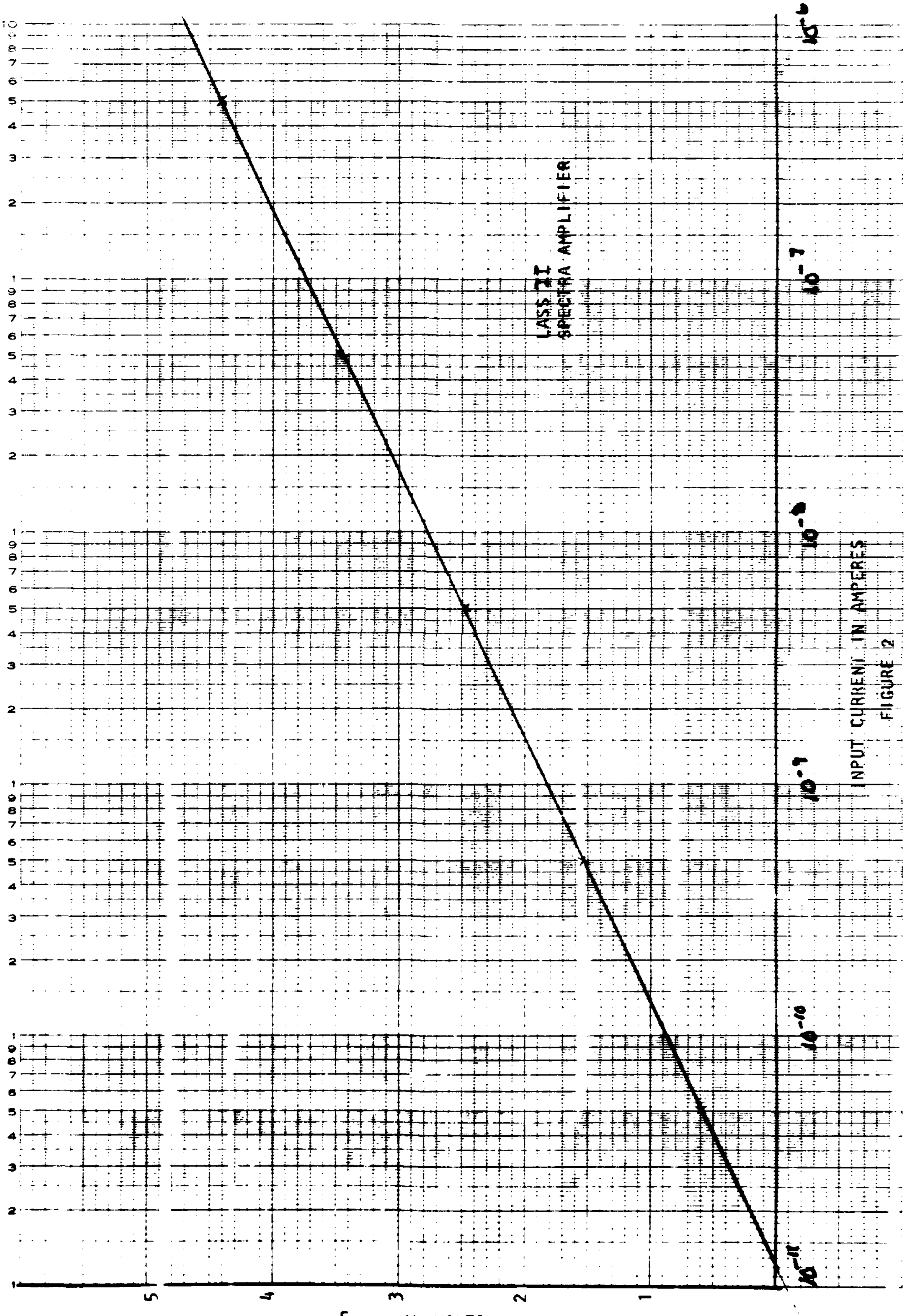
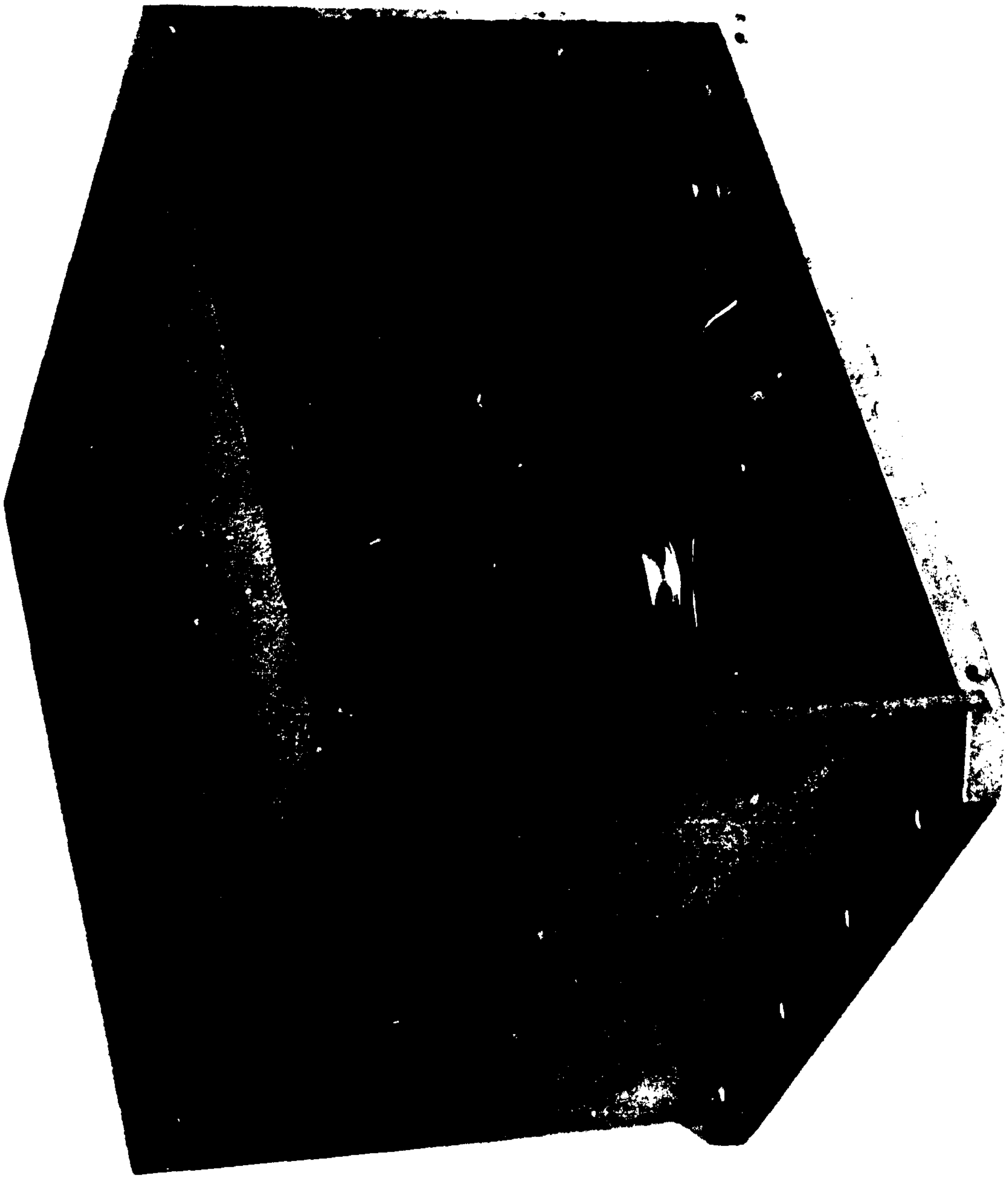
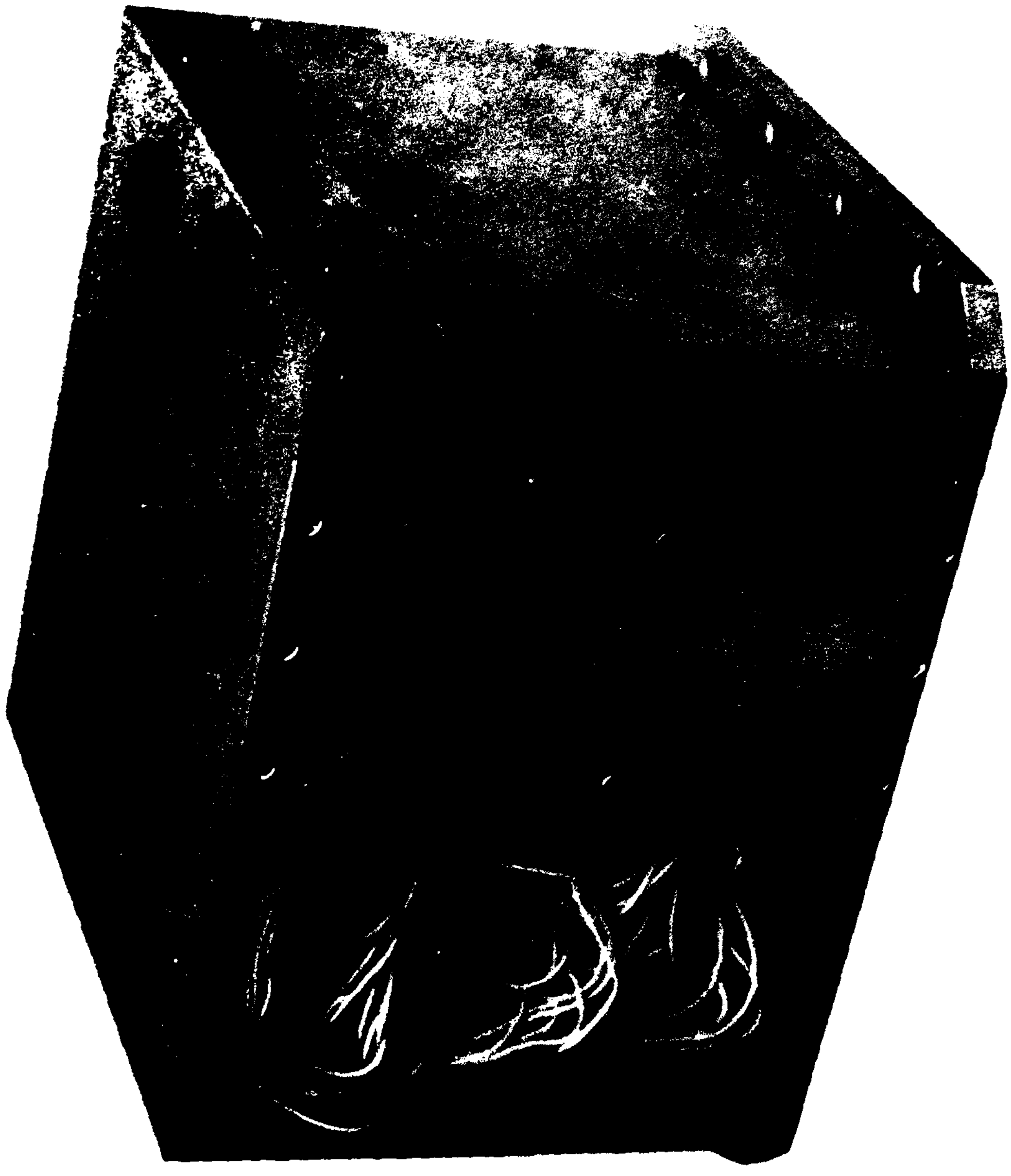

LASS II
SPECTRA AMPLIFIER
INPUT CURRENT IN AMPERES
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
5
4
3
2
1
E_{out} IN VOLTS

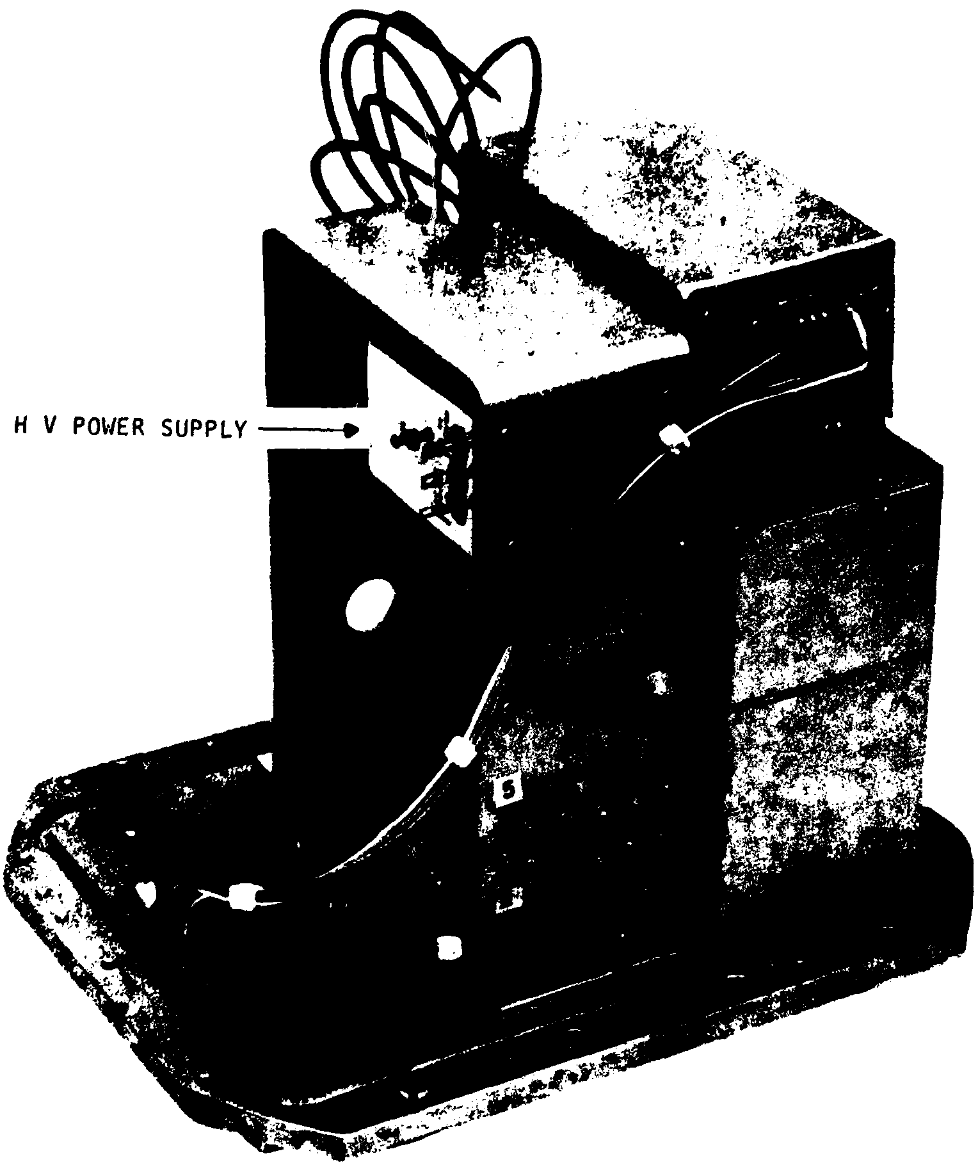
FIGURE 2



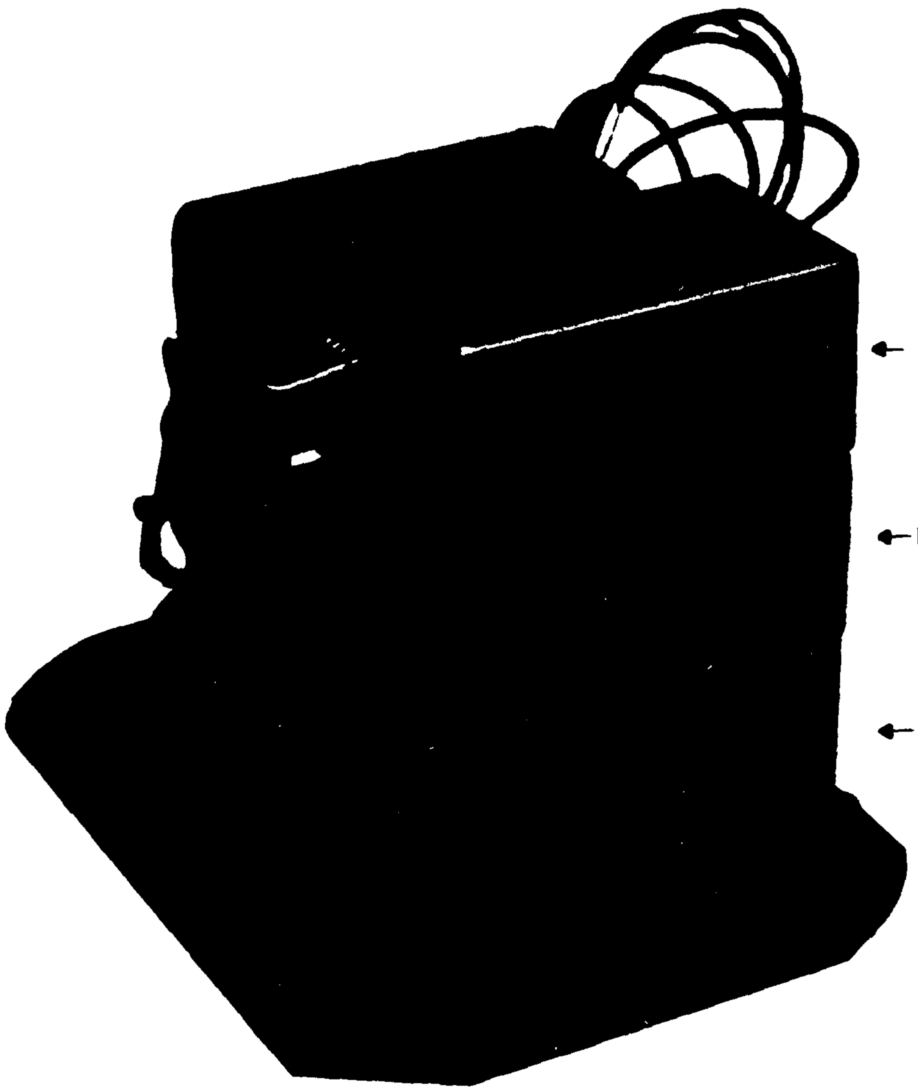
ELECTRONIC BOX FRONT FIGURE 3



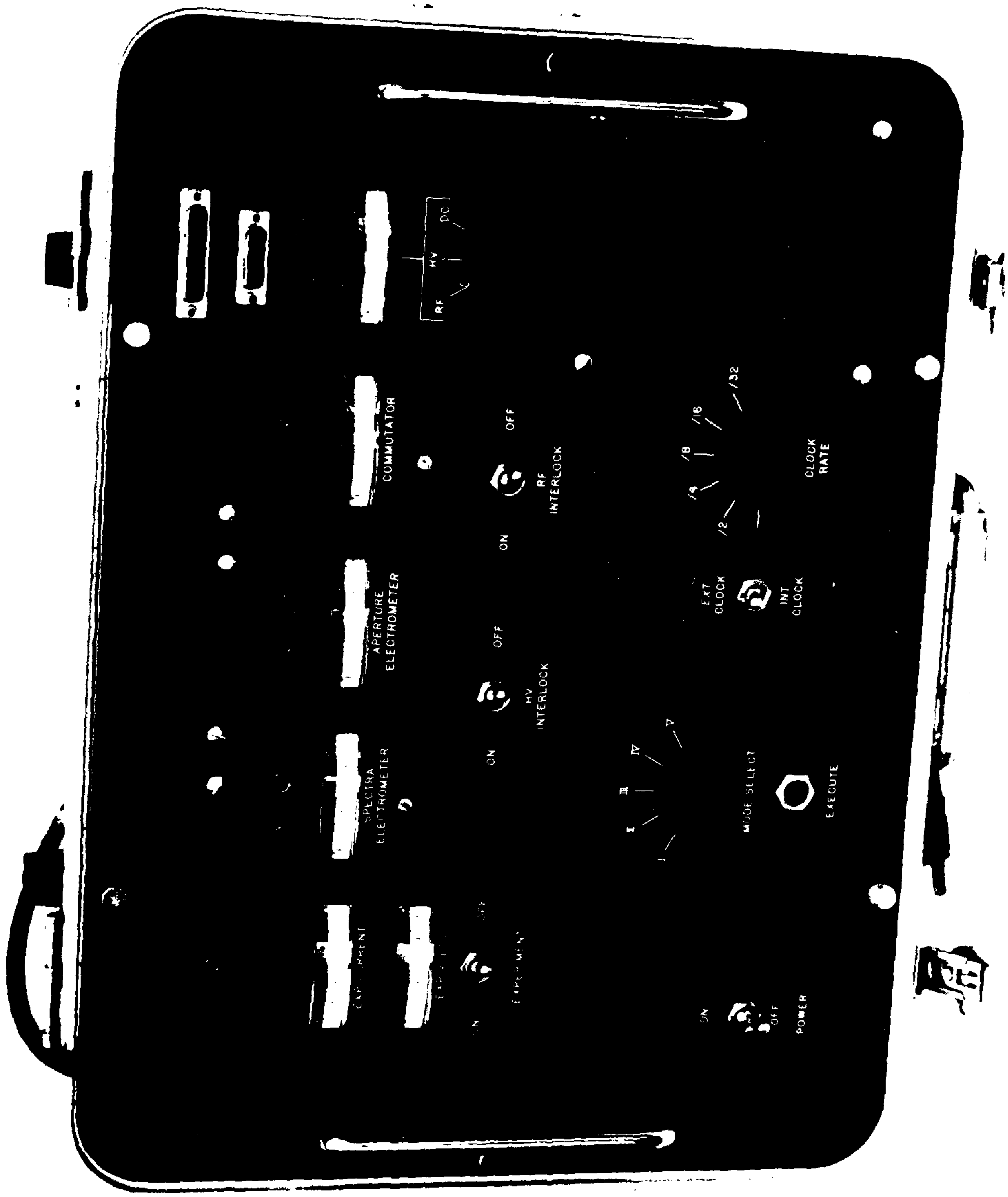
ELECTRONIC BOX REAR FIGURE 3



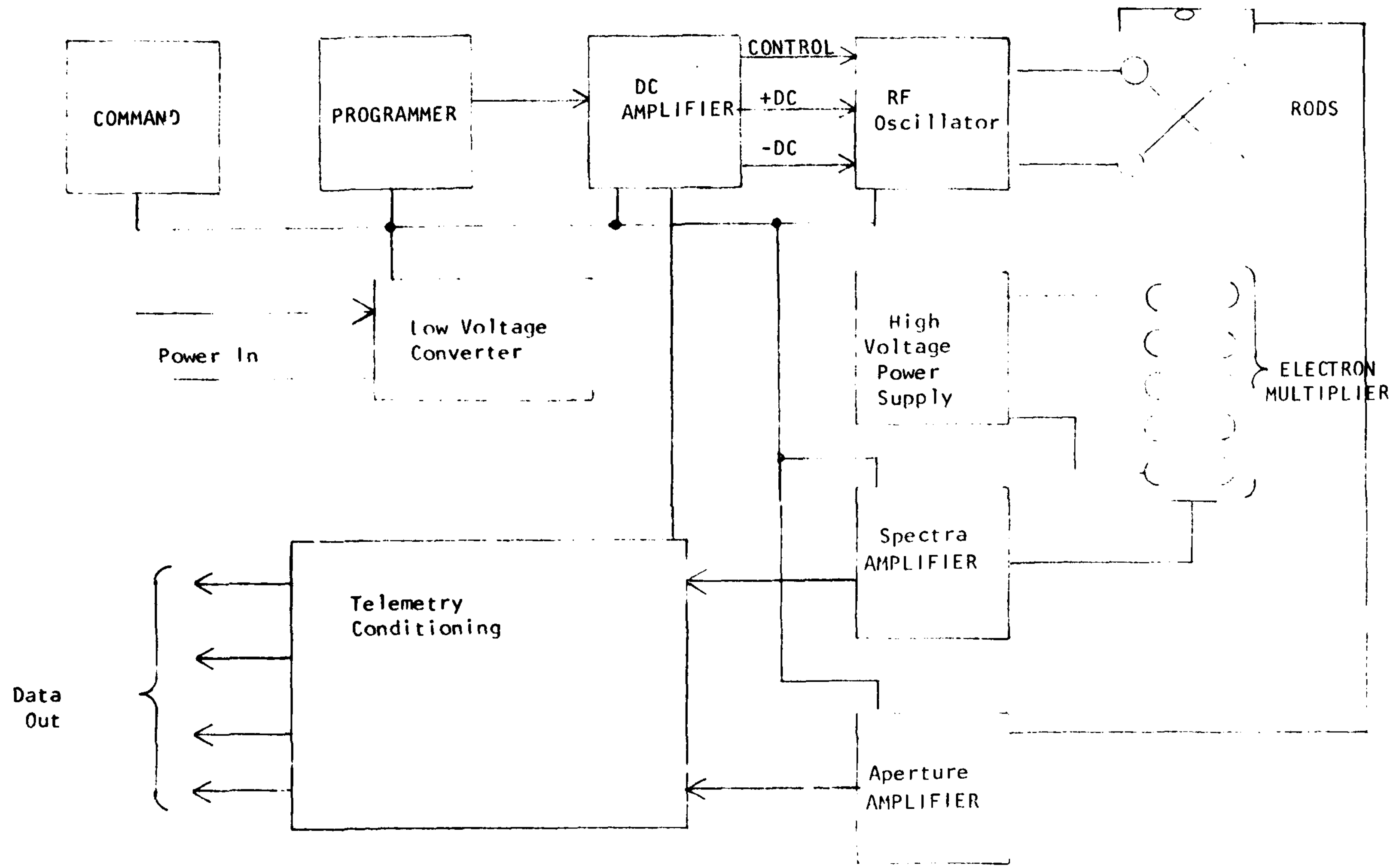
SENSOR PACKAGE FIGURE 4



SENSOR PACKAGE FIGURE 4

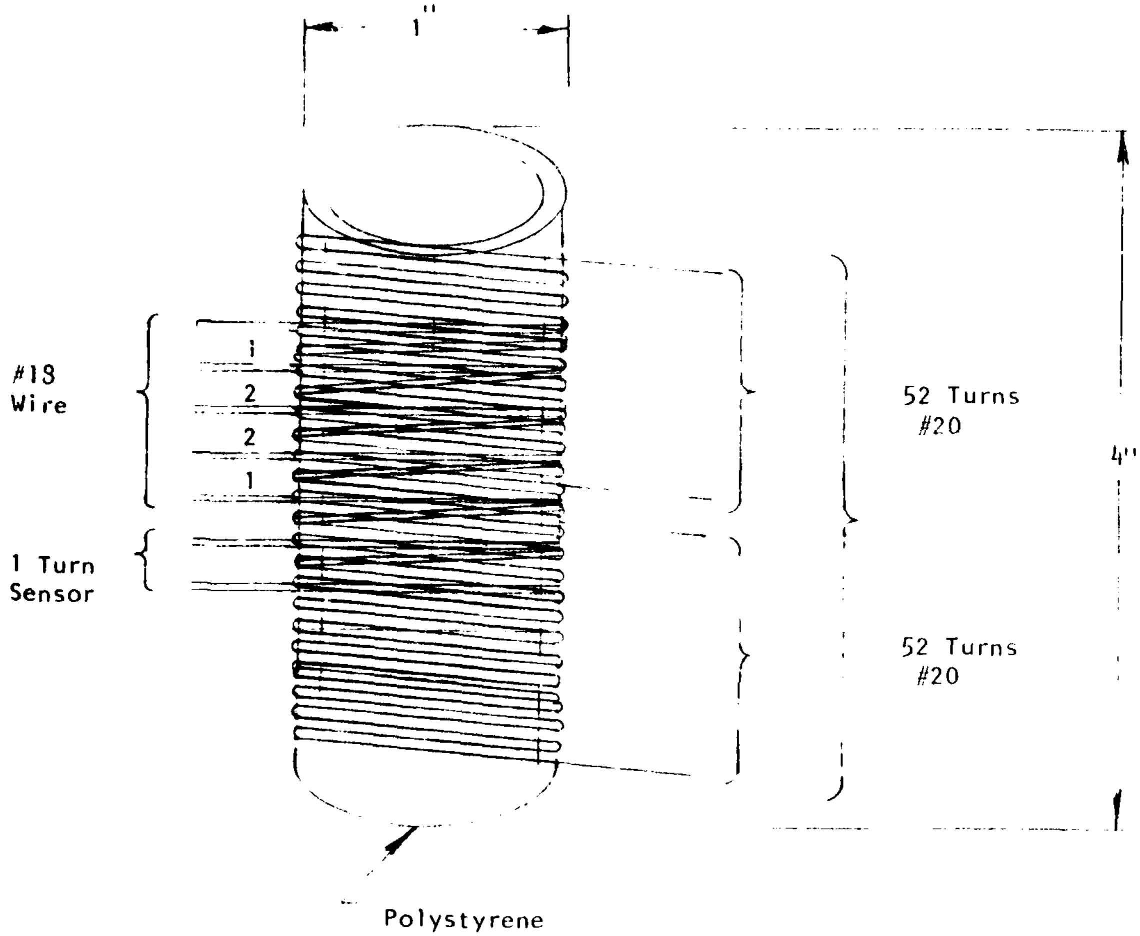


TEST CONSOLE FIGURE 5



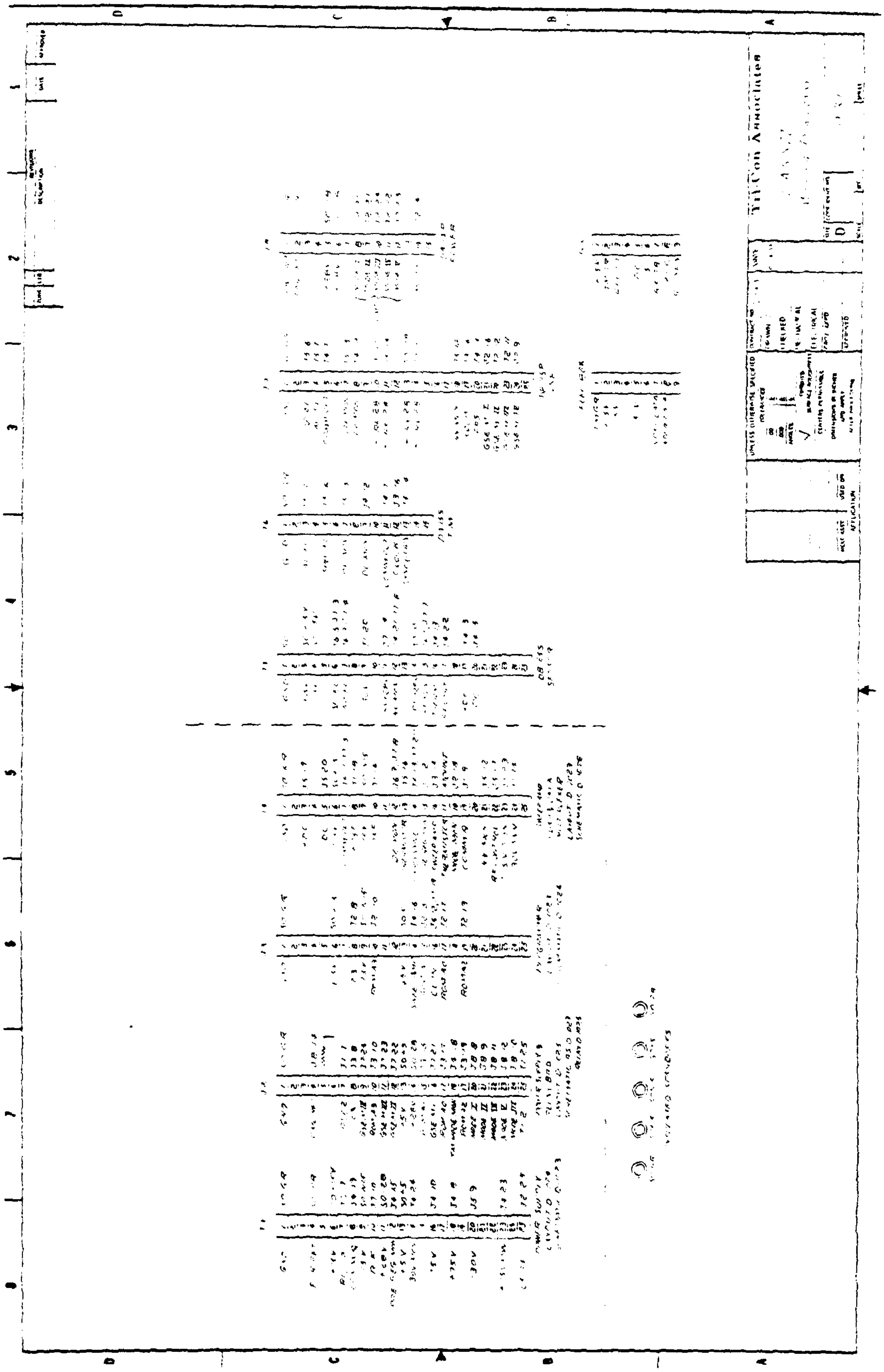
BLOCK DIAGRAM

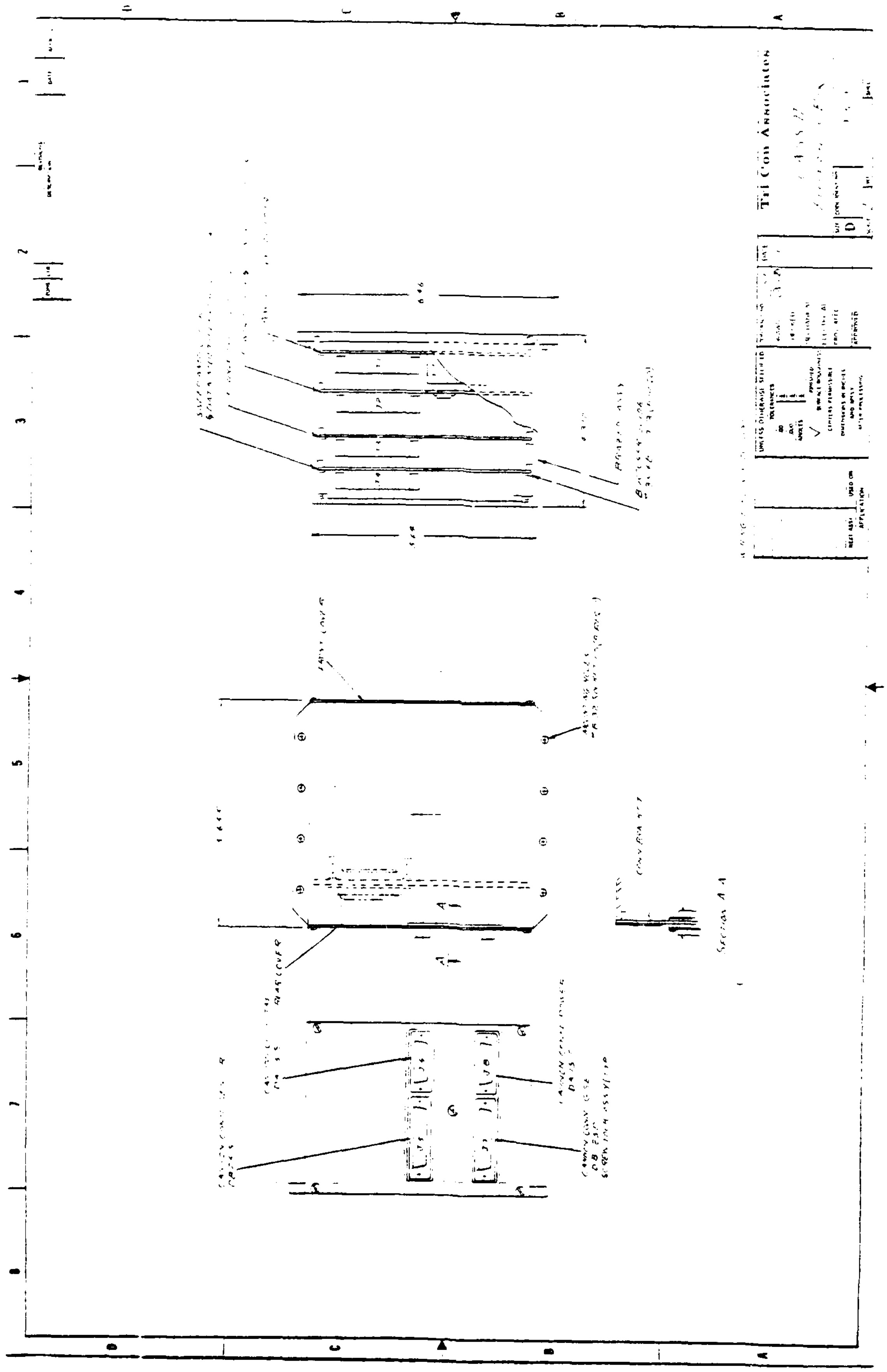
FIGURE 6

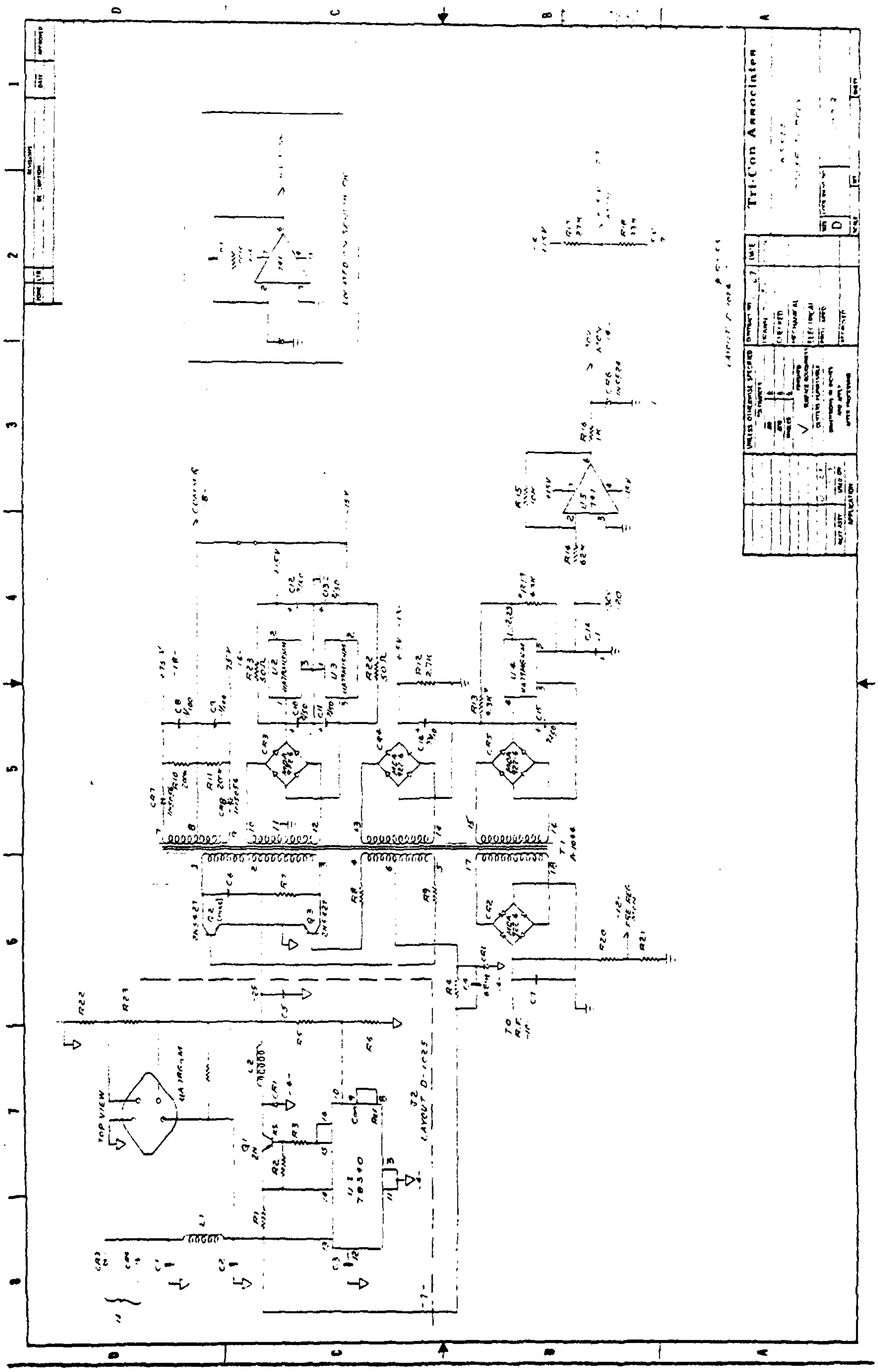


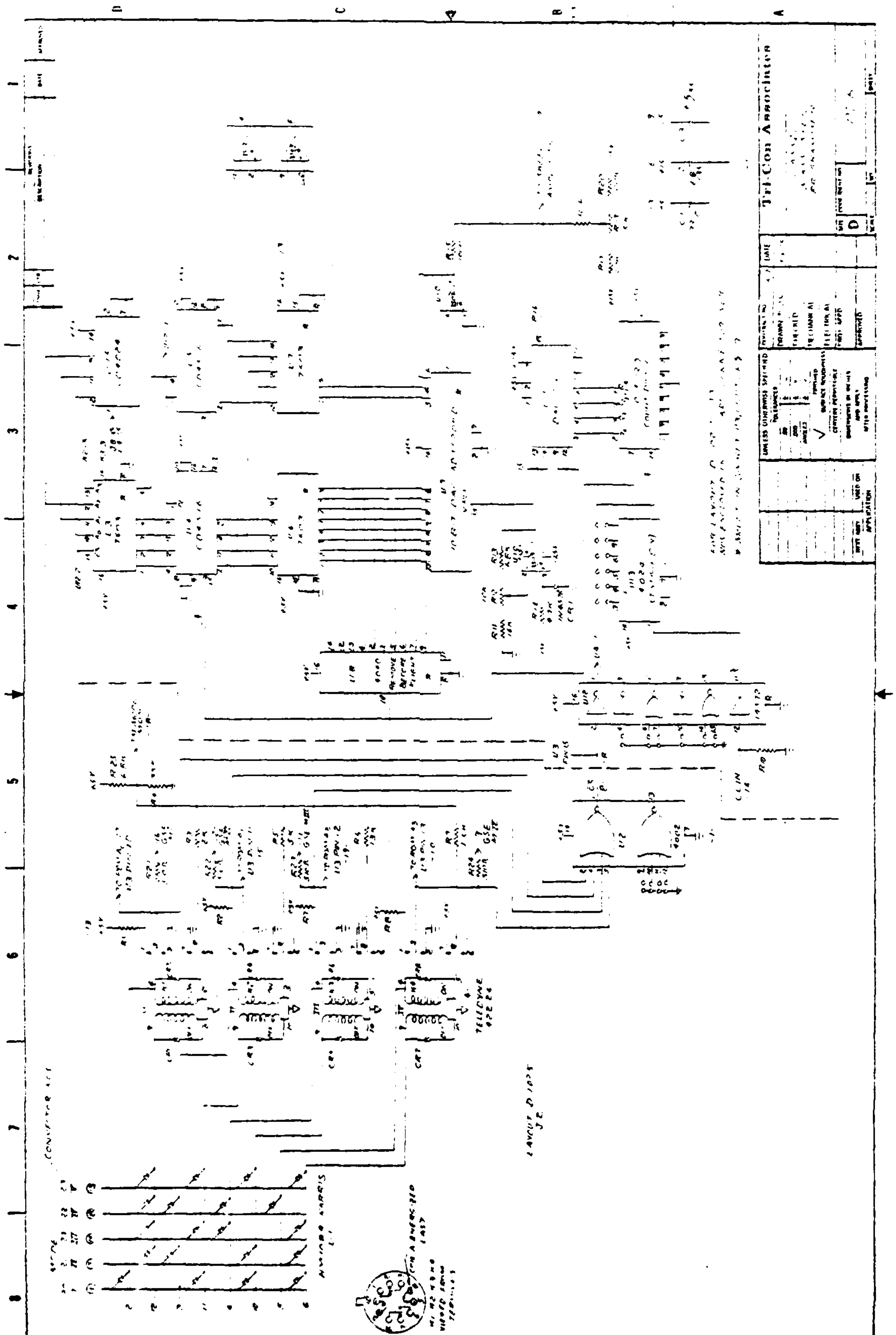
RF OSCILLATOR

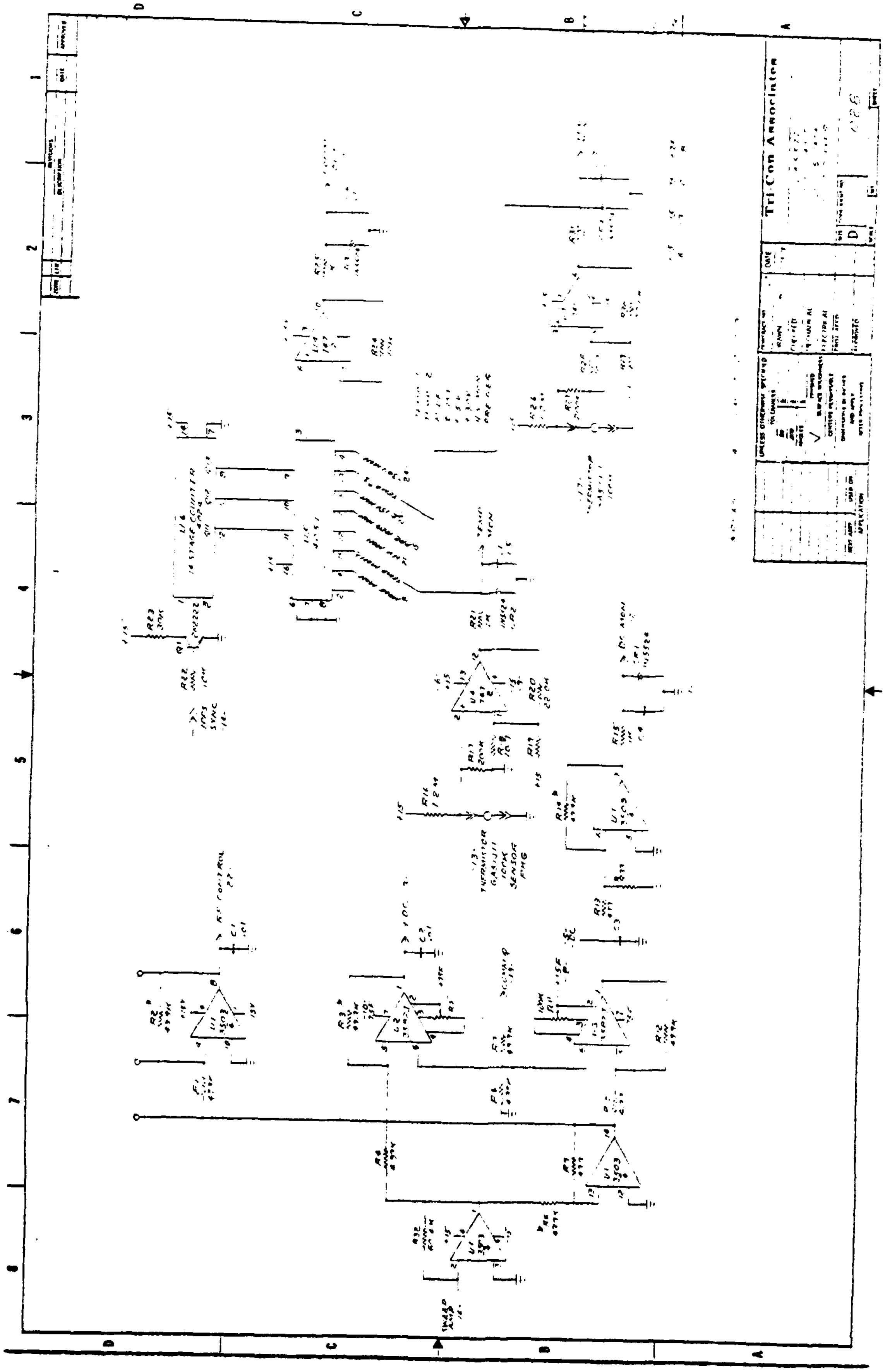
FIGURE 7

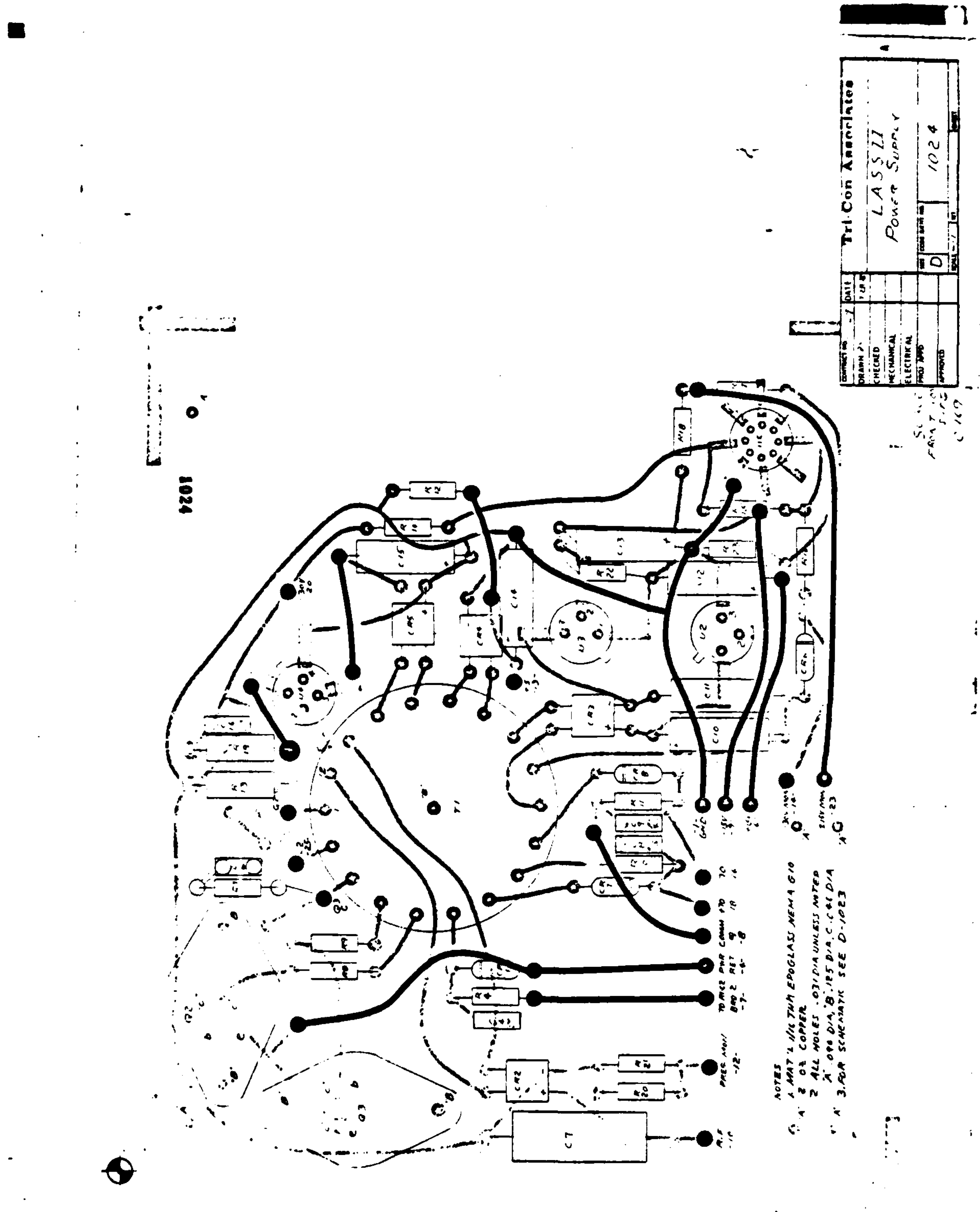


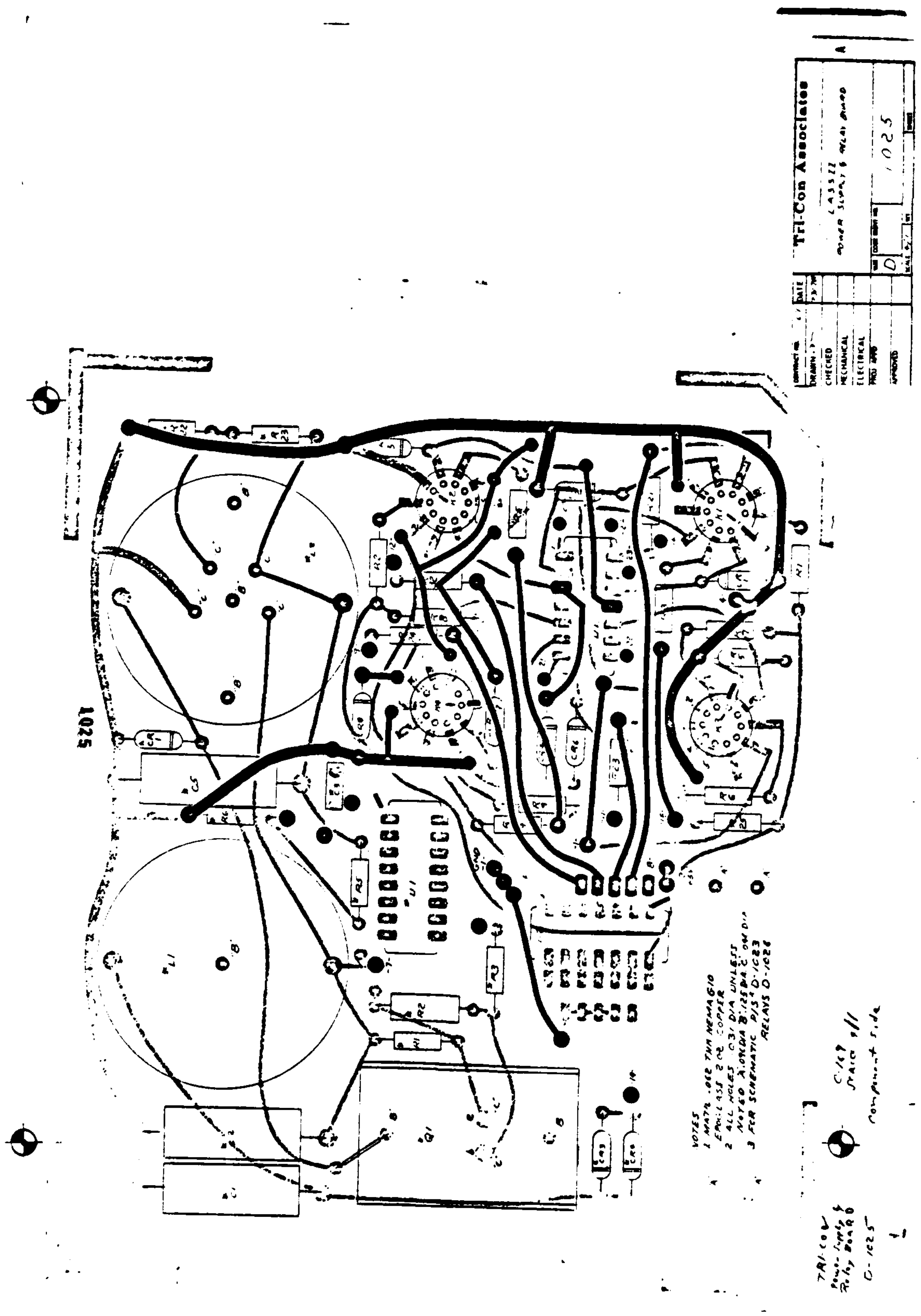

Tri Con Associates



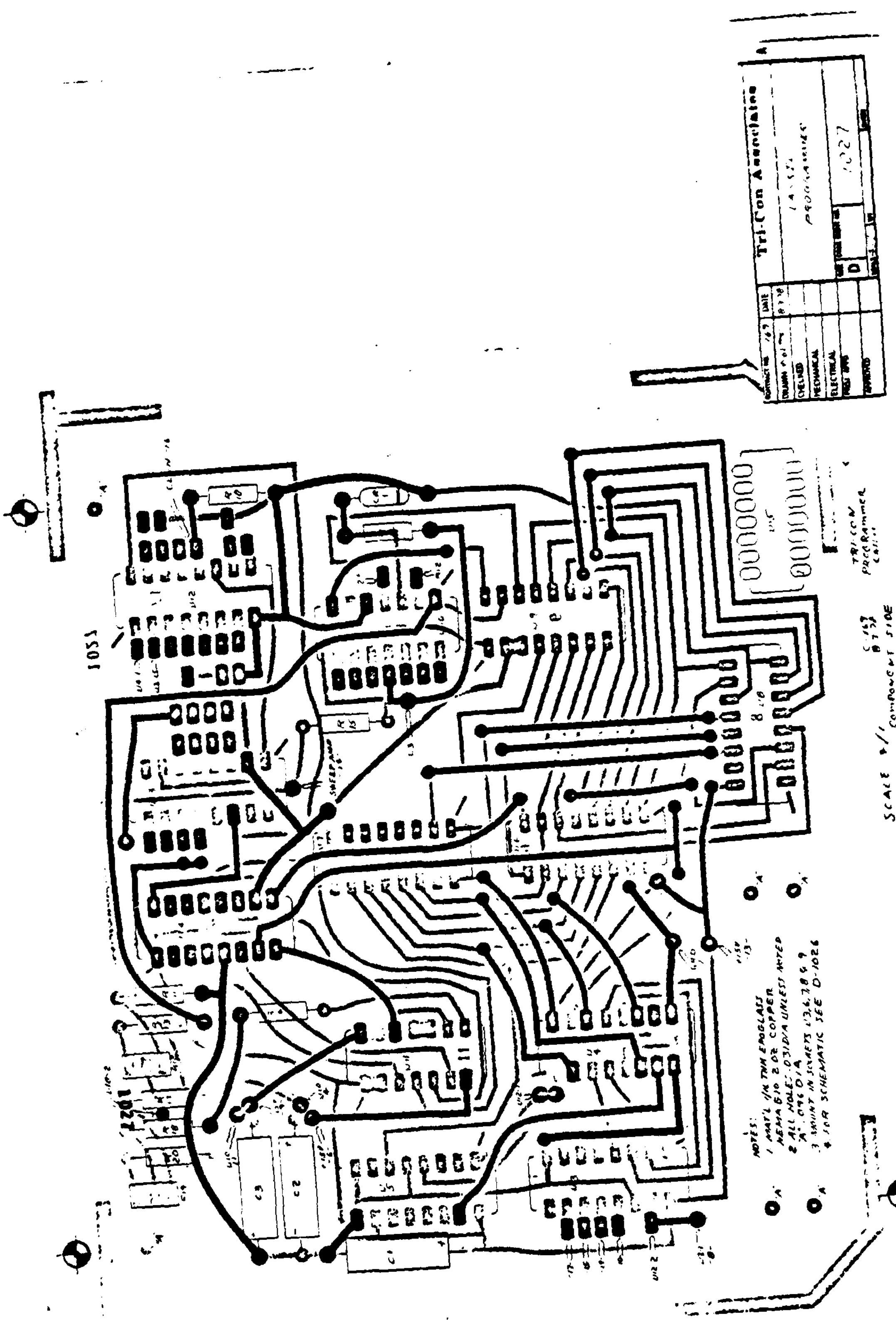

Tri-Con Associates

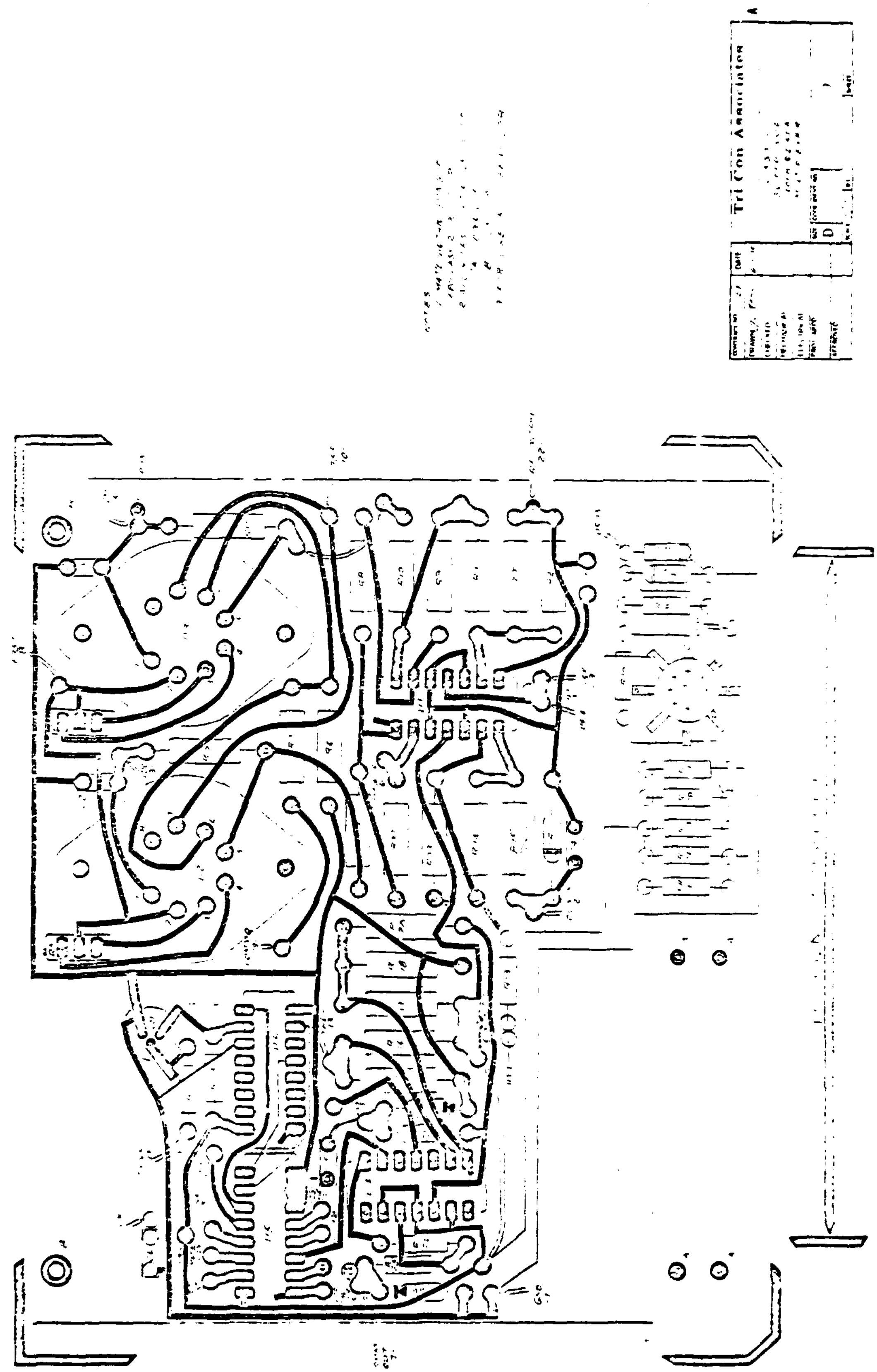

Tri-Con Associates

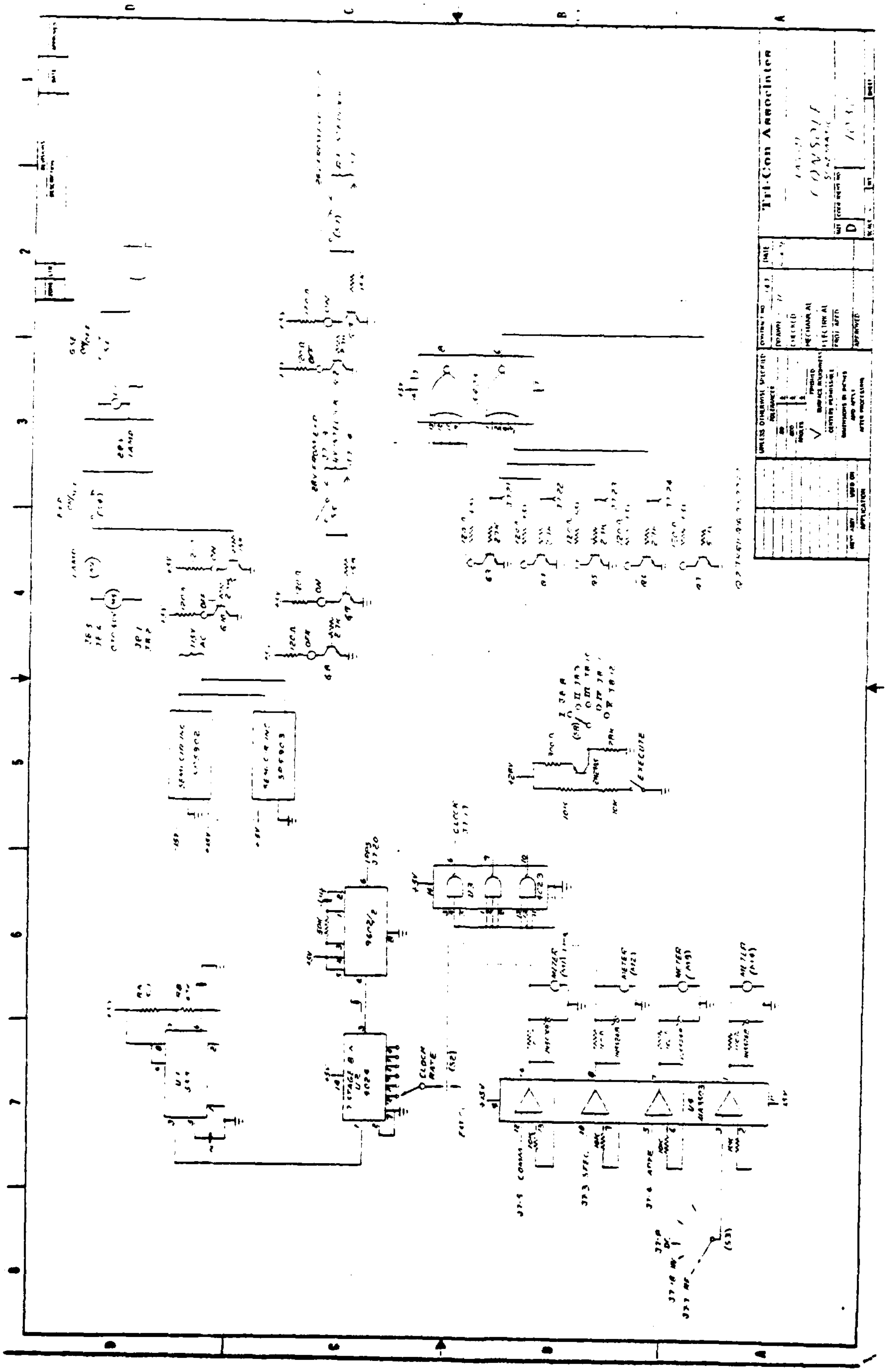

Tri-Con Associates
LASS II
Power Supply
D
1024
NOTES
1. MAT'L 1/16 THK EPOGLASS NEMA G10
2 OZ COPPER
2. ALL HOLES .031 DIA UNLESS NOTED
'A' .096 DIA, 'B' .125 DIA, 'C' .166 DIA
3. FOR SCHEMATIC SEE D-1023
1024

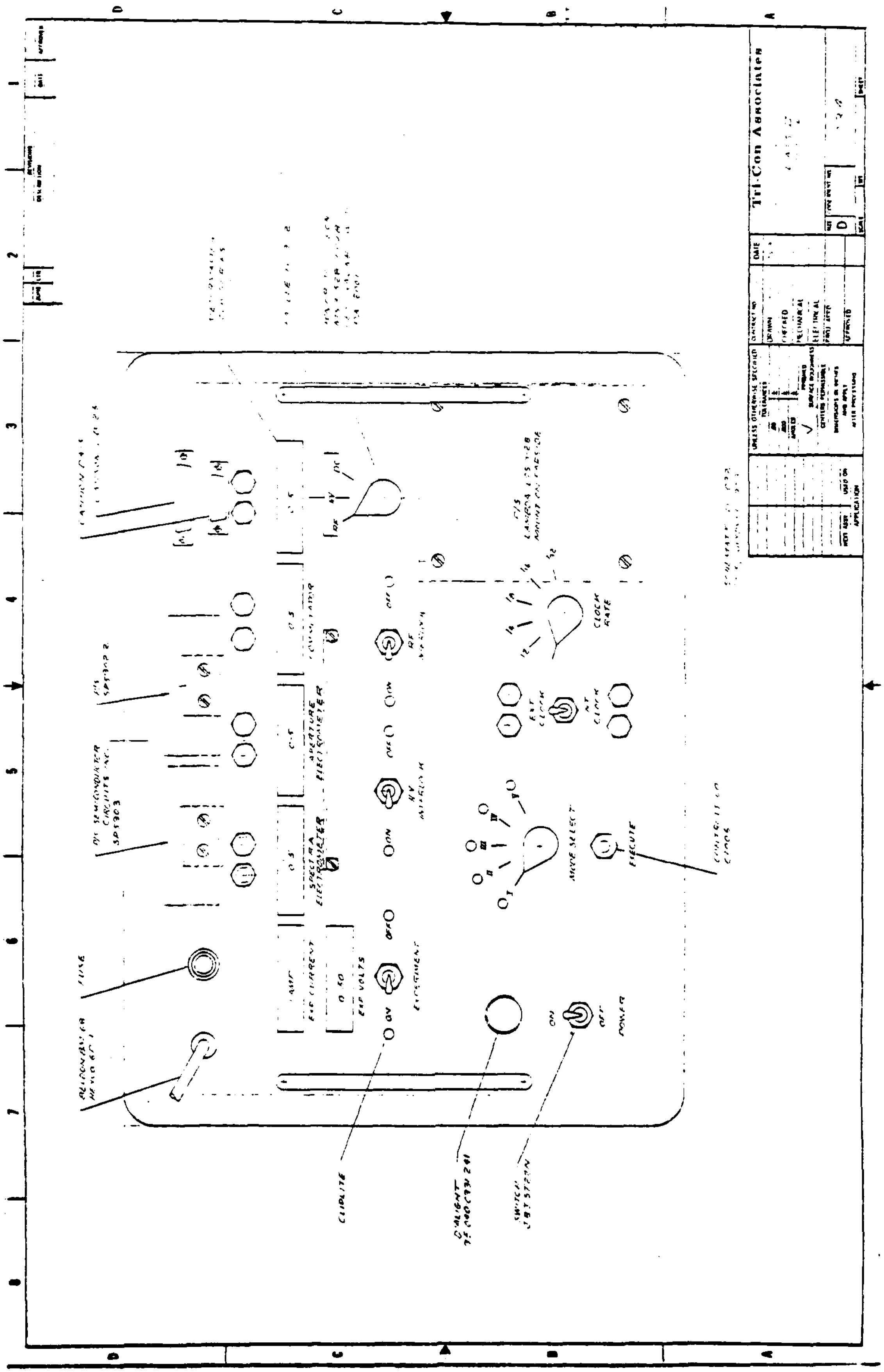


Tri-Con Associates
1025

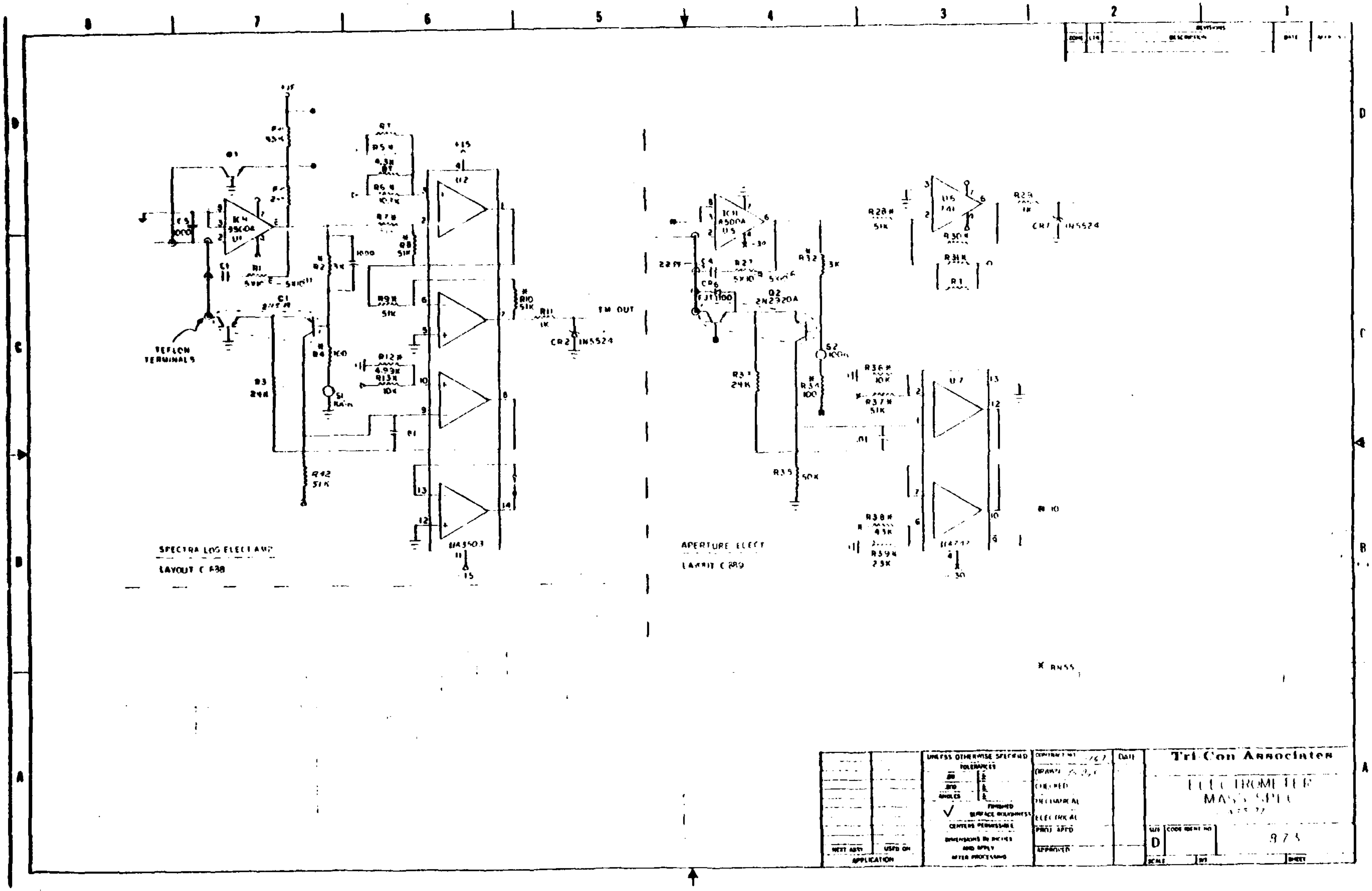

Tri-Con Associates
1027
SCALE 1/1 COMPONENT SIDE


Tri Con Associates

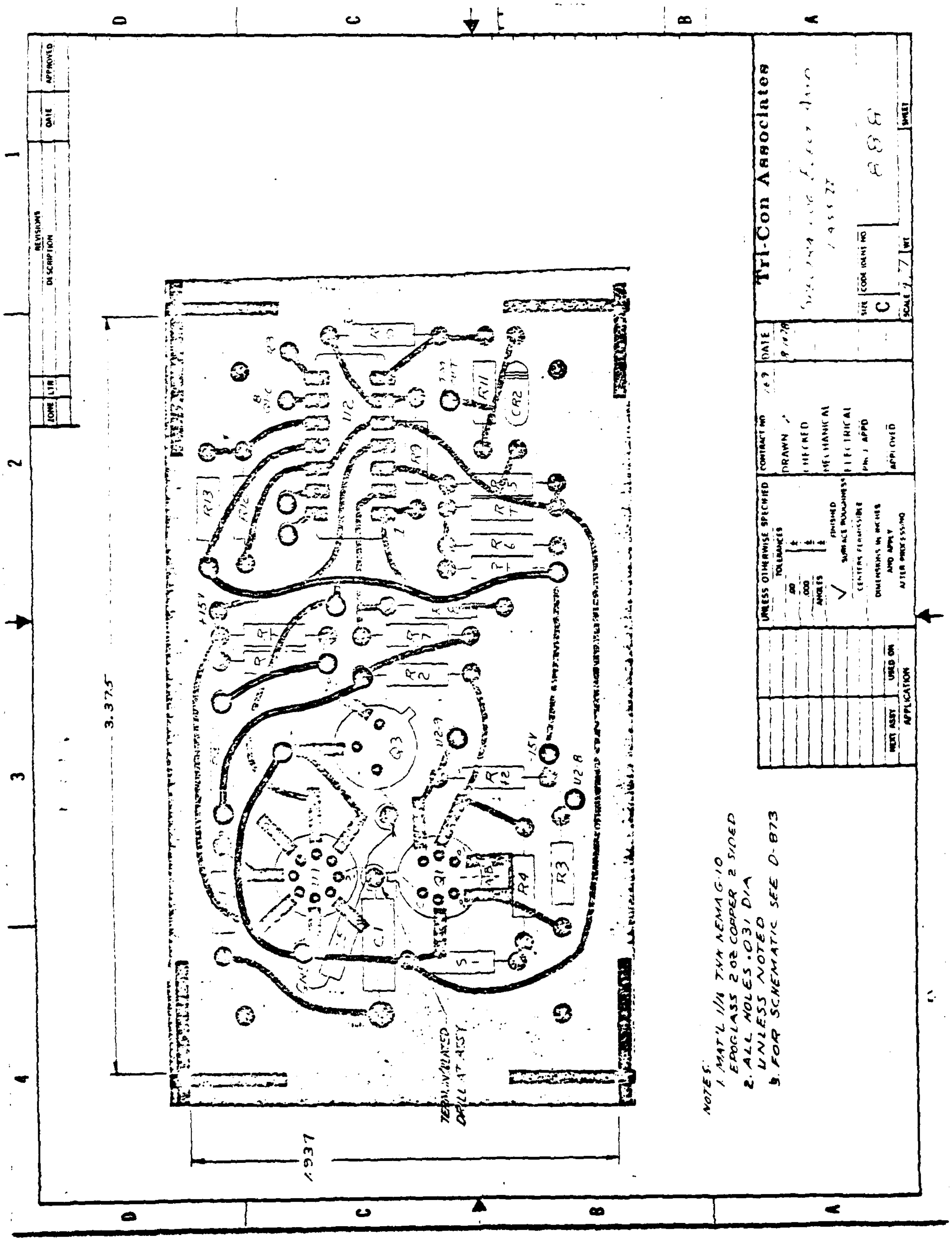

Tri-Con Associates
CLOCK RATE
EXECUTE

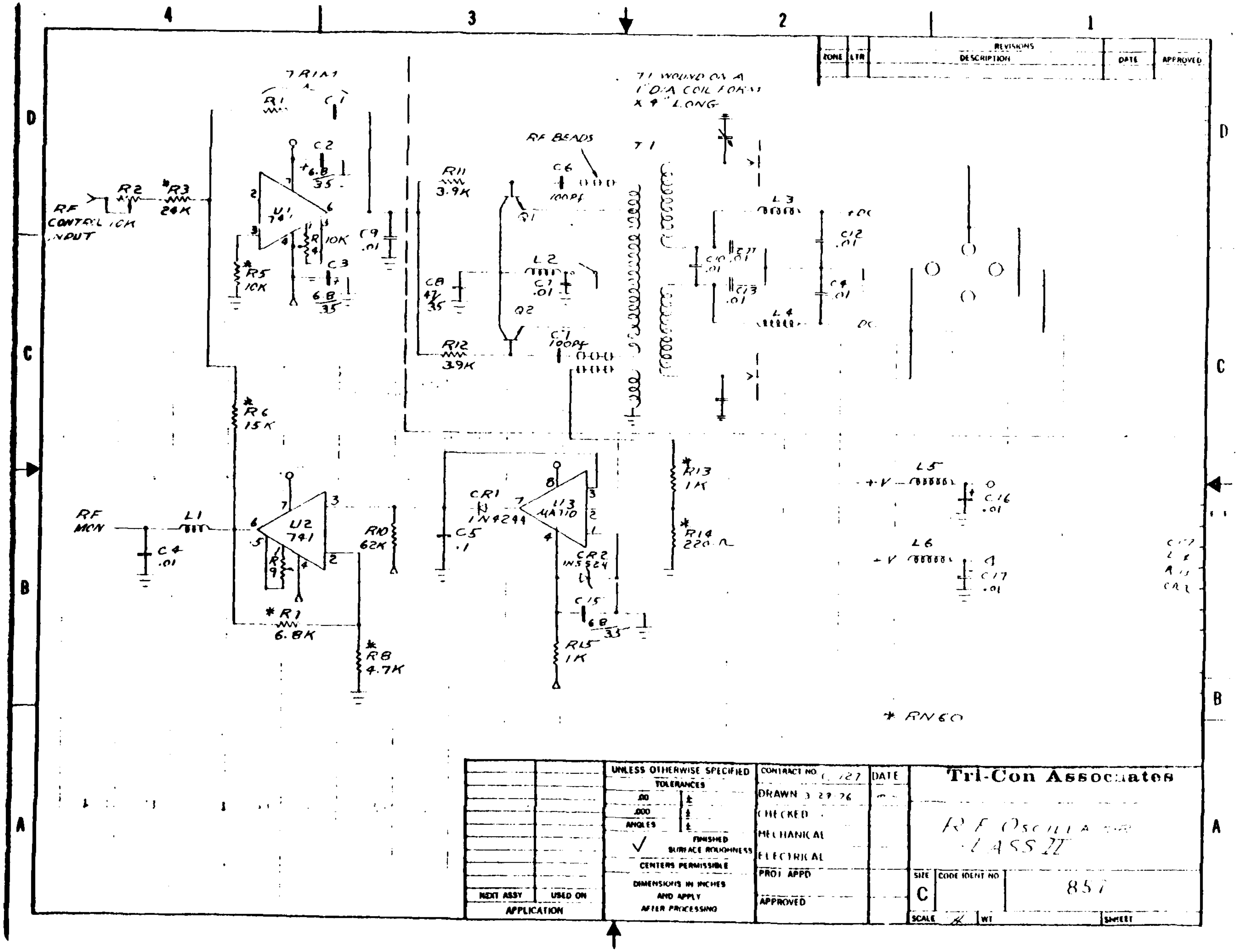


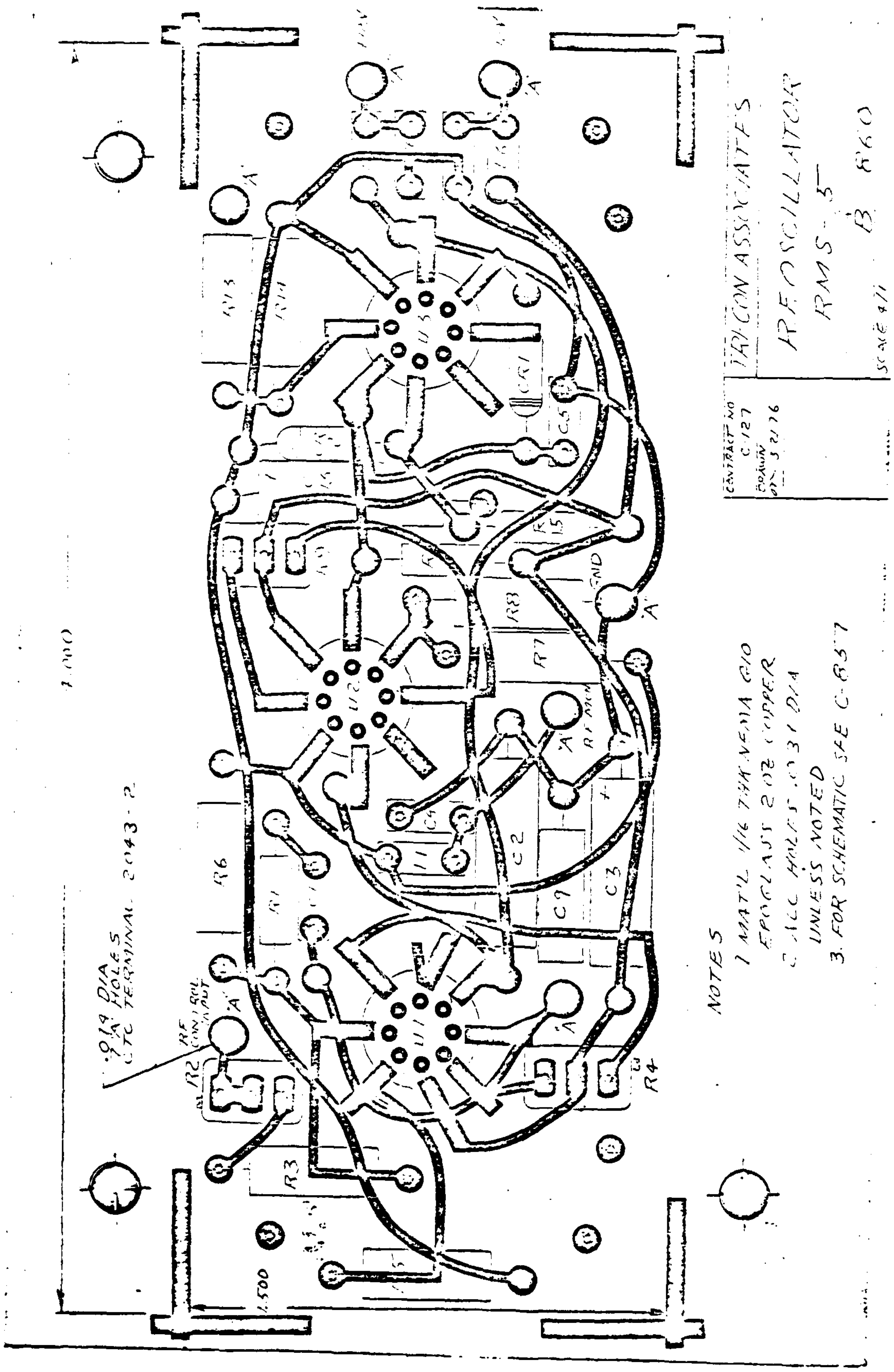
Tri-Con Associates
FUSE
ON
OFF
POWER
EXP CURRENT
EXP VOLTS
EXPERIMENT
SPECTRA ELECTROMETER
APERTURE ELECTROMETER
OSCILLATOR
HV MONITOR
RF MONITOR
MODE SELECT
EXECUTE
CLOCK RATE
EXT CLOCK
INT CLOCK



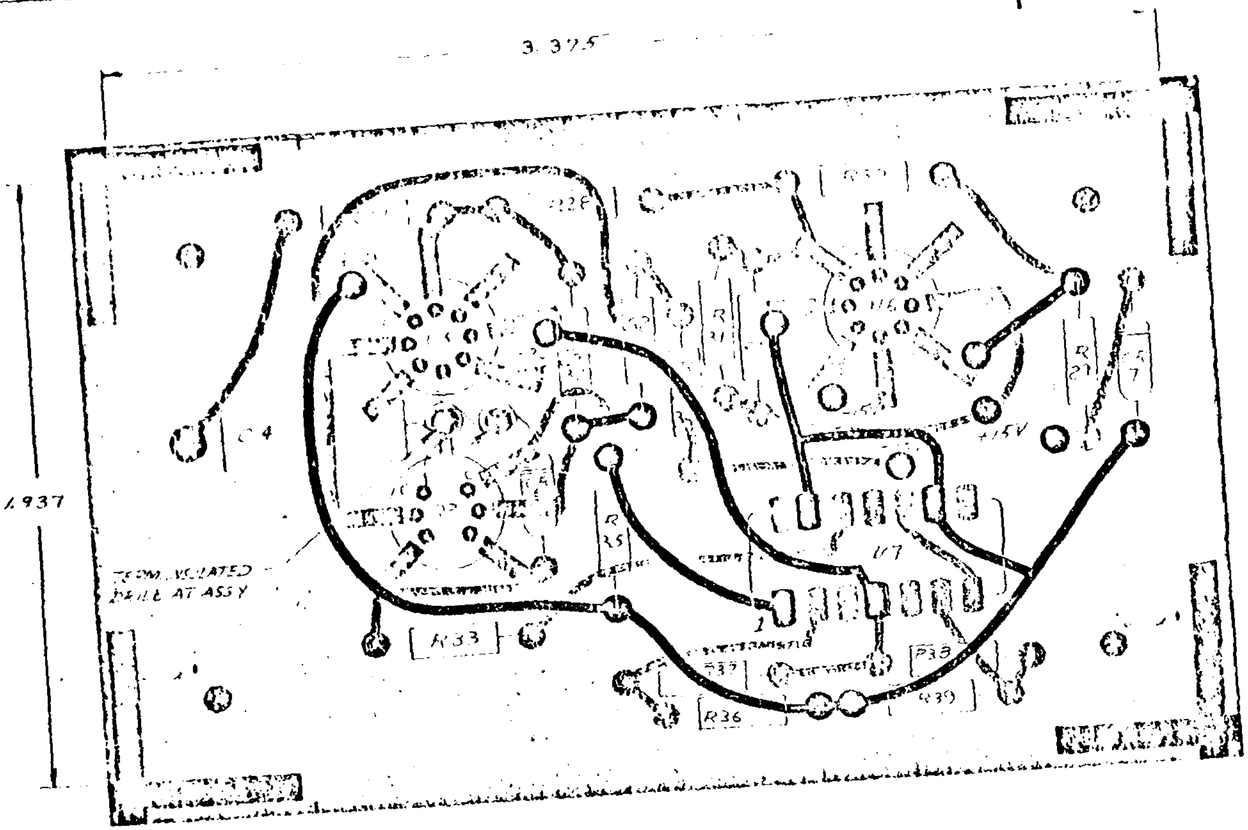
SPECTRA LOG ELECT AMP
LAYOUT C 838
APERTURE ELECT
TEFLON TERMINALS
TM OUT
2N2920A
1N5524
Tri-Con Associates
ELECTROMETER
MASS SPEC


Tri-Con Associates
NOTES:
1. MAT'L 1/16 THK NEMA G-10
EPOGLASS 2 OZ COPPER 2 SIDED
2. ALL HOLES .031 DIA
UNLESS NOTED
3. FOR SCHEMATIC SEE D-873
3.375
1.937
TEFLON INSULATED
DRILL AT ASSY
CR2
R11
R13
R12
R9
R4
R3
R2
R1
C1
Q1
Q3
U2
15V
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED
SURFACE ROUGHNESS
DIMENSIONS IN INCHES
AND APPLY
AFTER PROCESSING
CONTRACT NO
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
APPROVED
DATE
SIZE
C
CODE IDENT NO
SCALE
WT
SHEET
NEXT ASSY
USED ON
APPLICATION


TRIM
RF CONTROL INPUT
RF MON
T1 WOUND ON A 1" DIA COIL FORM X 4" LONG
RF BEADS
U1 741
U2 741
U3 MA710
CR1 1N4244
CR2 1N5524
R1 6.8K
R2
R3 24K
R5 10K
R6 15K
R8 4.7K
R10 62K
R11 3.9K
R12 3.9K
R13 1K
R14 220 Ω
R15 1K
C2 6.8 35
C3 6.8 35
C4 .01
C5 .1
C6 100PF
C7 100PF
C8 47 35
C9 .01
C15 6.8 35
C16 .01
C17 .01
L1
L2
L3
L4
L5
L6
+V
* RN60
REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
UNLESS OTHERWISE SPECIFIED
TOLERANCES
.00 ±
.000 ±
ANGLES ±
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
NEXT ASSY
USED ON
APPLICATION
CONTRACT NO
DRAWN 3 29 76
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
DATE
Tri-Con Associates
SIZE C
CODE IDENT NO
857
SCALE
WT
SHEET
A
B
C
D
1
2
3
4



NOTES
1 MAT'L 1/16 THK NEMA G10 EPOGLASS 2 OZ COPPER
2 ALL HOLES .031 DIA UNLESS NOTED
3. FOR SCHEMATIC SEE C-837
TRICON ASSOCIATES
RF OSCILLATOR
RMS-5
B 860
SCALE 4/1
.014 DIA 7 'A' HOLES CTC TERMINAL 2043-2
RF CONTROL INPUT
GND
1.500



NOTES
1. MAT'L 1/16 THK NEMA G-10 EPOGLASS
2 OZ COPPER 2 SIDED
2 ALL HOLES .031 DIA
UNLESS NOTED
3. FOR SCHEMATIC SEE D-873

NEXT ASSY	USED ON	UNLESS OTHERWISE SPECIFIED	CONTRACT NO C 169	DATE	Tri-Con Associates
APPLICATION		TOLERANCES .00 ± .000 ± ANGLES ±	DRAWN		APERTURE ELECT
		FINISHED SURFACE ROUGHNESS	CHECKED		SIZE C CODE IDENT NO 889
		CENTERS PERMISSIBLE	MECHANICAL		SCALE WT SHEET
		DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING	ELECTRICAL		
			PROJ APPD		
			APPROVED		