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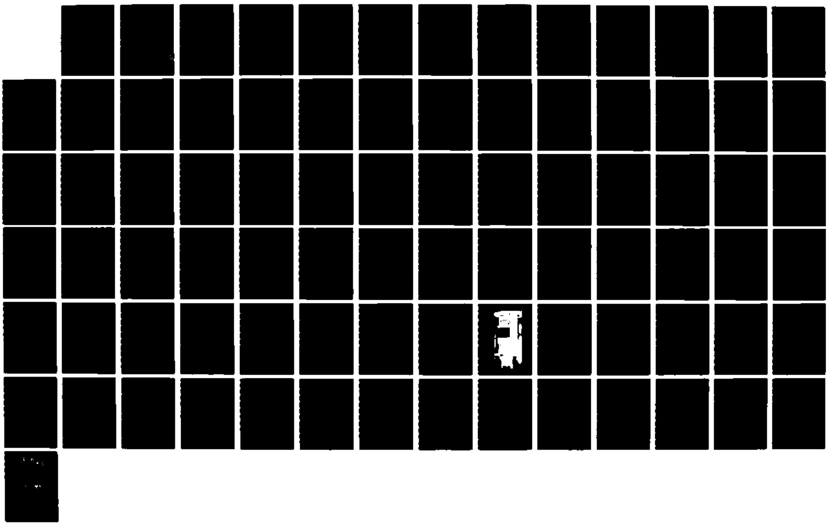

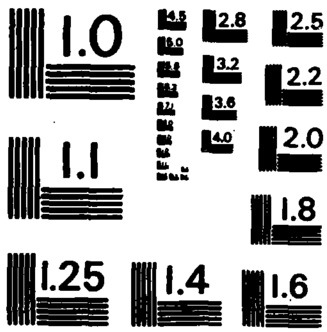

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AD-A162 149

AFGL-TR-85-0131

DESIGN SOUNDING ROCKET PAYLOAD SYSTEM TO STUDY VEHICLE CHARGING PHENOMENA

Robert S. Hills

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Cambridge, Massachusetts 02138

Date of Report: 29 May 1985

FINAL REPORT: Period Covered 1 October 1979 to 31 December 1984

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

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Electronics For Sounding Rocket Payload System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

(a) Reassemble and test the A31.603 rocket payload, previously flown at WSMR in January of 1978.

(b) Design a sounding rocket payload for the measurement of vehicle charging due to charge ejection in accordance with the results of the reassembly and retest of the A31.603 payload.

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1.0 OBJECTIVE OF CONTRACT

The objectives of this contract are the following:

(a) Reassemble and test the A31.603 rocket payload, previously flown at WSMR in January of 1978. Conduct spacecraft charging tests in a plasma using the vacuum chamber at Johnson Space Flight Center, Texas.

(b) Design a sounding rocket payload for the measurement of vehicle charging due to charge ejection in accordance with the results of the reassembly and retest of the A31.603 payload, and in accordance with "Specifications for the Instrumentation for the Spacecraft Charging Rocket-2 Payload".

(c) Fabricate and test a negative charge ejection system.

(d) Fabricate and test rocket payload sensor systems to measure the vehicle-to-plasma potential difference.

(e) Fabricate and test sensor systems to measure and identify charged particle return to the payload.

(f) Fabricate and test sensor systems to measure rapid changes in vehicle potential.

(g) Fabricate and test a microprocessor-based sounding rocket experiment controller.

(h) Fabricate and test one set of ground support equipment.

(i) Integrate at contractor's facility the above sensor systems with a rocket payload structure and instrumentation provided by the government.

(j) Provide engineering field services at JSFC for retesting the A31.603 payload.

(k) Provide engineering field services at WSMR for pre-launch testing of the spacecraft charging Rocket-2 Payload.

2.0 REWORK OF A31.603 PAYLOAD AT AFGL

All the wiring harnesses and connectors which were damaged during reentry on the recovered rocket payload A31.603 were replaced and checked out. The modular power supplies on the power control deck were replaced, and checked out. Other items were reworked as described in paragraphs 2.1 to 2.6 below.

2.1 Optical Isolator Command Line Drivers

The cards containing the 40 optical isolator command line drivers were checked out, integrated on the payload and the wiring checked out. The schematic for one channel of these command line drivers is shown in Figure 1. All 40 channels are identical.

2.2 Test Console For USFC

An auxiliary command connector was incorporated to allow for control of some of the experiments at JSFC by means of a JSFC test console.

A block diagram of this test console is shown in Figure 2.

2.3 PCM Optical Isolator

The PCM optical isolator was bench tested to determine its performance over a large dynamic range of duty cycles for successive 0 and 1 levels. It was determined that the fidelity was such that the TM PCM Decoder would have difficulty to accurately decode some marginal waveforms. Also, the telemetry system was unable to drive the isolator far enough into saturation to permit reliable decoding at the TM receiver. A LM311 comparator was added before the front end of the circuit. The circuit was optimized and the final schematic is shown in Figure 3.

2.4 Thermal Emission Probes (TEP)

The Thermal Emission Probes (TEP) (one 350 volt and one 500 volt) were bench checked and calibrated. One recovered TEP deployment boom was mechanically rebuilt to make it strong enough for the JSFC tests. Brackets were designed and fabricated to mount the boom with TEP's on the payload.

The wiring from the TEP preamplifiers and the main payload were checked out. This wiring is shown in JSFC wiring diagrams in Figures 4, 5, and 6.

2.5 Retarding Potential Analyzer (RPA)

The RPA consists of a sensor whose retarding grid is swept as shown in Figure 7. This voltage is generated by the sweep generator shown in Figure 8. The current collected is measured by a bipolar logarithmic amplifier whose response is shown in Figure 9.

The RPA sensor, whose grids were broken during reentry, touchdown, or handling, was disassembled and cleaned. The grids were replaced. The retarding grid was successfully Hi-potted to 5000 volts.

2.6 Nuclide Gun

The Nuclide Electron Gun was tested under vacuum conditions at AFGL. As a result of these tests the following operating specifications for the Nuclide electron gun are set as goals for the JSFC tests:

1. Gun to be fired by capacitor discharge.
2. Operating voltage - 5000 volts.
3. Operating currents - 100 - 10 - 1 - 0.1 mA maximum.
4. Discharge time - 0.3 to 0.5 seconds.
5. Recharge time - up to 120 seconds.
6. Recharge circuit - constant current.
7. Monitors - total emission, High Voltage, and Grid Voltage Monitors.
8. High Voltage Power Supplies
   5000 V 10 watt Tecnetics 9584-120
   1500 V Bias 3 watt Tecnetics 9567-115

A block diagram is given in Figure 10.

On September 17, 1980 the modified electron gun system was tested in the "Jumbo" vacuum tank at AFGL. The system was assembled in the forward portion of the previously recovered rocket payload A31.603. It consisted of:

(a) A 5000 volt capacitor charging power supply.
(b) A 1500 volt grid bias supply.
(c) A 20 uf, 5000 volt discharge capacitor.
(d) A mode programmer and high voltage relays to control the grid voltage and electron gun emission.
(e) A high voltage isolation filament transformer to power the electron gun filament.
(f) A modified Nuclide Electron Gun.

These components were assembled as shown in the photograph of Figure 11.

Prior to the testing done in "Jumbo" the system was bench tested through all its modes at TRI-CON. All monitors and calibrations were normal and no abnormalities or breakdowns occurred. All high voltage sections were tested for integrity at 7000 volts.

The September 1980 test is detailed in Quarterly Report #4 covering that period.

Performance was normal until the high voltage reached 2800 volts. At this level a discharge occurred that caused all monitors to go to limit levels. The experiment was then terminated. No change was observed in "Jumbo" pressure $6X10^{-6}$ mm.

The instrument was removed from the vacuum system and a diagnosis was made of the resultant faults.

Because localized outgassing backed up by the huge energy stored in the discharge capacitor was deemed to be the cause of the catastrophic failure, one component in the high voltage chain was suspect - the high voltage isolation filament transformer. Trouble had been experienced originally in that a vacuum could not be pulled on the transformer as received from the manufacturer. The re-encapsulation although allowed to cure under a vacuum was done under improvised conditions. Therefore, separate breakdown tests were conducted. The transformer was operated under vacuum conditions in the "Jumbo" tank. As soon as a vacuum of 10^{-6} mm was established the high voltage power supply was slowly turned up and at about 5000 volts sharp breakdowns were observed on the monitor oscilloscope.

After terminating the test the transformer terminal header was milled off. This revealed several pockets in the encapsulating compound just under this terminal header. These pockets could have been trapped gas which slowly escaped through the terminal header to provide the critical pressure which resulted in the observed breakdowns. The vacuum test was repeated and the results were negative - no breakdowns were observed.

The electron gun system was repaired. New high voltage wire rated by a factor of four, was used for the interwiring of the -5000 volt connections to the 20 uf high voltage discharge capacitor. A new high voltage isolation filament transformer which is commercial hermetically sealed was purchased and used in the assembly. The electron gun vacuum tests were repeated.

3.0 VEHICLE CHARGING TEST AT JSFC

The refurbished rocket A31.603 was shipped to Houston in March 1981 and most of the tests were conducted during the first week of April.

The physics of the charging phenomena is beyond the scope of this report, but, the performance of the rocket electronics and an outline of the test setup will be discussed.

3.1 Test Setup

The vehicle charging tests were performed in the large vacuum chamber at the Johnson Space Flight Center in Houston, Texas. The chamber is approximately 75 feet high and 50 feet in diameter, Figure 12.

The refurbished rocket was suspended from the ceiling with nylon rope and rigged to allow for vertical level changing and horizontal orientation. The interface between the vehicle and the test stand was via a 100 foot long cables which were terminated with some form of high voltage isolation. For example, the command and telemetry lines had 5000 volt opto-isolators located inside the test vehicle.

The power supplies which had to be tied to skin potential required a special penetration plate with high voltage feedthroughs and isolation transformers external to the vacuum chamber.

The floating of the power supplies provided a means of measuring the vehicle potential with external meters which could be compared to on board sensor measurements.

The two TEP's were deployed on a boom similar to their position in flight.

A 30 cm ion thruster which was used to generate a plasma was located on the third level catwalk, about 30 feet from the floor.

The magnetic field intensity and direction was also controlled during the test with video monitors recording the magnetic field effect on beam trajectories.

3.2 JSFC Test Procedures

The ion gun system performed well throughout all the test generating ion beams with various currents and energy levels. The beam currents in the low milliampere range and the energies in the kilovolt range.

The electron gun system used at JSFC test was quite different from the one used on the rocket flight. The JSFC test gun has a higher current and voltage capability and used a large high voltage capacitor as the source of energy. The system was wired to provide external control of filament power and accelerating voltage to allow for a rather coarse control of beam current and beam energy. A monitor of beam current and beam energy was recorded with the telemetry data.

The electron gun was operated in a pulse mode if the desired currents exceeded five milliamps, because of high voltage power supply limitations.

Control of the pulse width could be varied with an external one-shot that turned the control grid relay on and off.

Tests performed with the RPA, when the plasma source was on, and without any intentional vehicle charging, produced some unexpected results.

It appears that the charged particle density inside the grid housing was quite high so the amount and polarity of the current arriving at the collector was a result of the internal space charge variations and not due to external energetic particles.

The surface potential monitor was operating throughout the test and responded to vehicle charging.

Preliminary observations of the transient pulse monitor output, even when arcing occurred leaves some doubt that any useful data will be obtained from this experiment.

3.3 Observations

The test vehicle would charge up to between +10 and +12 volts in the presence of a plasma. With the higher mobility of electrons one would expect it to be slightly negative. If the vehicle is grounded through a Simpson Meter, set to read current, a positive 1.2 to 1.6 mA is collected when the 30 cm thruster is on. With a shutter in front of the hollow cathode plasma source the following vehicle currents were measured:

Shutter Open - Postive 250 μa
Shutter Closed - Positive 20 μa

When the simpson is removed in the shutter closed position (20 μa) the vehicle potential is +6 volts.

4.0 NEW CHARGING ROCKET PAYLOAD (BERT I)

The BERT I payload will study the effects of electron and ion beam ejection from a rocket.

It is a two-fold effort, with the primary interest being to understand spacecraft charging and the secondary goal of developing diagnostic instruments to detect and neutralize the charge before any damage occurs due to voltage breakdown.

The following instruments make up the payload:

Electron Gun	(2kV)
Ion Source	(Hughes)
Ion Source	(Capillaritron)
Mass Spectrometer	(AFGL)
Biased Surface Monitor	
High Resolution ESA	
Low Resolution ESA (IRT)	
Faraday Cups	
Total Light Photometers	
Boom Sensors	(3 Spheres & Electronics)
Boom Filament	
Plasma Source	(JPL)
TV Camera	

The instruments are controlled by a micro-computer programmer made by TRI-CON ASSOCIATES INC.

The electronics for all the instruments except the Hughes Ion Source, IRT ESA, AFGL Mass Spectrometer, JPL Plasma Source, and the TV Camera were made by TRI-CON ASSOCIATES, INC.

The software for the programmer was developed by TRI-CON and finalized by AFGL after hardware delivery when final specifications were frozen.

4.1 Electron Gun

The Electron Gun consists of the gun itself and the power source for the gun.

4.1.2 Gun Assembly

Previous flights with a Machlett Type EE65 required an elaborate break off mechanism to expose the gun elements to the environment. Two types of break seal mechanism were previously used and both methods had some serious drawbacks. The mechanical method used a pair of squibs and a wedge to lift the cover off of the tube.

The problem with this method was gas leaking from the squib contaminating the cathode. The electrical method required a special battery pack which could supply about sixty amperes for a few seconds and was not used for anything else. The sixty amperes was used to heat and crack a ceramic band which then allowed the cover to be removed by a spring loaded arm.

To eliminate the breakoff mechanism a non-poisoning cathode, which can be exposed to air, is required. Such a gun was obtained from Kimball Physics of Wilton, New Hampshire. The pertinent specifications are:

(1) Beam Energy: Adjustable from 50 ev to 2000 ev.

(2) Beam Current: 10 microamps to 20 milliamps. 20 milliamps to be available at energies of 200 volts and above.

(3) Cathode: Cathodes to be field replaceable and constructed of material which will not degrade or lose its emission characteristics if exposed to air.

(4) Maximum cathode power of 20 watts.

The cathode assembly which fits inside of a cylinder and is wired to a vacuum feedthrough is similar to the structure depicted in Figure 13. The emitting material is thorium oxide which is bonded on a Tungsten disk. The heating of the emitter is effected by passing 6 amps at approximately 2.6 volts through the wire-disc assembly. This experiment is designed to deliver a current range of from 0 to 20 mA at four voltage levels of 500, 1000, 1500 and 2000 volts. The flight energy levels will be chosen prior to launch and may be similar to the following modes:

Mode I	1 kv	20 mA
II	2 kv	1 mA
III	1 kv	1 mA
IV	500 v	1 mA
V	2 kv	50 μA
VI	1 kv	50 μA
VII	500 v	50 μA

The mechanical mounting is on a 2 3/4 inch conflat flange to allow for vacuum penetration. The gun is connected to the electronics package by way of a high voltage cable and mating connector.

4.1.3 Power Source

The power source for the electron gun experiment is comprized of the following subcircuits (Drawing D-3002):

- I Switching Regulator
- II Control Oscillator
- III Low Voltage Power
- IV Heater Power
- V Variable High Voltage

The switching regulator (Drawing D-3002) is designed around a Fairchild regulator module 78S40. The device modulates the on/off time of the series pass module PIC 600 and controls the energy stored in the coil L1. The switching regulatro reduces the power normally dissipated in a conventional series regulator. There are two switching regulator circuits because of the variable high voltage requirement.

The control oscillator allows the transformers to operate in the non-saturating mode thereby, reducing the large current spike associated with transformer saturation. The net effect is to reduce the power dissipated in the switching transistors and also reducing the amount of noise feedback on the power input line.

The CD 4047 multivibrator generates a 40 kilohertz square wave that is used to switch the hex fet power transistors which in turn supply power to the transformer. The low voltage power is used to operate the signal conditioning circuits such as operational amplifiers, opto-isolators and digital-to-analog converters along with the memory and digital logic circuits.

There are two sets of low voltage power supplies, one referenced to payload ground and the other floating on the variable high voltage.

Because of the nature of the experiment the heater power is supplied on a separate transformer. The electron gun will not be sealed except for pre-flight tests and a system of interlocks was built into the circuit to prevent filament power turn on at atmosphere. Also, the output winding of the heater power transformer is floating on the high voltage and extra insulation and care in fabrication was taken care of.

The two electron gun parameters of interest to the payload scientist are the accelerating voltage of the emitted electrons and that portion of the emitted current that leave the gun.

The energy of the electrons is established by the high voltage supply which is programmable for eight levels from 500 volts to 2000 volts. The high voltage supply sets the negative bias on the heater cathode housing relative to the ground anode.

The telemetry monitors for the electron gun experiment are all relatively slow and can be handled by subcomm words. All of the monitors are analog voltages, eliminating the need for clock pulses and word gates.

The monitors provide the following information:

- I Current Level Select
- II (a) Voltage Level Select
  - (b) Gun On/Off
  - (c) Current High /Low/All
- III High Voltage Monitor
- IV Beam Current Monitor

The box size for the electron gun experiment is approximately 7.8 x 7.3 x 5.2 inches. The electron gun is mounted in a pressurized chamber with a high voltage cable connecting the gun to the electronics package. The schematic of the electron gun is given in Figures 14 and 15.

4.2 Capillaritron Ion Source

The capillaritron source was developed to offer an alternative means of generating ion beams which are used in the study of spacecraft charging. Previous sources required a hot filament or hollow cathode configuration which resulted in poorer reliability and longer starting time.

The capillaritron source was developed by PHRASOR Scientific Company located in Duarte, California.

The source consists of three groups of three nozzles, each with a different type of gas. The nozzles are biased with 3000 volts which results in the formation of ions at the tip of the nozzles. The gas reservoir, regulator and control valve was supplied by AFGL, and the electronics was designed and fabricated by TRI-CON ASSOCIATES, INC. A block diagram of the system appears in Figure 16.

During the BERT I flight, the capillaritron will be used to study the charging effects, if any, on three different species of gas with widely different masses. The three proposed gases Helium (M_4), Argon (M_{40}), and Xenon (M_{130}), will each supply three nozzles. The programmer will select the individual gases or any combination of the three. Each gas and nozzle configuration is independent of each other except for the controller, and low voltage power supply. The proposed pre-launch condition is to have all gases flowing prior to launch at a rate determined from vacuum testing.

In addition to generating ions, a tungsten filament is available to add electrons to the beam for studying the effects of ion beam neutralization.

4.2.1. Electronics

The low voltage power supply (D-3067) Figure 17 is designed to convert the 28 volt battery power into the various voltages needed to operate the capillaritron instrument.

The capillaritron logic board schematic is shown in Figure 18, Drawing D-3068. The left hand side of the dotted line is the low voltage programmer and the right hand side is high voltage power supplies and current monitors.

The programmer is designed to operate either internally or externally. The internal operation is stored in a 2K x 8 bit PROM. If a minimum mode time of 0.5 second is used, then the PROM can store almost seventeen minutes of data before it has to repeat itself.

When the instrument is to be controlled externally the commands are latched in to PROM U_7. The command table is given below:

Function	Address (Hex)	Data (Hex)
External	$\overline{Cs}$ 03	80
Helium HV	$\overline{Cs}$ 0c	01
Argon HV	$\overline{Cs}$ 0c	02
Xenon HV	$\overline{Cs}$ 0c	04
He Ar Xe HV	$\overline{Cs}$ 0c	07
Neut Fil	$\overline{Cs}$ 0c	08
Neut I 1 mA He	$\overline{Cs}$ 0c	19
Neut I .1 mA He	$\overline{Cs}$ 0c	29
Neut I .01 mA He	$\overline{Cs}$ 0c	49
Neut I 1 mA Ar	$\overline{Cs}$ 0c	1A
Neut I .1 mA Ar	$\overline{Cs}$ 0c	2A
Neut I .01 mA Ar	$\overline{Cs}$ 0c	4A
Neut I 1 mA Xe	$\overline{Cs}$ 0c	1C
Neut I .1 mA Xe	$\overline{Cs}$ 0c	2C
Neut I .01 mA Xe	$\overline{Cs}$ 0c	4C
Neut I 1 mA) He Ar Xe)	$\overline{Cs}$ 0c	1F

The high voltage circuits drawn on the right hand side of the dotted line in Figure 18, Drawing D-3068, have been isolated from the low voltage logic because of the high probability of arcing.

Each set of three nozzles will have their own gas system and separate high voltage power supply. The power supplies have a 3000 volt six watt rating. The expected current from each supply under full load was stated 1.2 mA or about 300 microamp per nozzle.

The load of 1.2 mA results in about 3.6 watts or a little more than 50% of its maximum load. The beam current for each gas sample is monitored by measuring the return current in each supply by way of its floating output return.

The neutralizer circuit is a thermionic emitter with a self-biasing current source to set the emission level. The three specified levels are a factor of 10 apart and are 1 mA, 011 mA, and 0.01 mA. A monitor of the emission currents is obtained from an optically coupled isolation amplifier. A wire mesh screen which is electrically tied to vehicle ground will always be more positive than the filament and serve as the electron extractor.

4.3 The Mass Spectrometer was supplied by AFGL and was not TRI-CON's responsibility.

4.4 Electron/Proton Spectrometer

The design, fabrication, and testing of the Electron/Proton Spectrometer done by TRI-CON ASSOCIATES, INC. under the supervision of Mr. William McMahon of AFGL.

The instrument specifications are:

(1) Energy Ranges
   - (a) Channel I Electron — 20 ev to 200 ev
   - (b) Channel IIa Electron — 100 ev to 5000 ev
   - (c) Channel IIb Electron — 100 ev to 5000 ev

(2) Scan Rate - approximately two scans per second (576 ms/scan) controlled by the telemetry clock.

(3) Steps per Scan - 64, 9 ms dwell time per step.

(4) Actual Plate Voltage Difference
   - (a) Low Energy ± 8 volts to ± 80 volts
   - (b) High Energy ± 20 volts to ± 1000 volts

(5) Maximum Count Accumulation Per Measurement 2^{16} or 65,536 counts each channel.

(6) Telemetry Requirements

(a) Three 16 bit words - Data

(b) One 16 bit word for step position.

(c) Shift Pulses and word gates for each of the above.

(d) Eight analog monitors.

4.4.1 Sensor

The ESA sensor housing was supplied by AFGL and contains the deflection plates, three channel electron multipliers (CEM) and three charge sensitive amplifiers. The integration of the CEM and pulse amplifiers into the sensor housing was completed by TRI-CON ASSOCIATES. A block diagram of the sensor package is shown in Figure 19. The CEM electron multiplier is manufactured by Galileo Electro Optics in Westboro, Massachusetts.

The CEM is a continuous surface dynode as apposed to the venetian blind or discrete dynode type of electron multiplier. The gain of the CEM at the applied bias voltage of 2800 volts is approximately $5x10^7$. The particular CEM's used in the ESA instrument will have a biased cone at the entrance of the channel to increase the collecting cross-sectional area above the nominal inside channel diameter of .040 inches.

The pre-amplifier is a hybrid assembly manufactured by Amptex Inc. of Bedford, Massachusetts and has the following pertinent characteristics:

Input Threshold	1.6×10^{-3} Coolomb	
Cout Rate	4×10^{6} CPS	
Output Pulse		
(a) Rise Time	6	NS
(b) Fall Time	20	NS
(c) Width	220	NS (Adjustable)
(d) Amplitude	5 volts	
Quiescent Current -	3 mA	

4.4.2 Electronics Package

The electronics package does contain the remaining circuits to complete the ESA instrument. A block diagram is given in Figure 20.

The subsystems can be grouped into the following:

(a) Accumulators and telemetry interface.
(b) Sweep generation.
(c) High voltage bias supplies.

4.4.2.1 Accumulators

The counts accumulator and shift register are shown in Drawing D-3008, Figure 21.

The counters U_7 and U_8, Channel IIa and U_{11} and U_{12} Channel IIb allow for accumulating 2^{16} or 65,536 pulses before overflow occurs. The accumulation time is derived from the telemetry format, by using the leading edge of the data word gate to inhibit, dump, and reset the counters. After a data transfer from the counters to the registers (U_5 and U_6 Channel IIa and U_9 and U_{10} Channel IIb), a train of shift pulses clocks the data to telemetry.

As an aid for laboratory test and calibration, U_1 and U_2 (D-3008) were added to the circuit to allow for monitoring the count rate of each channel without requiring a PCM system.

U_1 is a GSE controlled multiplexer which gate the data from any one of the three channels. U_2 is a "D" type flip-flop that is wired in the toggle mode to stretch the CEM pulses for displaying on an oscilloscope during various alignment procedures.

4.4.2.2 Sweep Generators

The sweep generator (C-3010, Figure 22) is designed to produce non linear 64 step waveforms. The shape of the waveform enhances the data acquisition when comparing the step to step energy level change. A linear sweep would have high energy differential changes or large $^{\Delta E}/_{\Delta V}$ at the start of the sweep and a $^{\Delta E}/_{\Delta V}$ low at the end of the sweep because all the voltage steps would be equal.

The design for both energy channels is similar except for adjacent step ratios and voltage magnitudes. For the low energy channel, an increment of 1.037 is required to step from 8 volt to 80 volt (ratio of 10) in 64 steps. (x^3=10).

For the high energy channels and increment of 1.064 is required to step from 20 volts to 1000 volts (ratio of 50). (x^{63}=50)

The low energy step generator actually generates 64 voltages between 0.8 and 8 volts. It is followed by inverting and non-inverting amplifiers to produce the plus and minus step voltages between 8 volts and 80 volts.

The high energy step generator generates 64 voltages between 0.2 and 10 volts and is followed by inverting and non-inverting amplifiers to produce plus and minus step voltages between 20 volts and 1000 volts. The circuit of the high voltage amplifiers is Figure 23. Thus with instrument factors of 1.25 and 2.5 the final energy ranges are 20 ev to 200 ev and 100 ev to 5000 ev.

The actual measured step voltages are given in Table I.

4.4.2.3 High Voltage Bias Supplies

An instrument of this nature usually requires a variety of different voltage levels and can result in a heavy and inefficient package.

When the requirements are simple, flight quality converters are usually purchased from Tecnetics Inc. of Boulder, Colorado. However, to eliminate six separate converters, a high voltage card was designed and the schematic appears in Drawing C-3014.

The transformer is designed around a ferroxcube ferrite potted core and oscillates at about 30 KHz. The output is multi-tapped to produce a 600 volt and 800 volt square wave. The square wave is then applied to a Cockcroft Walton multiplier which results in the $\pm$ sweep voltage (1200 volts) and the CEM bias ($\pm$2800 volts).

Also a winding to generate ± 100 volts for the low energy sweep bias is contained on the transformer. The high voltage power supply schematic is given in Figure 24.

4.4.3 ESA Tests

High voltage problems were encountered in the High Resolution ESA due to the high energy ion beam environment used for testing in the vacuum tank. The ESA was operated in the tank and did respond to electrons in both the electron measuring channels. The responses occurred at the correct ESA energy level corresponding to the beam energy.

However, during the test, the ESA input current increased (due to heat rise in the vacuum) and blew the console fuse. A second test was made with a heavier fuse and a failure occurred in the high voltage power supply. The unit was returned to TRI-CON and repaired and modified to take less current which also reduced the overheating.

Tests were attempted using the ion beam generator in the vacuum tank. High voltage arcing occurred on the high voltage step generator card when the ion beam was operated at the 2000 ev level. The arcing destroyed both LF347 quad amplifier chips, the inputs of which were not diode protected. The problem was encountered several times and it was realized that the ion beam must be prevented from entering the electronics box. A test was made with the unit completely shielded in aluminum foil. This test was successful and on August 31 data was taken at the following beam electron-volt values: 175, 268, 340, 430, 545, 720, 920, 1175, 1500, 1935, 2485, 3175, and 4100. At each of the above beam settings the instrument stepped for 5 or 6 16% incremented steps around the actual beam energy. The results have been recorded by TRI-CON and AFGL and are acceptable.

To insure that the high energy beams do not cause breakdown on the high voltage amplifier board it was decided to pot the entire high voltage section of the board with RTV 11 silicone rubber.

The complete instrument was subjected to vibration and shock tests at the AFGL facility on September 12 and September 14. The tests were done on all three axes. The vibration level was 6 G for 5 minutes - random. The shock was 25 G with a duration of 11 milli-seconds. The instrument was not operating during the tests, but, does still operate correctly on the bench after the tests. It was checked on November 16 in the vacuum with the electron and ion sources and confirmed sensor operation.

The instrument has been installed in the payload rack and energized by the system external power. The instrument telemetry output has been successfully interfaced with the rocket telemetry system. The digital readout of the four data signals has been correctly displayed on the telemetry panel CRT: low and high step numbers on words 24, 25; low energy electron counts on words 26, 27, of even minor frames and high energy electron counts on words 24, 25; high energy ion counts on words 26, 27 of odd minor frames.

The low energy and high energy step levels are synchronized. The command function which would set the high energy step to a selected step is disabled. The command function can be made to work again by removing the single wire between U_{13} pin 12 and U_{14} pin 1 on the buffer card. In this mode the low and high energy step levels are not synchronized. The complete ESA was operated in the JSFC vacuum chamber in March

1985. A breakdown of the high energy sweep amplifiers occurred a few minutes into the test, but good charging information was obtained until breakdown.

It was determined by microscopic examination of the defective components (OP420 quad op-amps) that that the -15 volt busses in both units had be overstressed, perhaps by an arc from the channeltron high voltage circuits located on the same board. A new amplifier card was fabricated with an improved layout, and the channeltron high voltage circuits were transferred to a new-added-on card. The instrument was then operated in the AFGL vacuum tank in April and performed correctly with both electron and ion sources. The sweep voltages were measured again and found to be unchanged from the original values.

A bench check test console was made by TRI-CON. It supplies power and simulated telemetry signals to the ESA instrument so that the PCM telemetry outputs can be observed on a scope. (The instrument contains a test oscillator controlled by the console). The console also contains a decade counter and display to read counts from the analyzer-amplifier before digital processing. This feature will be used during calibration.

4.5 Biased Surface Monitor

The specifications for the Biased Surface Monitor are as follows: Area of biased surface $\approx 100\ cm^2$ surface to be biased negatively with respect to rocket payload at:

500	volts
1000	volts
1500	volts
2000	volts

Voltages stepped sequentially at 2 steps per second. Current collected to be measured by logarithmic monitor over 4 decades at 1.25 volts per decade with full scale sensitivity of 200 microamps.

Analog monitors of bias voltage, monitor current, and low voltage power supply (plus and minus 15 volts).

Input Current		Voltage Tel
200	μa	5.00
20	μa	3.75
2	μa	2.50
200	na	1.25
20	na	0

Bias voltage steps to be commanded from BERT I data lines or free running at the above mentioned 2 step/second.

The schematic of complete biased surface monitor is C-4024 shown in Figure 25.

The biased surface monitor was completed and initially delivered to AFGL on July 31. Check-out had shown the necessity for shielding the high voltage wires in the connector wiring section of the electronics box. The wires are directly underneath the collection plate and the ripple on the high voltage was capacitively coupled to the amplifier input.
Some residual ripple is also present due to actual ripple on the step generator output. This can be reduced by an RC across the step generator feedback resistor. This slows the response of the step generator. However, this also makes the step rise times longer and the displacement current spikes wider (more than 100 ms or one fifth of the dwell time). So as finally delivered on August 28, the instrument has no RC across the feedback resistor. The step dwell time is set at 500 ms. The displacement current spikes are 10 ms long at each step and 50 ms long at the reset.

A 300 megohm resistor has been temporarily connected across the input to give an artificial input current of 45 na or about 0.44 volts at the output.

4.6 Boom Deployed Sheath Monitors and BAD Filament

Two booms are displayed from the lower section of the payload. One boom mounts two gold plated spheres, one meter and two meters from the payload and take on a voltage corresponding the sheath charge. This voltage is measured with respect to payload frame. The other boom mounts one sphere and also a filament described below.

Each sphere has an amplifier located in its mount and also electronics in a box on the payload itself. The schematic is given in Figure 26.

The filament is designed to emit electrons to remove a negative charge from the payload.

It is commanded on when required. A schematic is given in Figure 27.

4.7 Total Light Photometer

The data processing amplifier electronics assembly for the Total Light Photometer was judged to be unacceptable for rocket flight conditions. The circuit was redesigned using more recent state of the art integrated circuits. The new schematic is shown in Figure 28. A new layout was made with a small reduction in volume over the old layout.

4.8 BERT I Controller

A microprocessor based controller serves as an on board computer for the BERT I Rocket Payload.

The complexity of the payload, which includes an ion gun, an electron gun and numerous diagnostic instruments, would severely strain the limits of a hardwired logic controller.

4.8.1 Processor Selection

The Motorola MC6809 type microprocessor is the third generation of the 6800 family and one of the most versatile of the eight bit microcomputing chips.

The 6809 was selected because of familiarity with the 6800 instruction set and the improvement in the architecture which allows for some sixteen bit data manipulation.

Sixteen bit processor chips are presently available but, the software and peripheral support have not reached the optimum level. Also, a sixteen bit processor would be considered too powerful for the task of controling the BERT I Payload.

4.8.2 Controller Design Consideration

A number of aspects influenced the design of the BERT I Controller. One of the most important considerations is isolation from any instrument containing high voltage. It is almost impossible to predict or eliminate high voltage breakdown during a rocket flight, unless, all high voltage power supplies are contained in a pressurized container.

The programmer on a prior rocket flight suffered considerable damage when arcing occurred in the high voltage section of a retarding potential analyzer. Some of the instruments containing high voltage (>300 volts) which are part of the BERT I payload are:

(a) Electron Gun
(b) Ion Gun
(c) Electrostatic Analyzer
(d) Mass Spectrometer
(e) Automatic Discharge System

All of the above mentioned have a power supply of 2000 volts or greater.

Another consideration in the design was flexibility in subsystem layout and packaging. Subsystems could be used on future payloads and/or in laboratory type ground support equipment.

The third consideration is ease in programming and operation. The controller has resident firmware for entering programs by way of a TTY, which will aid in the development of flight software during laboratory qualification test.

4.8.3 Subsystems

The subsystems are separated into four groups with the following designations:

(a) CPU and Decoder
(b) RAM/ROM Board
(c) High Voltage Isolation
(d) Low Voltage $I/_0$

4.8.3.1 CPU and Decoder

The CPU and Decoder circuit is drawn on schematic 3023, Figure 29. The microprocessor is the Motorola MC6809 which has eight bidirectional data lines and sixteen address lines so that multiplexing of the data or address is not required.

The address lines are decoded into thirty-two sections of two thousand words each, using 54LS154 four line to sixteen line decoders. U_6 and U_7 are eight line tri-state buffers to improve output drive capabilities. U_8 is an eight bit bidirectional "buffer" to permit data transfer both in and out of the CPU.

4.8.3.2 RAM/ROM

The address decoding on the CPU board is done in 2K word segments to allow for pin compatibility with the industry standard 2716 prom.

The board layout permits the designer to use RAM, ROM, or EPROM on the same board and to interchange them with a minimum amount of effort. The address data and power lines are the same for:

(a) MCM 2716 UV Erasable PROM

(b) MCM 4016 2Kx8 Static RAM

(c) MCM 2816 EE PROM

Up to 16K of memory will be available on one board.

4.8.3.3 High Voltage Isolation

The high voltage isolation is shown on Drawing 3030 and is accomplished by using opto-isolators and separate low voltage power supplies.

The CPU outputs data and addresses by way of a MC6821 peripheral interface adapter.

The PIA has two eight bit output ports, one of which will generate the external eight bit uni-directional data bus and the other will serve as an address bus. The four most significant address lines will be decoded to generate fourteen instrument enable lines, plus two analog data-in-lines. The four least significant address lines will be used in conjuction with the enable line to select different functions within the instrument.

All data from the CPU to the high voltage instruments will be digital, similar to command information.

To reduce the complexity of the isolation card data from the instruments to the CPU will be analog with the conversion from A to D made in the controller.

Provisions are made to accept thirty analog signals by way of U_5 and U_6. A selected analog signal will pass through the isolation amplifier U_{10} and the analog-to-digital converter U_9 before it is placed on the internal data bus.

Analog voltages can be sampled for any length of time because of the output latches in the MC6821.

The A/D converter is of the successive approximation type and will make the eight bit conversion in about 20 μ seconds.

A 20 μ second conversion time allows the processor to wait for the results and eliminates the handshaking usually required between the CPU and slow responding peripherals.

4.8.3.4. Low Voltage Interface

The low voltage interface board, Drawing D-3041, will supply the auxilliary functions of:

(a) Programmable Timer
(b) Baud Rate Generator
(c) Teletype Interface
(d) Two Additional I/O Ports

The programmable timer contains three independent 16 bit counters which are used to set intervals such as gun on, gun off, etc., during the operation of the flight program.

The Baud rate generator is a 12 bit counter which will count down from the processor clock. Proper selection of the processor crystal frequency will yield outputs that correspond to standard Baud rates such as:

19.2 K
9600
4800
2400
1200
600
300
150

4.8.4 Summary

The above mentioned microprocessor controller is an integral part of the BERT I Rocket Payload.

The controller can issue up to 16 commands to 14 different experiments, all optically isolated from the controller.

The controller can interrogate up to 30 analog voltages for the purpose of monitoring performance or making a decision.

4.9 Intersegment Voltmeter

The intersegment voltmeter is designed to measure the potential difference between the payload and the rocket which could occur as a result of particle ejection from the main experiment housing. Results from this experiment will yield data on the contribution of available collecting area to vehicle charging and possibly sheath dimensions.

The circuit for the intersegment voltmeter, Figure 30 is basically a high input impedance operational amplifier followed by three telemetry buffer amplifiers. The 5×10^{10} ohm resistor is used to allow for maximum charging at low plasma densities.

The critical areas in this design are:

(a) Insulators between sections should have low leakage up to 5000 volts.

(b) High Voltage Cables and connectors and the routing of them through the payload section.

(c) High voltage relays.

The experiment must be able to survive high voltage arcing if the vehicle charges up to the design goal of 5000 volts.

In past experiments relay assemblies consisting of a Hamlin 10,000 volt reed and a Coto Coil were used in high voltage applications.

The coupling between reed and coil was rather high and the results were damaged relay drive transistors and more important, program failures. The relays in this design are manufactured by ITT and are rated for 12,000 volts.

4.10 Faraday Cups

The Faraday Cup is a collecting target mounted on the skin of the main payload section. The collector is used to sample the number and polarity of charge particles returning to the vehicle during electron and ion gun emissions. A suppressor grid which is biased at -15 volts is placed in front of the target to reduce secondary emission.

The specification for this sensor as requested by the project scientist are:

(a) Positive Current 10^{-10} to 10^{-5} amps.
(b) Negative Current 10^{-10} to 10^{-5} amps.
(c) A minimum of -10 volts on the suppressor grid.
(d) Two telemetry channels sampled at least every 10 milliseconds.

A schematic of the circuit appears in Figure 30. The circuit is a bipolar electrometer with two telemetry buffer amplifiers. The input amplifier is a high input impedance operational amplifier with a bias specification in the region of 100 femto amps low leakage dual transistors perform the logging transfer function with Q_2 used for negative polarity and Q_4 used for positive polarity.

The transfer function follows the equation:

$$Eo = K_1 + K_2 \text{ Log}_{10} \text{ I in}$$

and a plot of the output volts versus input current appears in Figure 31. The gain values in the circuit are selected to yield the constants of $K_1 = 10$ and $K_2 = 1$.

Two Faraday Cup systems are mounted in the payload, looking normal to the rocket and 180° with respect to each other.

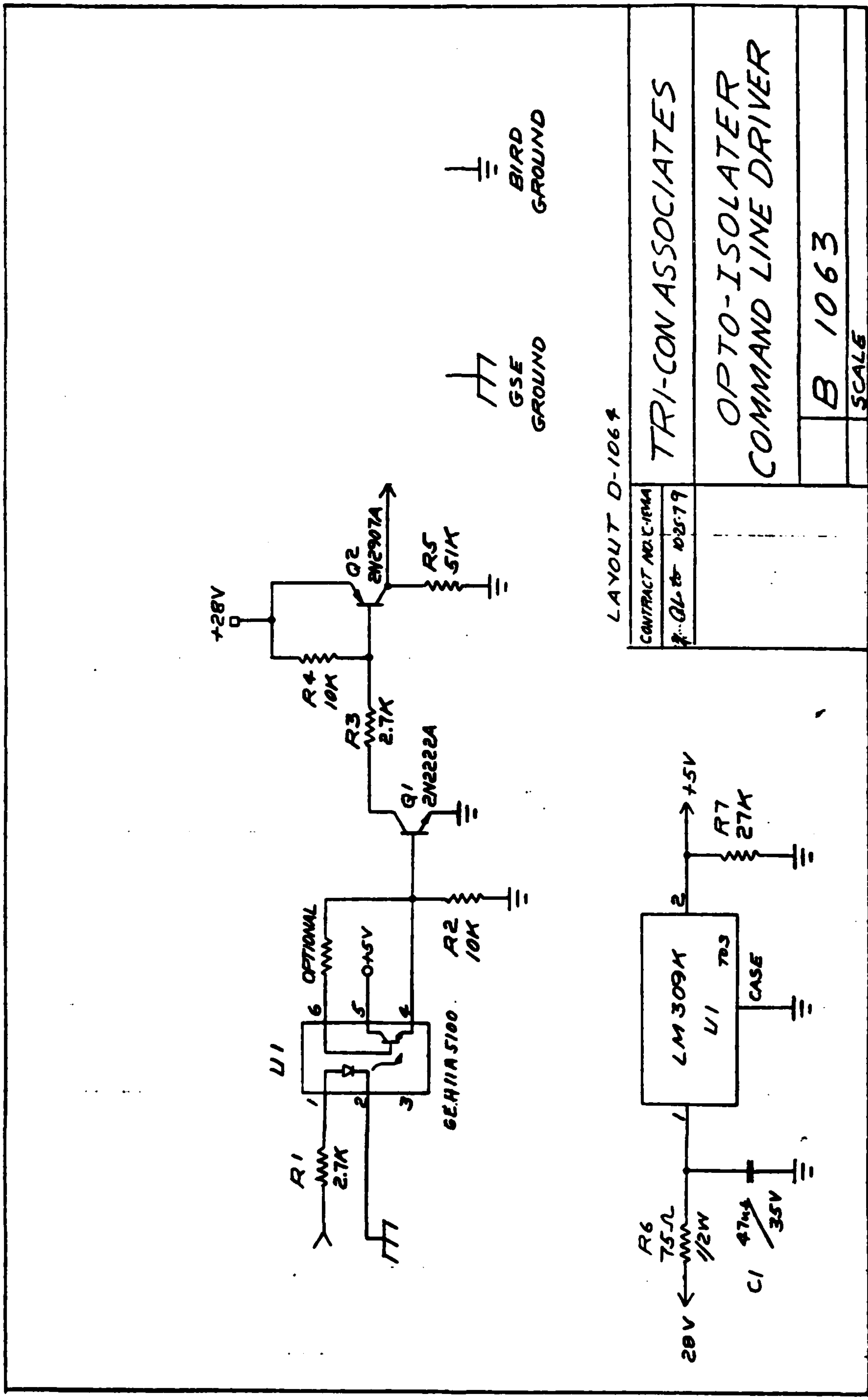

TRI-CON ASSOCIATES
OPTO-ISOLATER
COMMAND LINE DRIVER
B 1063
SCALE
LAYOUT D-1064
BIRD GROUND
GSE GROUND
+28V
Q2 2N2907A
R5 51K
R4 10K
R3 2.7K
Q1 2N2222A
+5V
R7 27K
R2 10K
OPTIONAL
U1
R1 2.7K
LM309K
U1
CASE
R6 7.5Ω 1/2W
C1 35V
28V

FIGURE 1

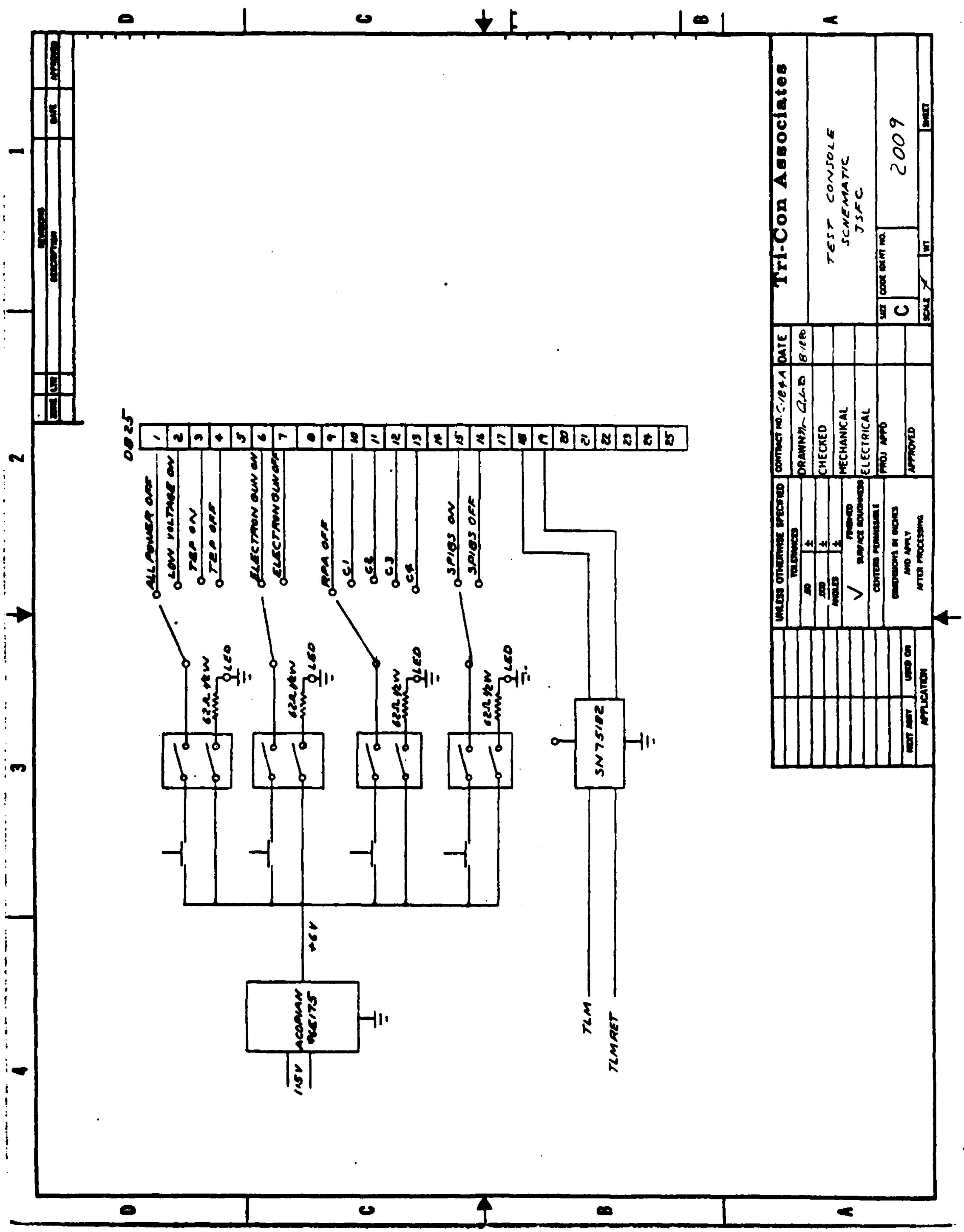

DB25
ALL POWER OFF
LOW VOLTAGE ON
TEP ON
TEP OFF
ELECTRON GUN ON
ELECTRON GUN OFF
RPA OFF
C1
C2
C3
C4
SPIBS ON
SPIBS OFF
62Ω 1/2W
LED
115V
ACOPIAN
+6V
SN75182
TLM
TLM RET
Tri-Con Associates
TEST CONSOLE
SCHEMATIC
JSFC
2009
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
FINISHED SURFACE ROUGHNESS
CENTERS PERMISSIBLE
DIMENSIONS IN INCHES AND APPLY AFTER PROCESSING
CONTRACT NO.
DATE
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
PROJ APPD
APPROVED
NEXT ASSY
USED ON
APPLICATION
SIZE
C
CODE IDENT NO.
SCALE
WT
SHEET
REVISIONS
ZONE
LTR
DESCRIPTION
APPROVED

FIGURE 2

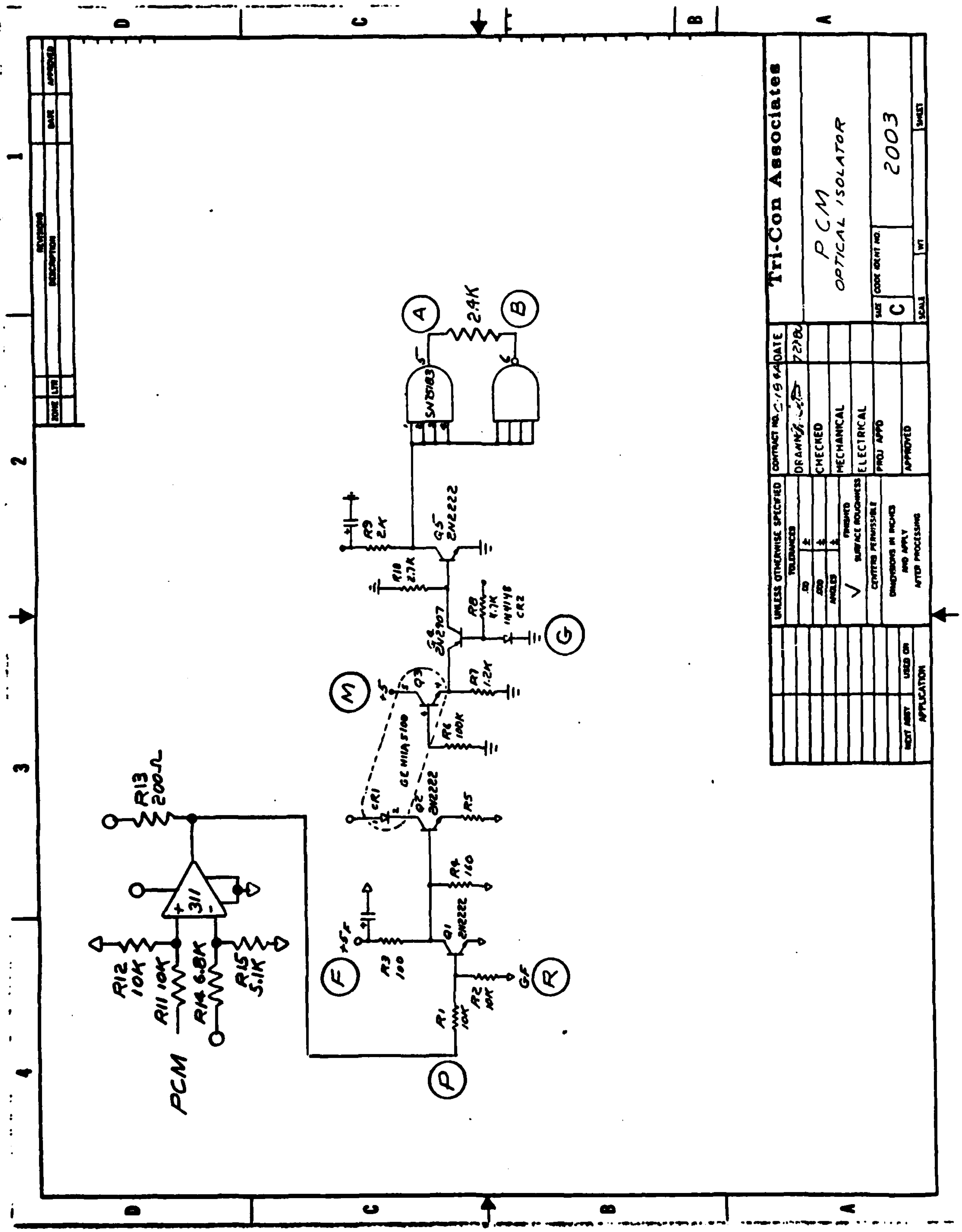
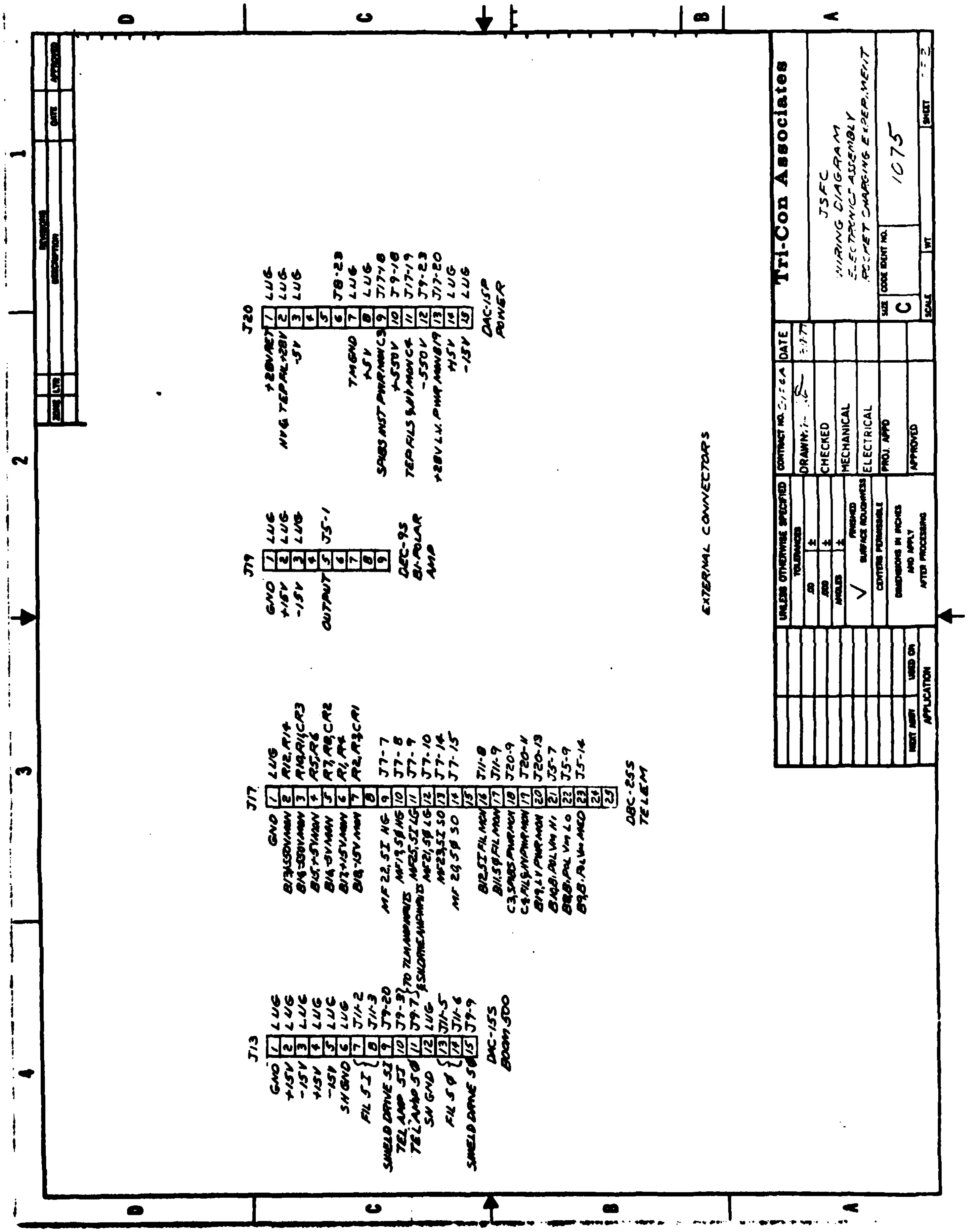
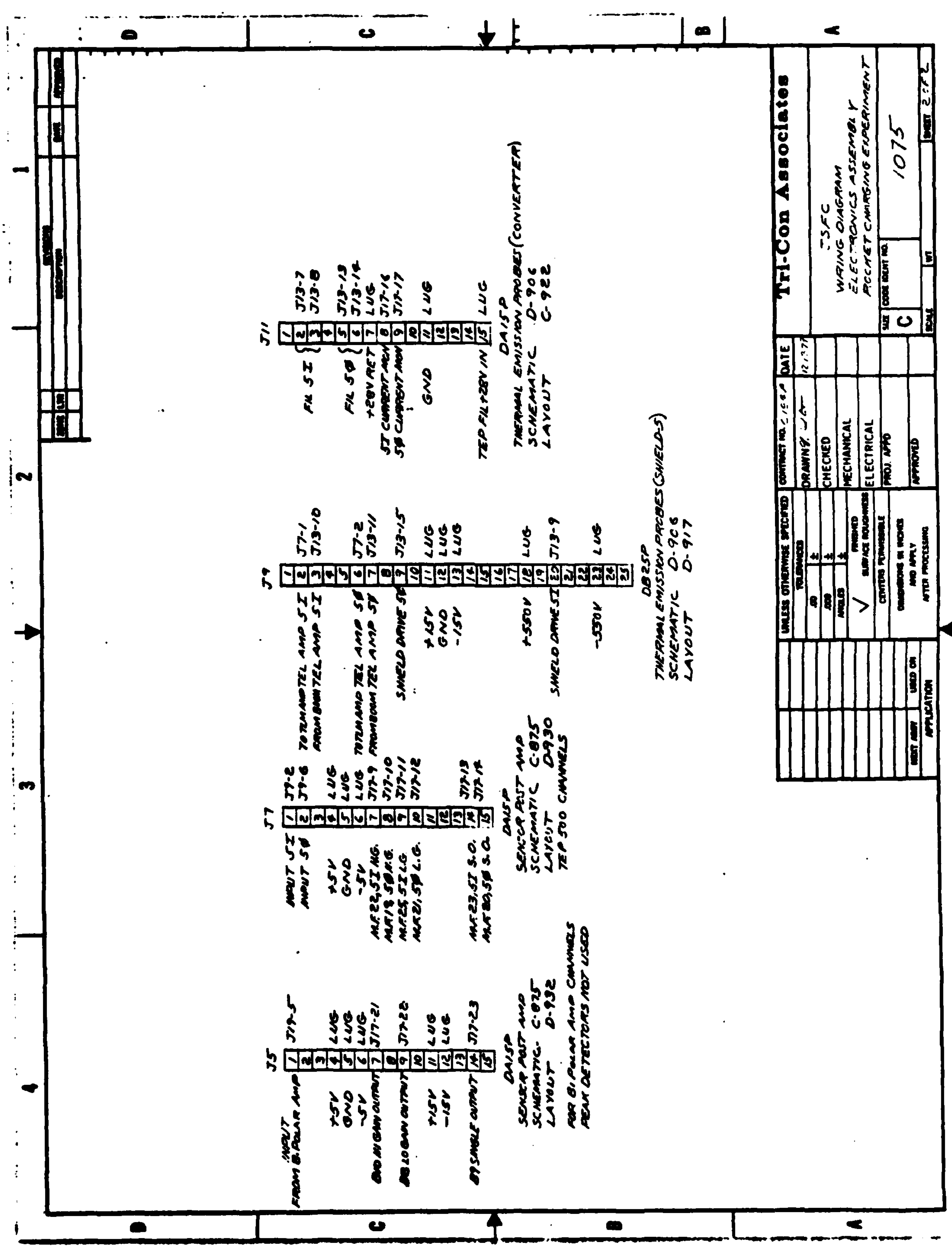

Tri-Con Associates
PCM
OPTICAL ISOLATOR
2003
R13 200Ω
311
R12 10K
R11 10K
R14 6.8K
R15 5.1K
PCM
Q1 2N2222
Q2 2N2222
Q5 2N2222
CR1
GE H11A5100
R3 100
R4 160
R6 100K
R7 1.2K
R9 2K
R18 2.7K
2.4K
SN75183

FIGURE 3



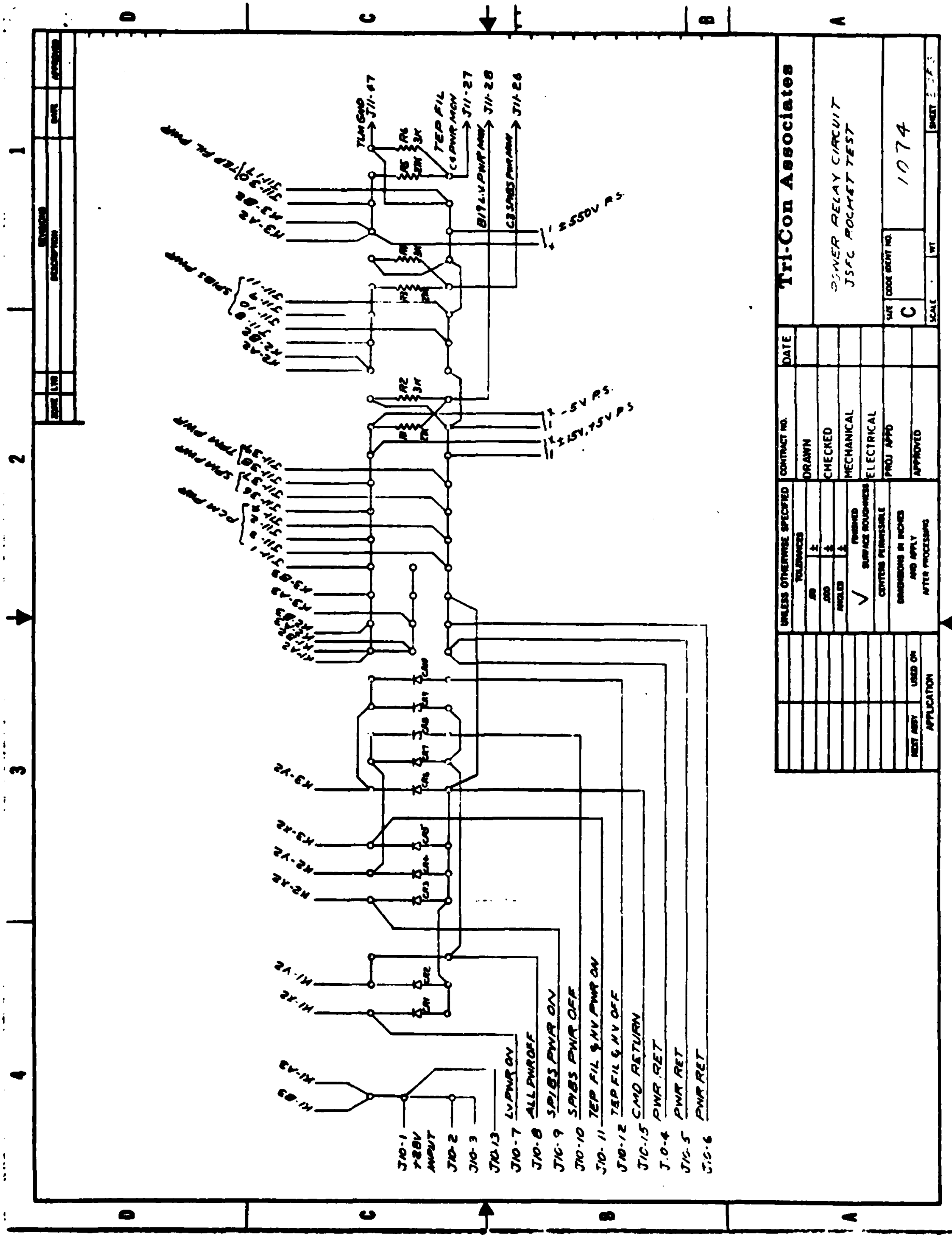
Tri-Con Associates
JSFC
WIRING DIAGRAM
EXTERNAL CONNECTORS
J13
J17
J19
J20
DAC-15S
BOOM SDO
DBC-25S
TELEM
DEC-9S
BI-POLAR
AMP
DAC-15P
POWER
1075

FIGURE 4



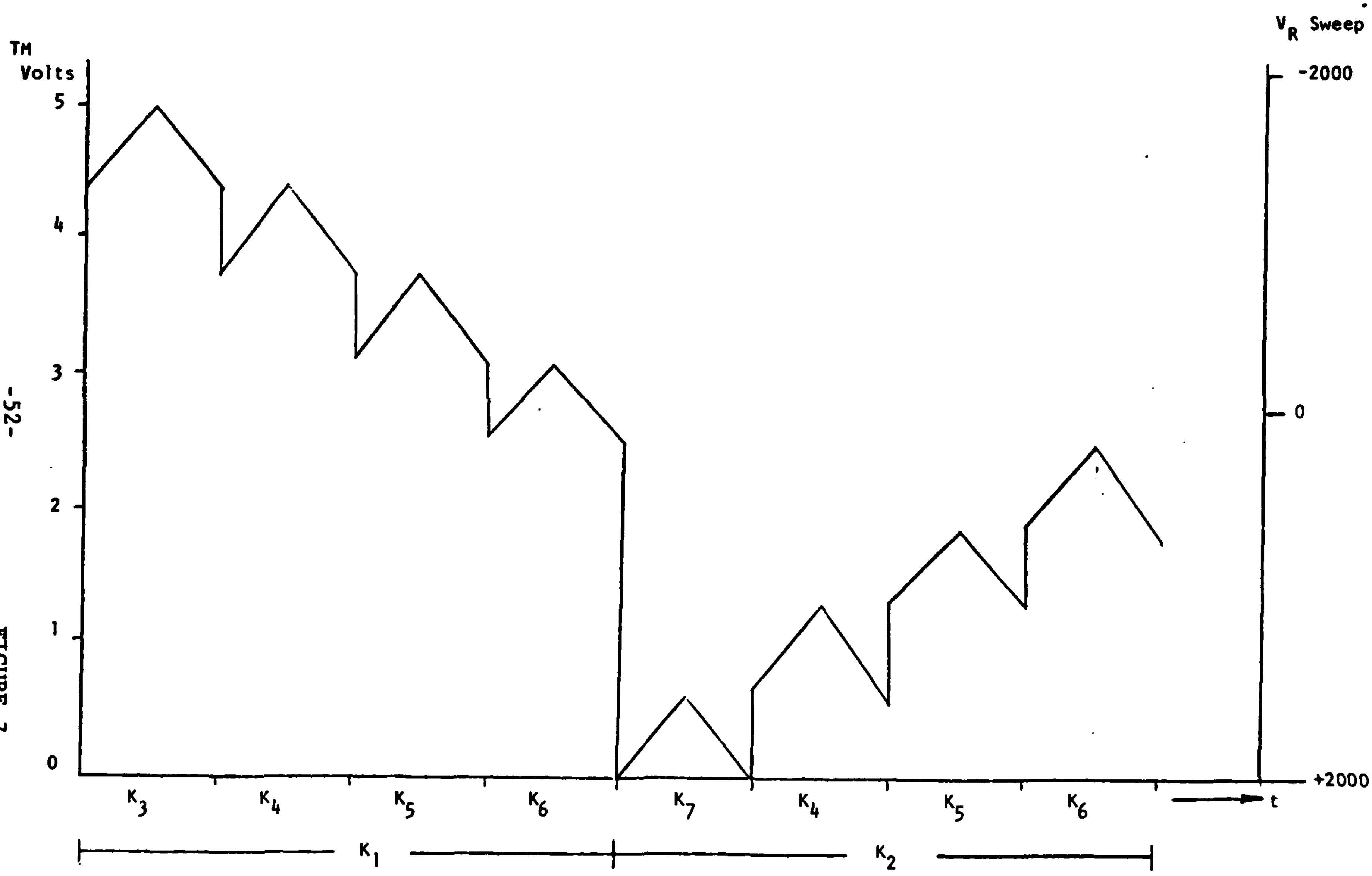
Tri-Con Associates
TSFC
WIRING DIAGRAM
ELECTRONICS ASSEMBLY
ROCKET CHARGING EXPERIMENT
1075

FIGURE 5



Tri-Con Associates
POWER RELAY CIRCUIT
JSFC POCKET TEST
1074
LV PWR ON
ALL PWR OFF
SPIBS PWR ON
SPIBS PWR OFF
TEP FIL & HV PWR ON
TEP FIL & HV OFF
CMD RETURN
PWR RET
PWR RET
PWR RET

FIGURE 6



RPA SWEEP MONITOR

FIGURE 7

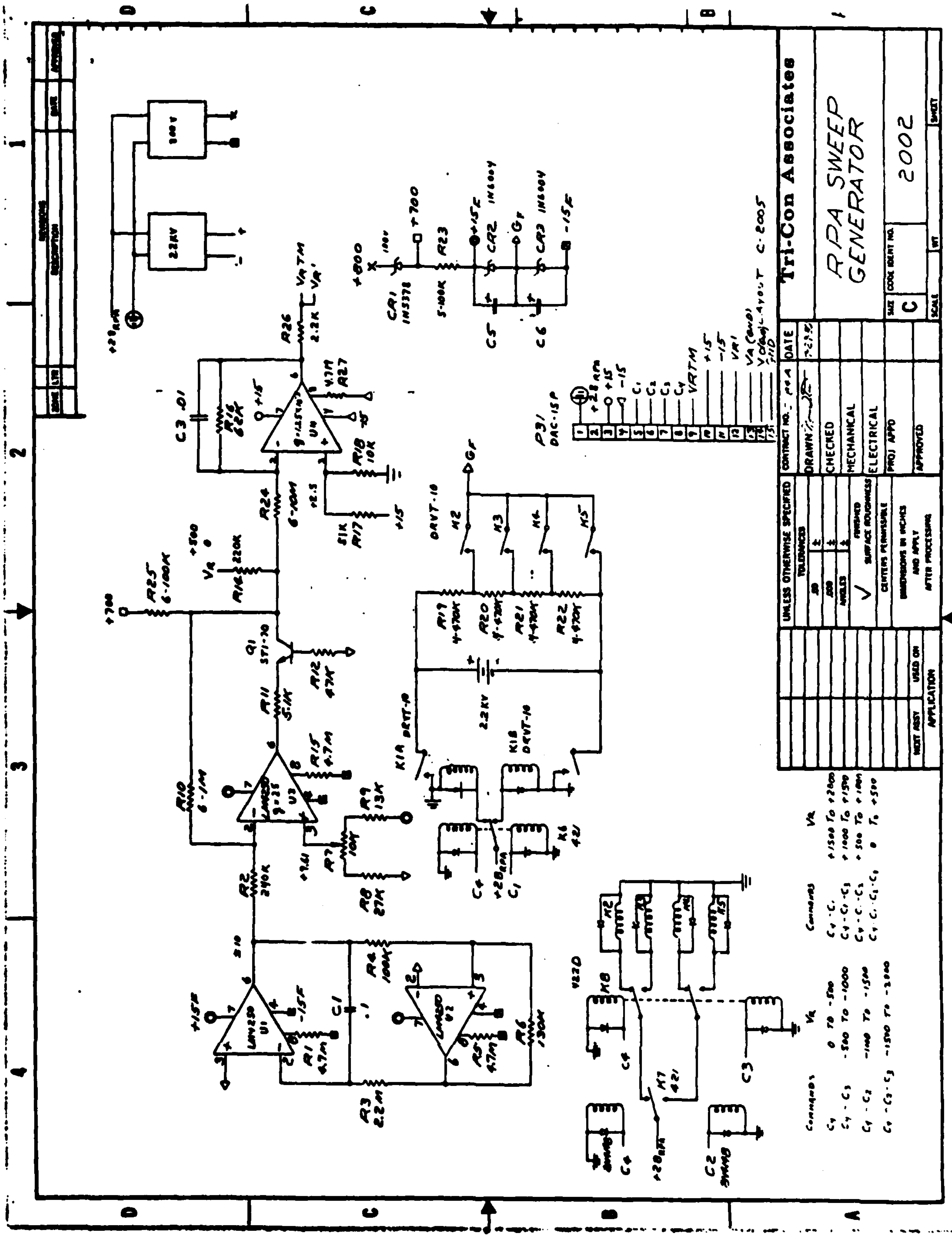
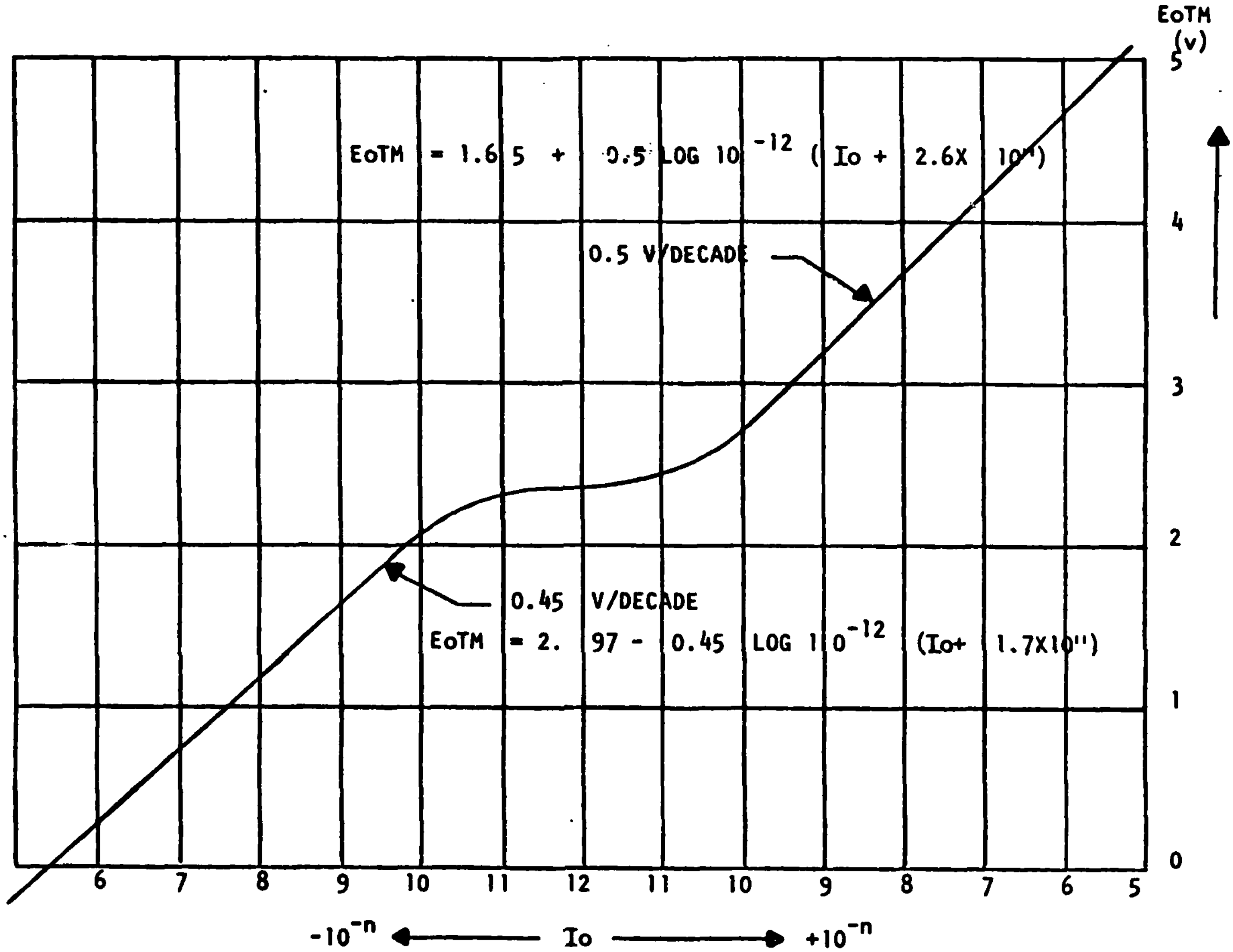
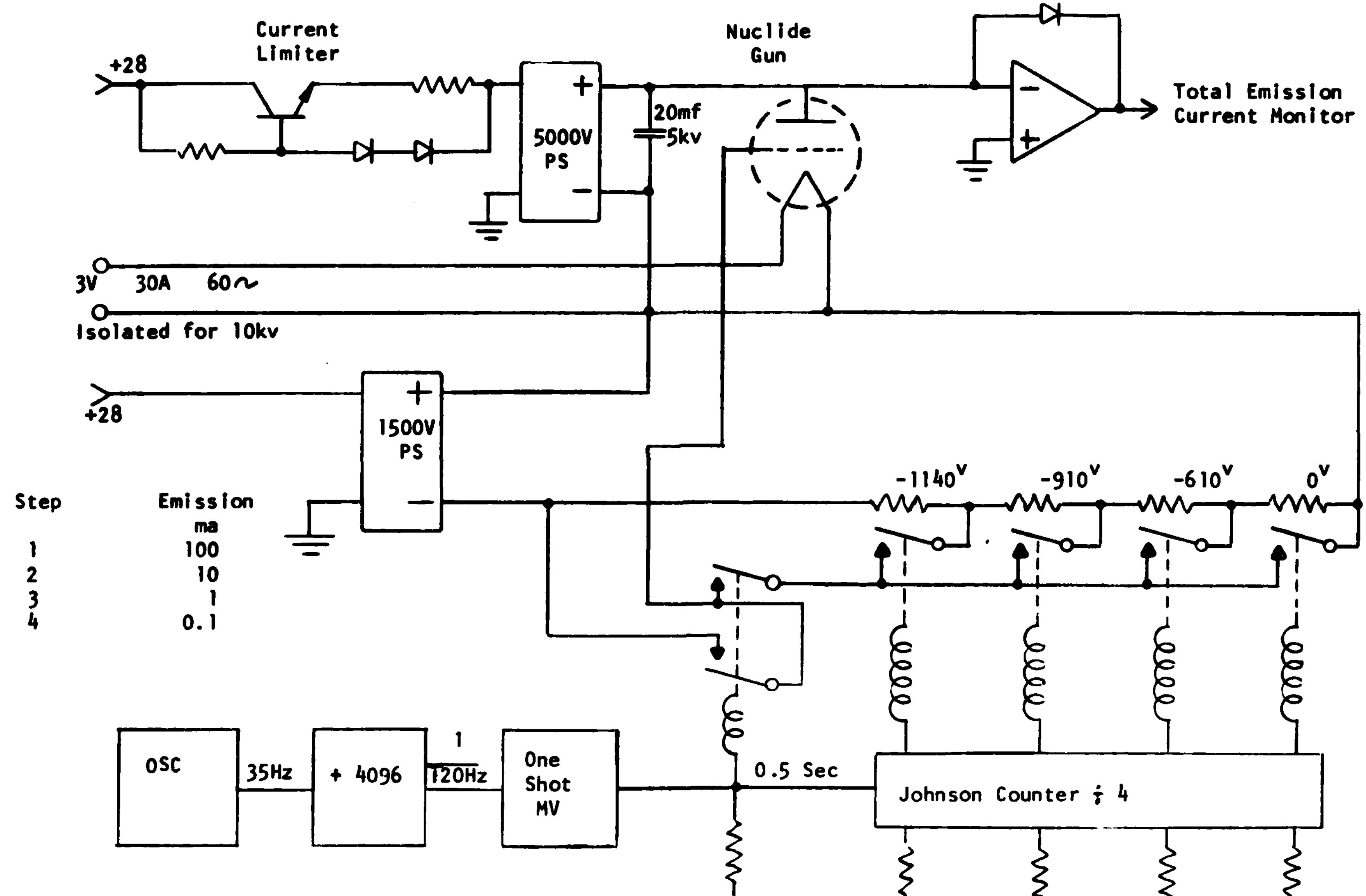


FIGURE 8



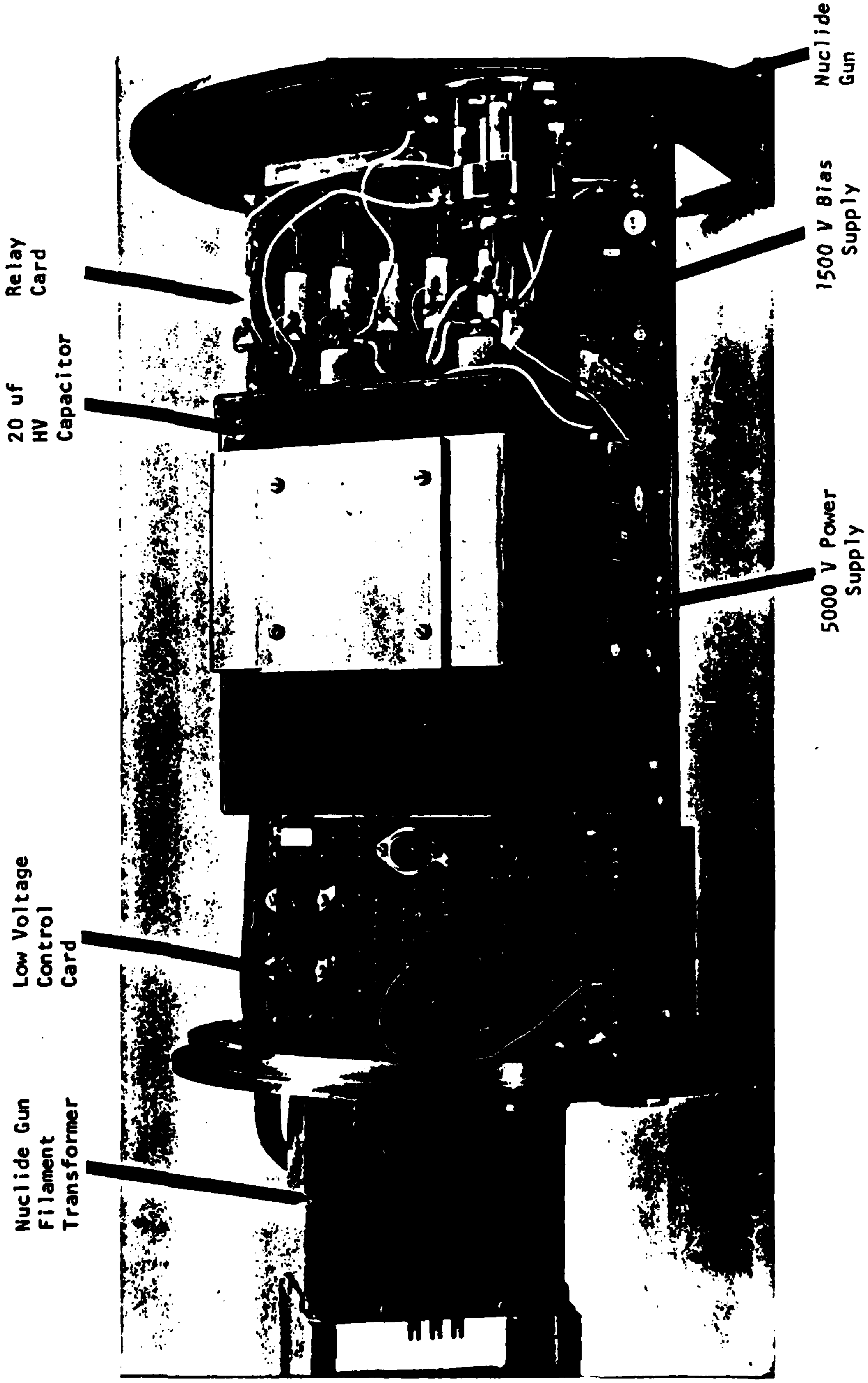
RPA BIPOLAR LOG AMP
DWG C896
5/23/80

FIGURE 9



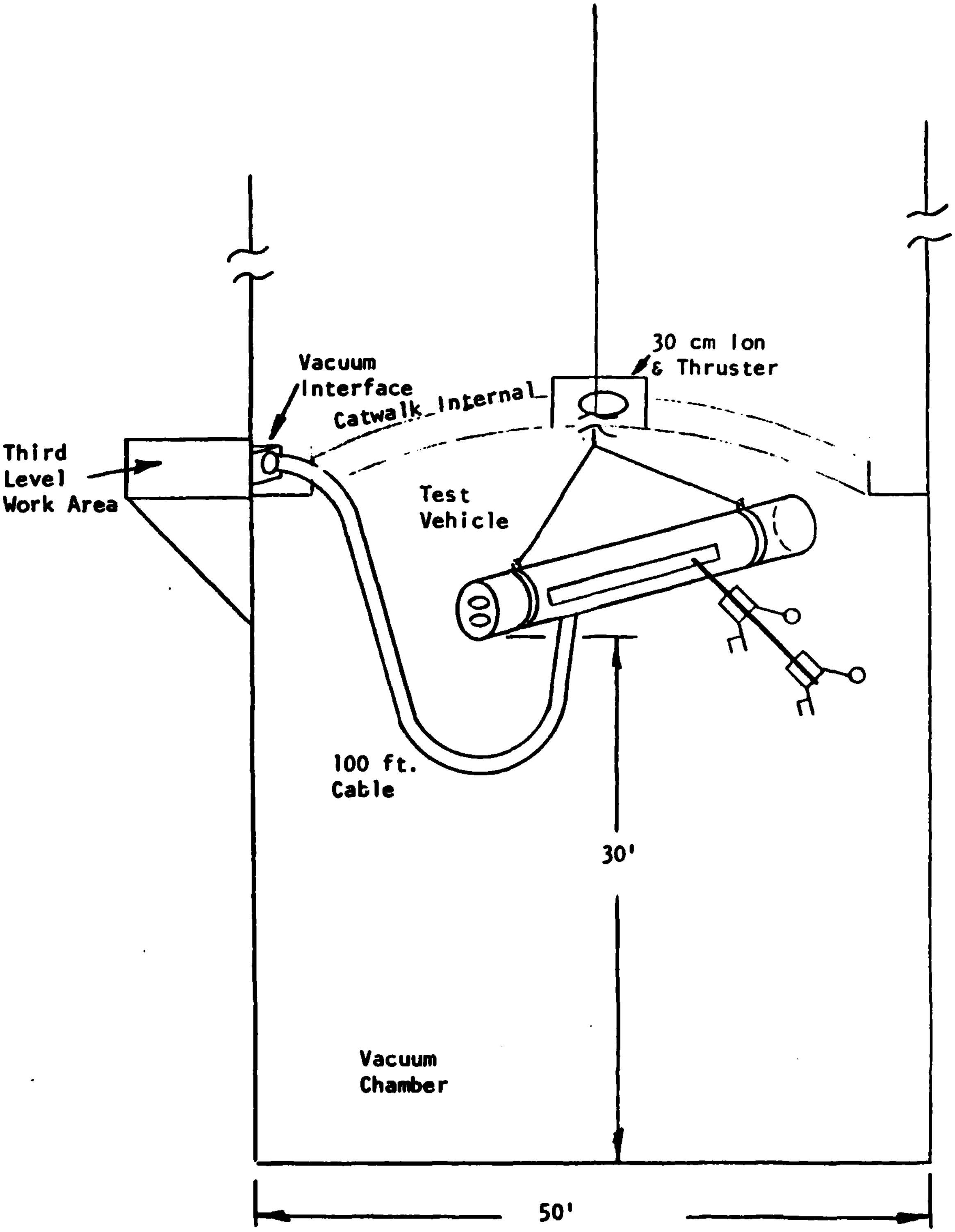
BLOCK DIAGRAM
ELECTRON GUN DISCHARGE
PROGRAM JSFC

FIGURE 10



Nuclide Gun Filament Transformer
Low Voltage Control Card
20 uf HV Capacitor
Relay Card
5000 V Power Supply
1500 V Bias Supply
Nuclide Gun

FIGURE 11



VEHICLE CHARGING
TEST SETUP
JSFC

FIGURE 12

KIMBALL PHYSICS
ELECTRON GUN

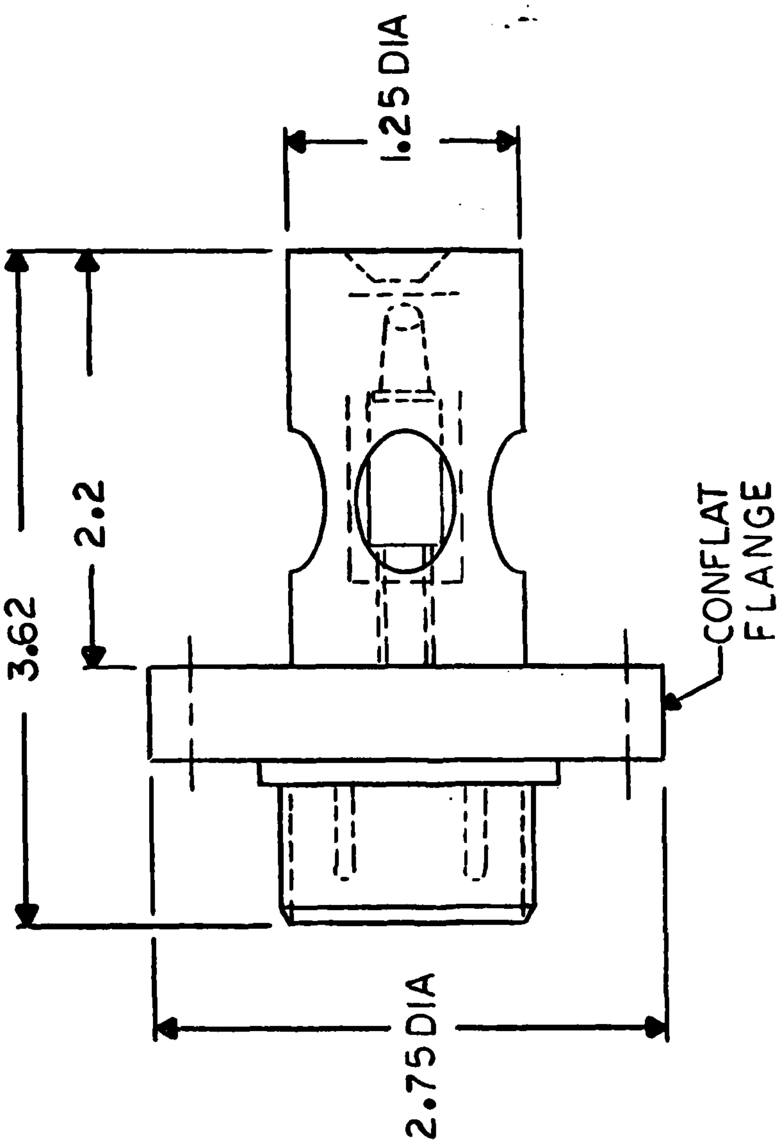
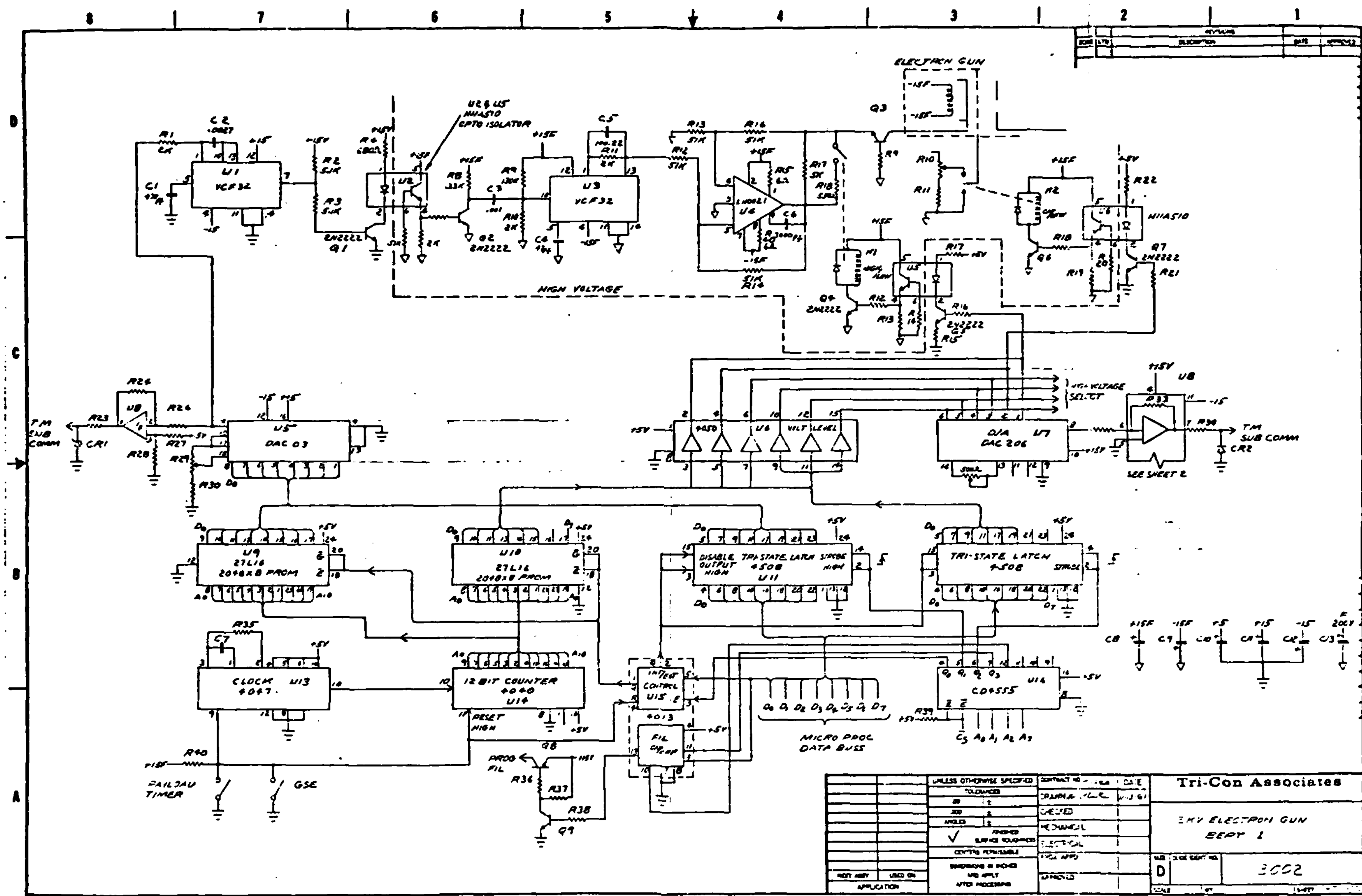


FIGURE 13



ELECTRON GUN
HIGH VOLTAGE
U2 & U5 H11AS10 OPTO ISOLATOR
U1 VCF32
U3 VCF32
U5 DAC 03
D/A U7 DAC 206
U9 27L16 2048x8 PROM
U10 27L16 2048x8 PROM
DISABLE OUTPUT HIGH TRI-STATE LATCH STROBE HIGH 4508 U11
TRI-STATE LATCH 4508 STROBE
CLOCK U13 4047
12 BIT COUNTER 4040 U14
RESET HIGH
CD4555 U16
4013
MICRO PROC DATA BUSS
HV VOLTAGE SELECT
TM SUB COMM
SEE SHEET 2
PROG FIL
FAILSAFE TIMER
GSE
Tri-Con Associates
2KV ELECTRON GUN
EEPT 1
3002

FIGURE 14

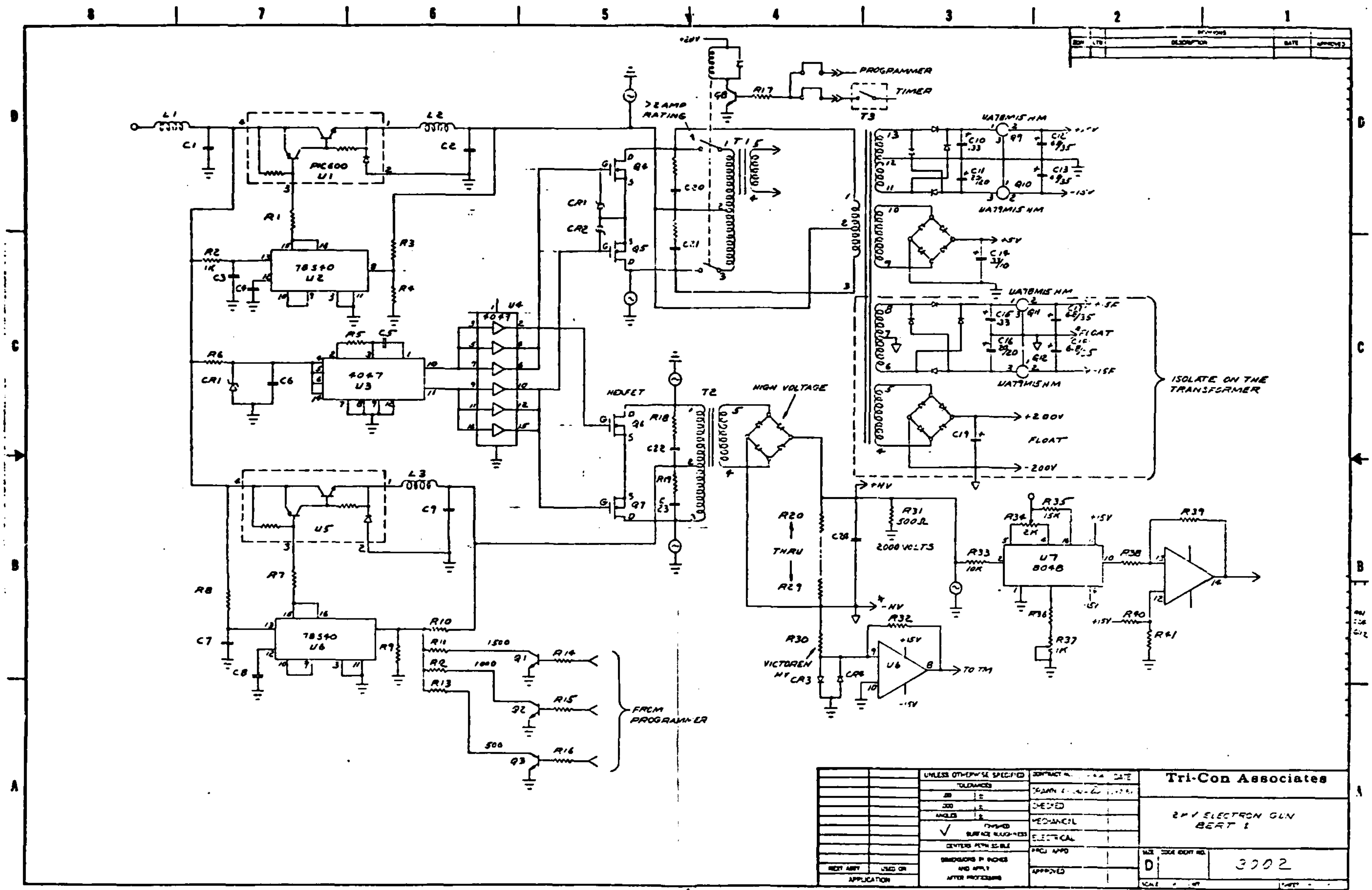
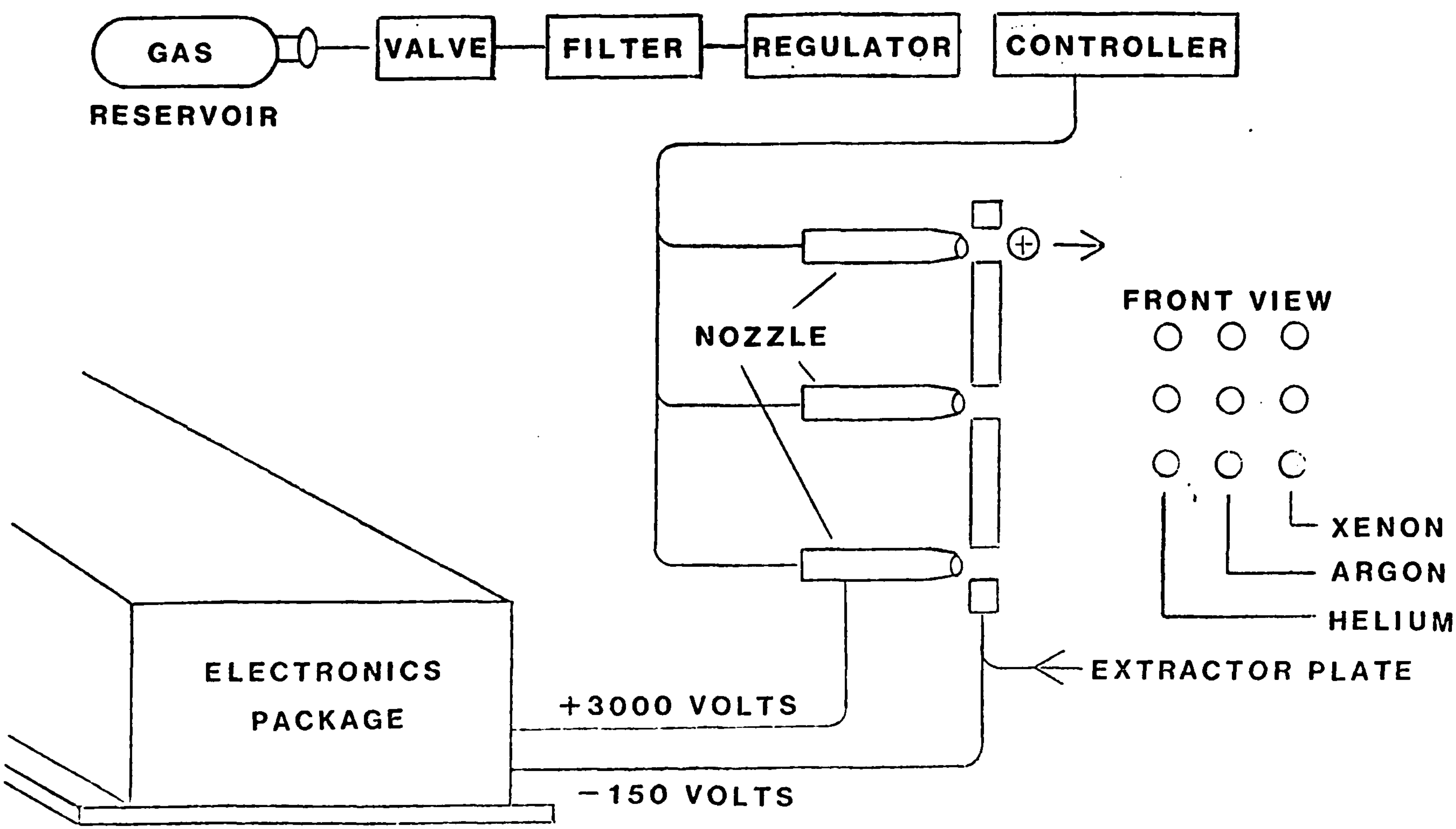


FIGURE 15



BLOCK DIAGRAM
CAPILLARITRON ION SOURCE

FIGURE 16

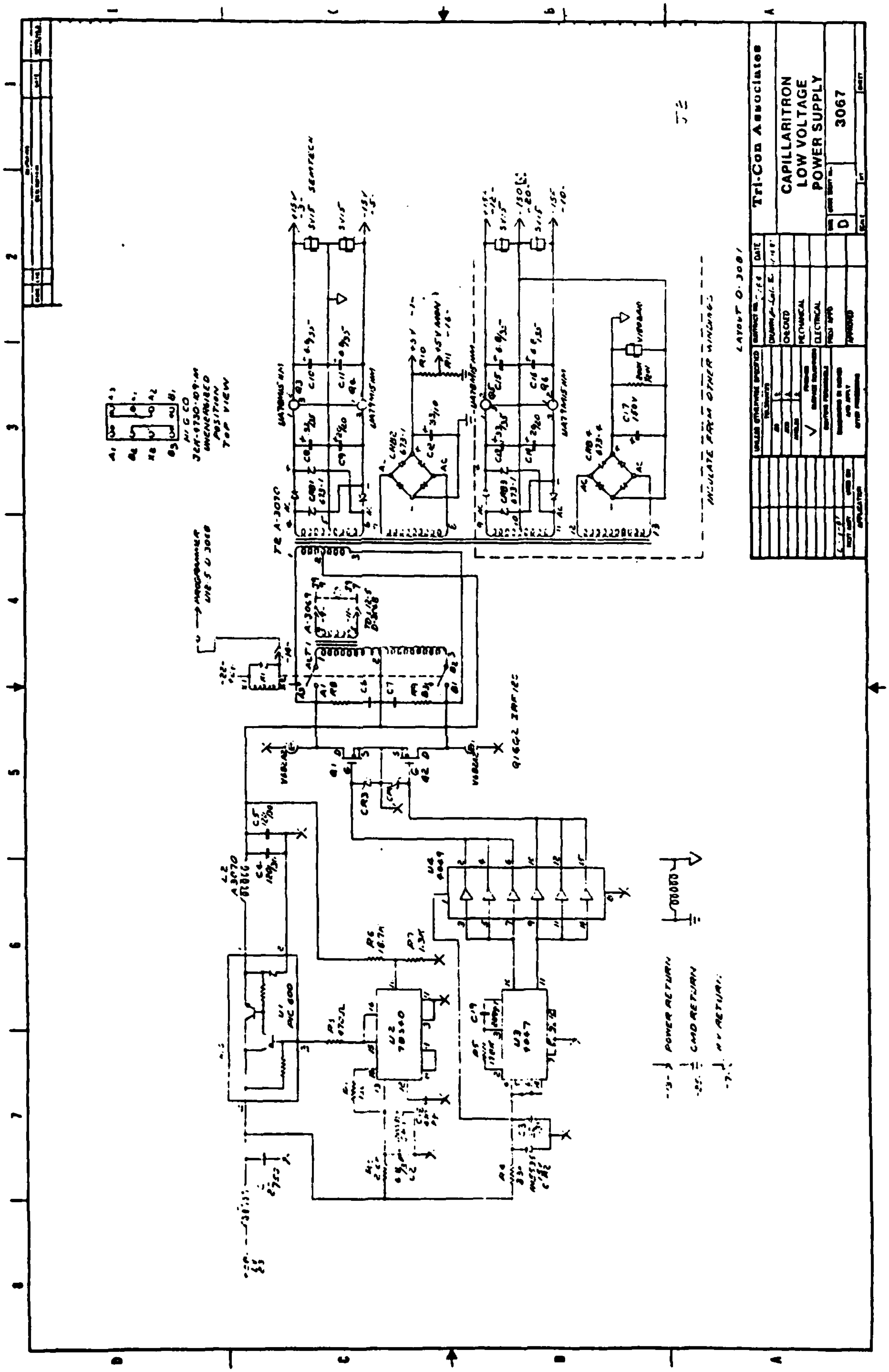

Tri-Con Associates
CAPILLARITRON
LOW VOLTAGE
POWER SUPPLY
3067
INSULATE FROM OTHER WINDINGS
LAYOUT D-3081
POWER RETURN
CMD RETURN

FIGURE 17

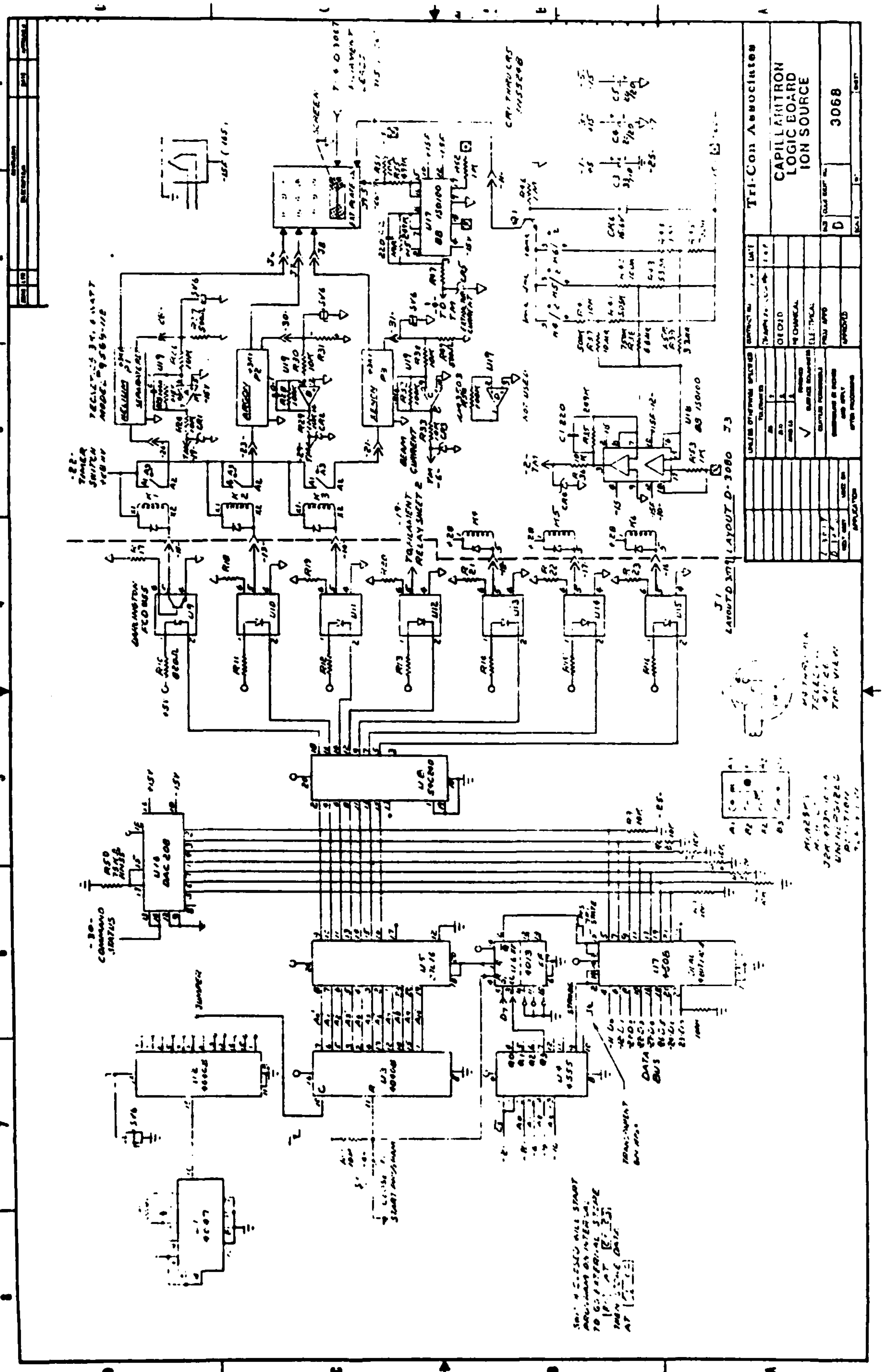
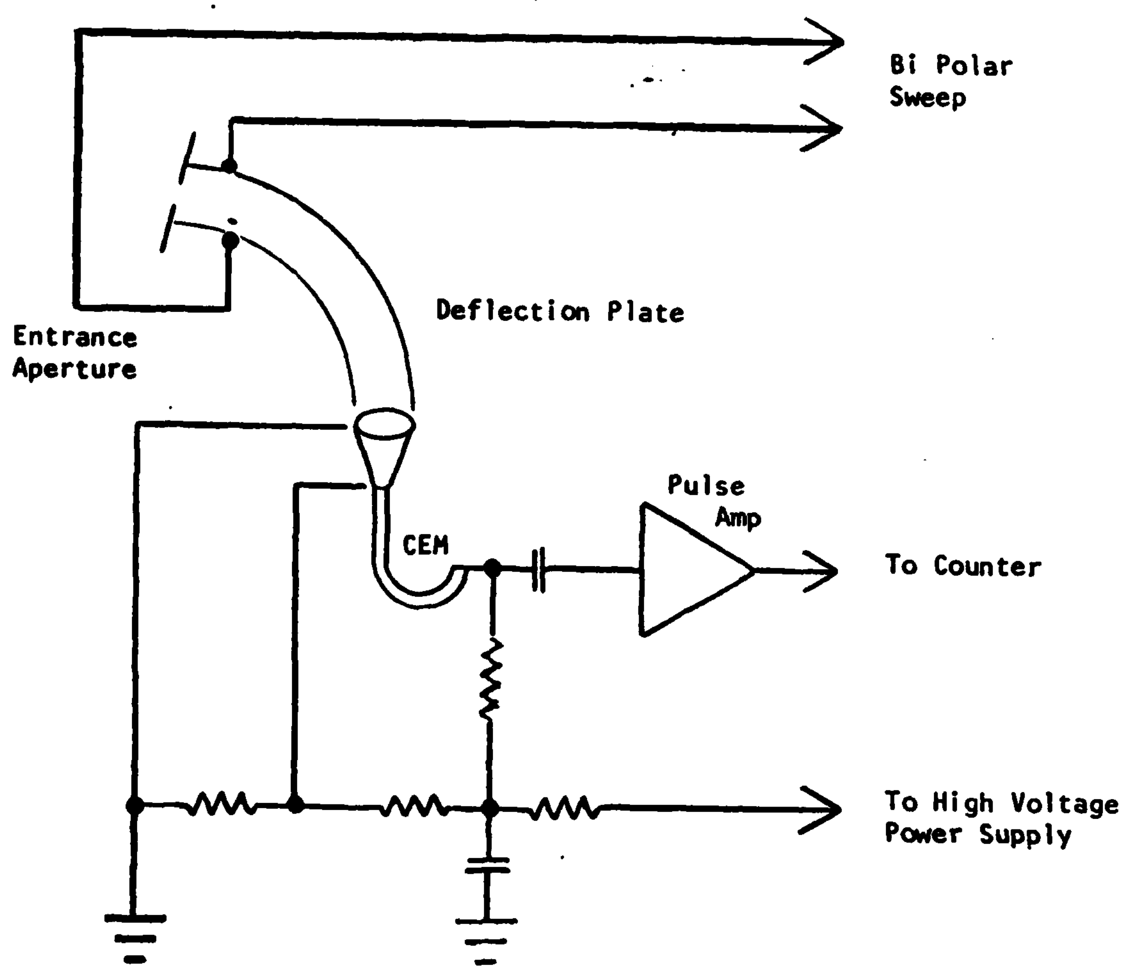
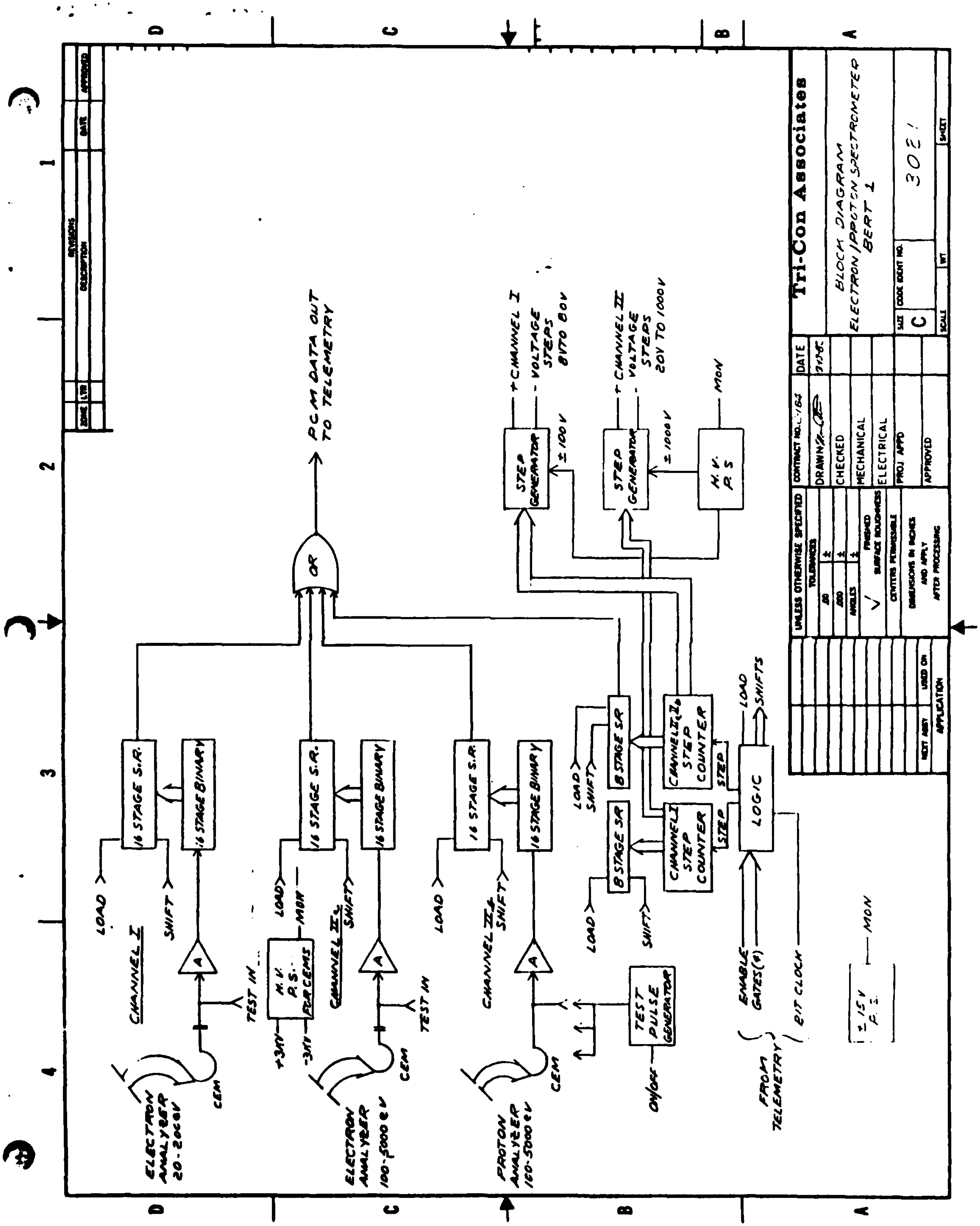

Tri-Con Associates
CAPILLARITRON
LOGIC BOARD
ION SOURCE
3068

FIGURE 18



SENSOR PACKAGE

FIGURE 19



Tri-Con Associates
BLOCK DIAGRAM
ELECTRON/PROTON SPECTROMETER
BERT 1
ELECTRON ANALYZER 20-200eV
CEM
CHANNEL I
16 STAGE S.R.
16 STAGE BINARY
LOAD
SHIFT
TEST IN
H.V. P.S. FOR CEMS
+3KV
-3KV
MON
CHANNEL II
ELECTRON ANALYZER 100-5000 eV
PROTON ANALYZER 100-5000 eV
TEST PULSE GENERATOR
ON/OFF
8 STAGE S.R.
CHANNEL I STEP COUNTER
CHANNEL II STEP COUNTER
STEP
LOGIC
ENABLE GATES(4)
BIT CLOCK
FROM TELEMETRY
OR
PCM DATA OUT TO TELEMETRY
STEP GENERATOR
±100V
+ CHANNEL I
- VOLTAGE STEPS 8V TO 80V
±1000V
H.V. P.S
+ CHANNEL II
- VOLTAGE STEPS 20V TO 1000V
±15V P.S.

FIGURE 20

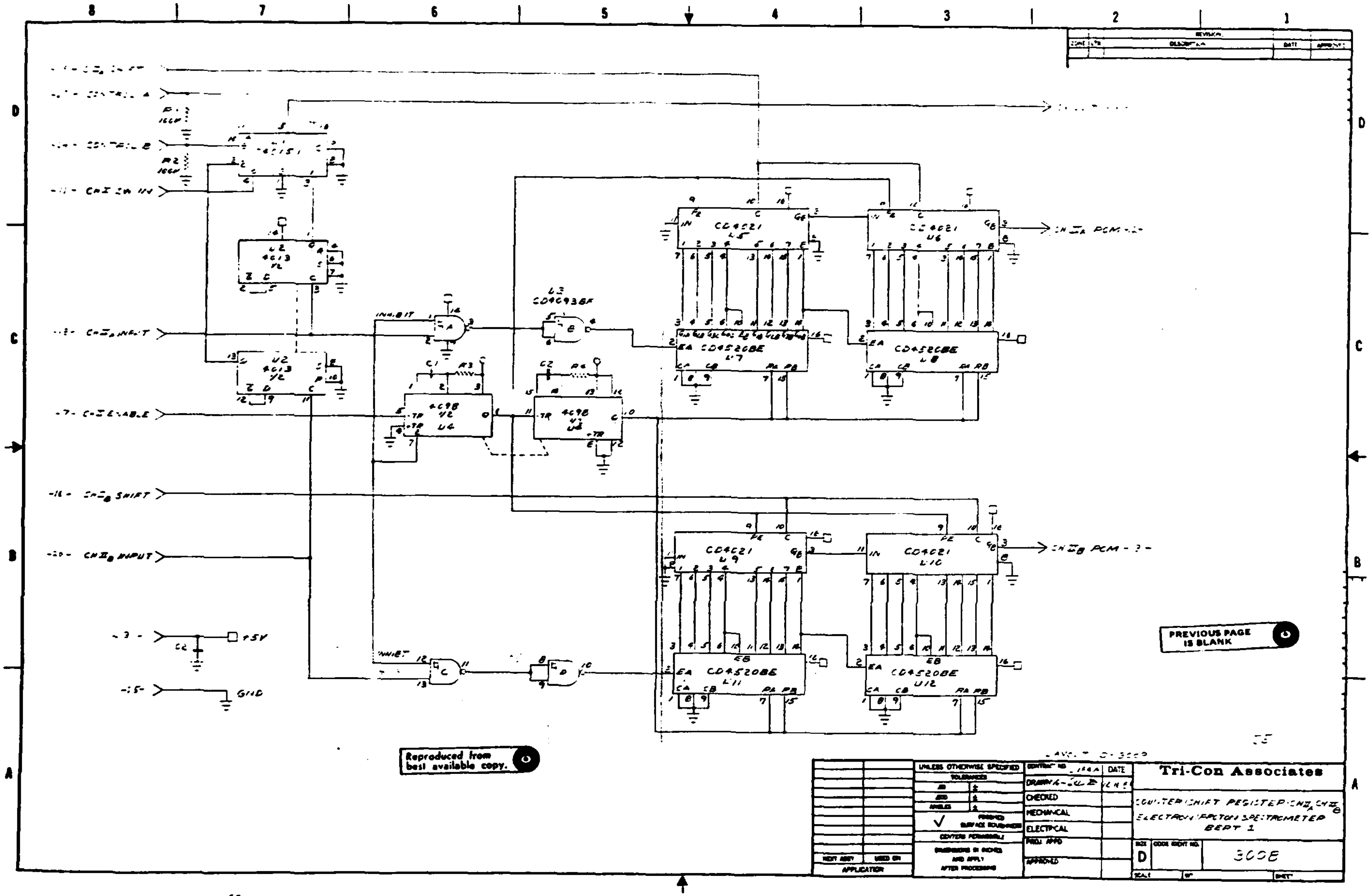

Tri-Con Associates
CD4021
CD4520BE
CD4098BE
4098
4013
+5V
GND
INHIBIT
UNLESS OTHERWISE SPECIFIED
TOLERANCES
CHECKED
MECHANICAL
ELECTRICAL
APPROVED
APPLICATION
NEXT ASSY
USED ON
D
PREVIOUS PAGE IS BLANK
Reproduced from best available copy.

FIGURE 21

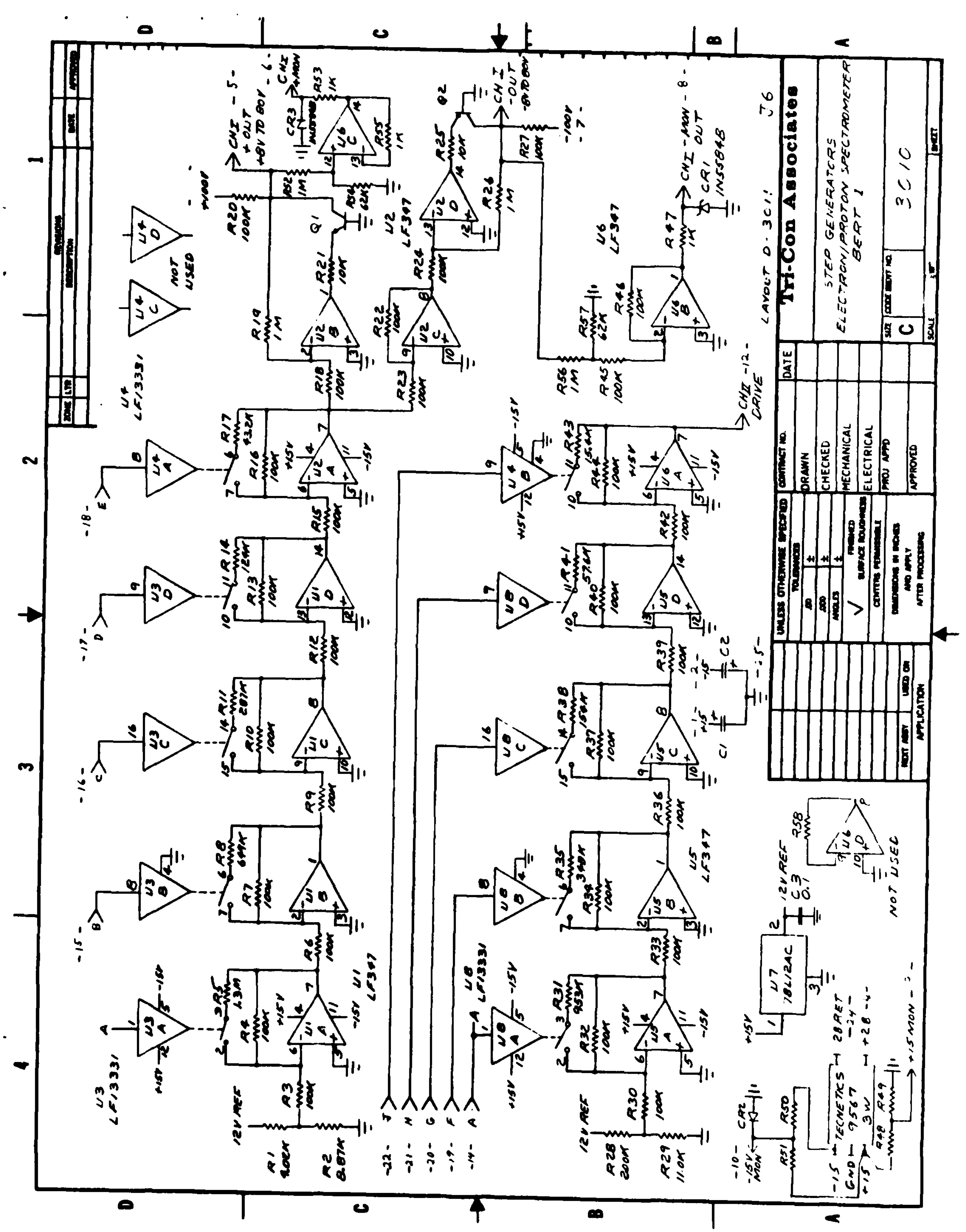

Tri-Con Associates
STEP GENERATORS
ELECTRON/PROTON SPECTROMETER
BERT 1
LAYOUT D-3C1
J6
3C1C
NOT USED

FIGURE 22

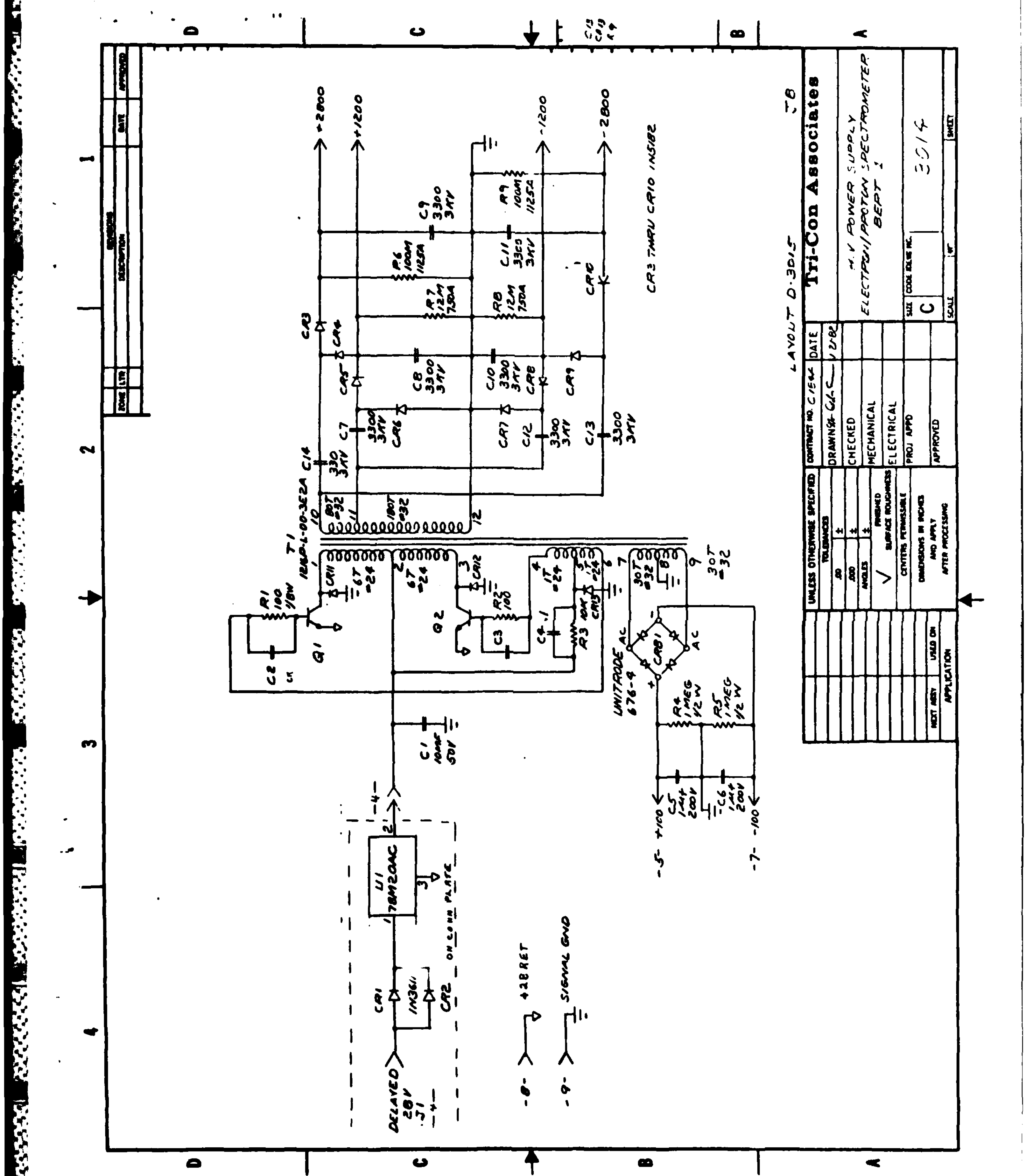
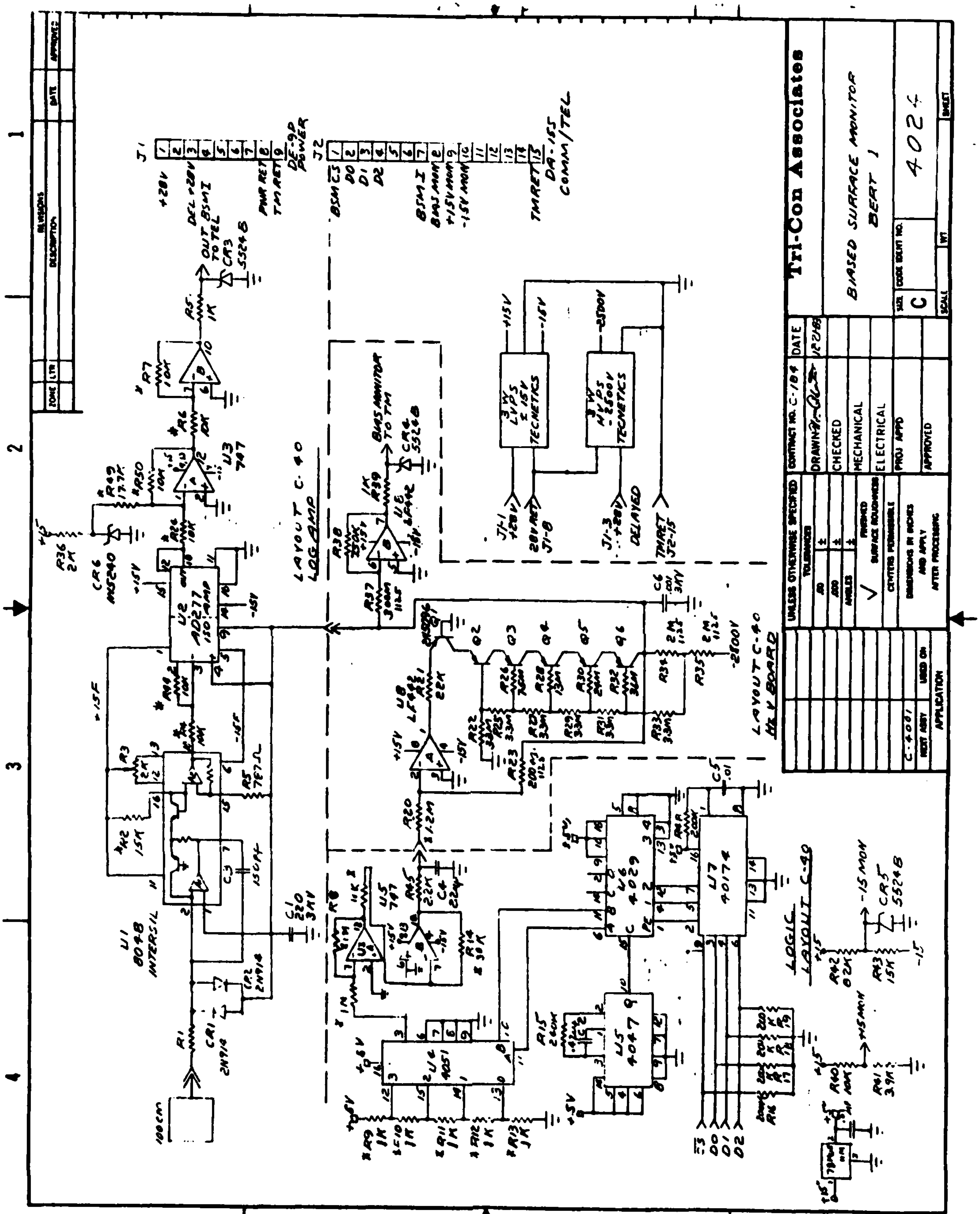

Tri-Con Associates
H.V POWER SUPPLY
ELECTRON/PROTON SPECTROMETER
BEPT 1
3014
LAYOUT D-3015
CR3 THRU CR10 IN5182
+2800
+1200
-1200
-2800
UNITRODE 676-4
DELAYED 28V
+28 RET
SIGNAL GND
U1 78M20AC

FIGURE 24



Tri-Con Associates
BIASED SURFACE MONITOR
BERT 1
4024
LAYOUT C-40
LOG AMP
LAYOUT C-40
HV BOARD
LOGIC
LAYOUT C-40

FIGURE 25

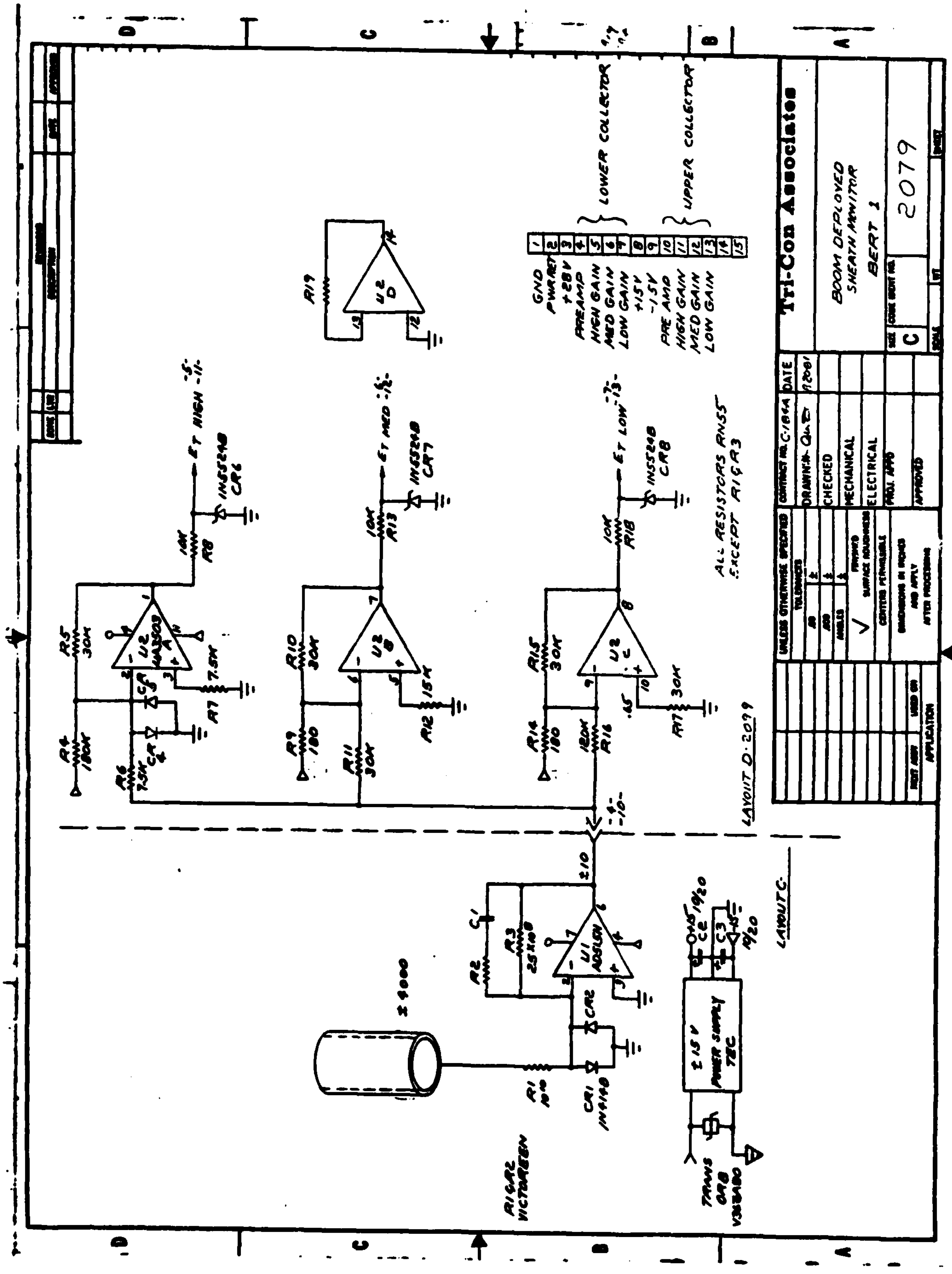

Tri-Con Associates
BOOM DEPLOYED SHEATH MONITOR
BERT 1
2079
C
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
APPROVED
GND
PWR RET
+28V
PREAMP
HIGH GAIN
MED GAIN
LOW GAIN
+15V
-15V
PRE AMP
HIGH GAIN
MED GAIN
LOW GAIN
LOWER COLLECTOR
UPPER COLLECTOR
ET HIGH
ET MED
ET LOW
ALL RESISTORS RN55 EXCEPT R1 & R3
LAYOUT D-2099
LAYOUT C
±15V POWER SUPPLY TEC
TRANS ORB
POWER SUPPLY

FIGURE 26

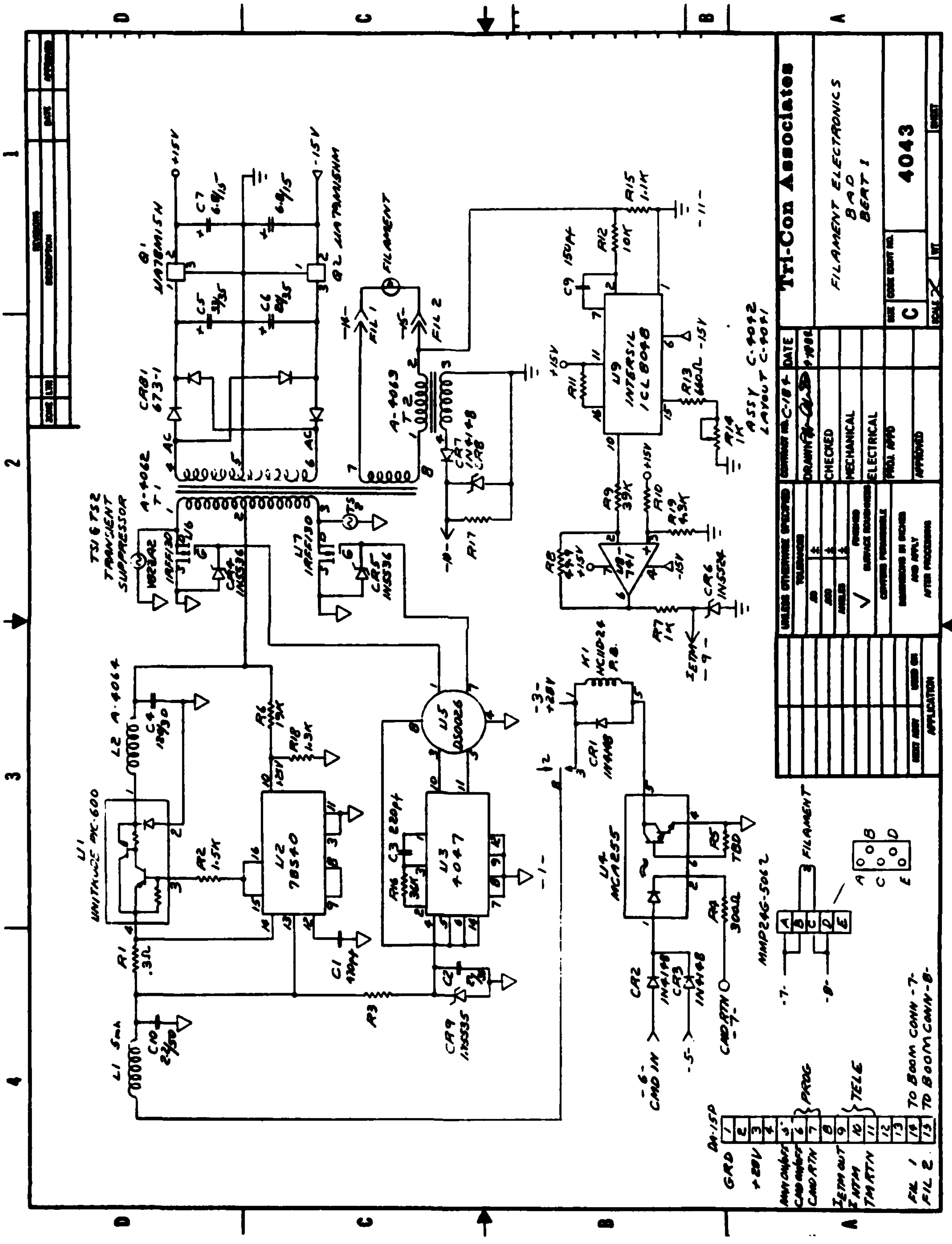


FIGURE 27

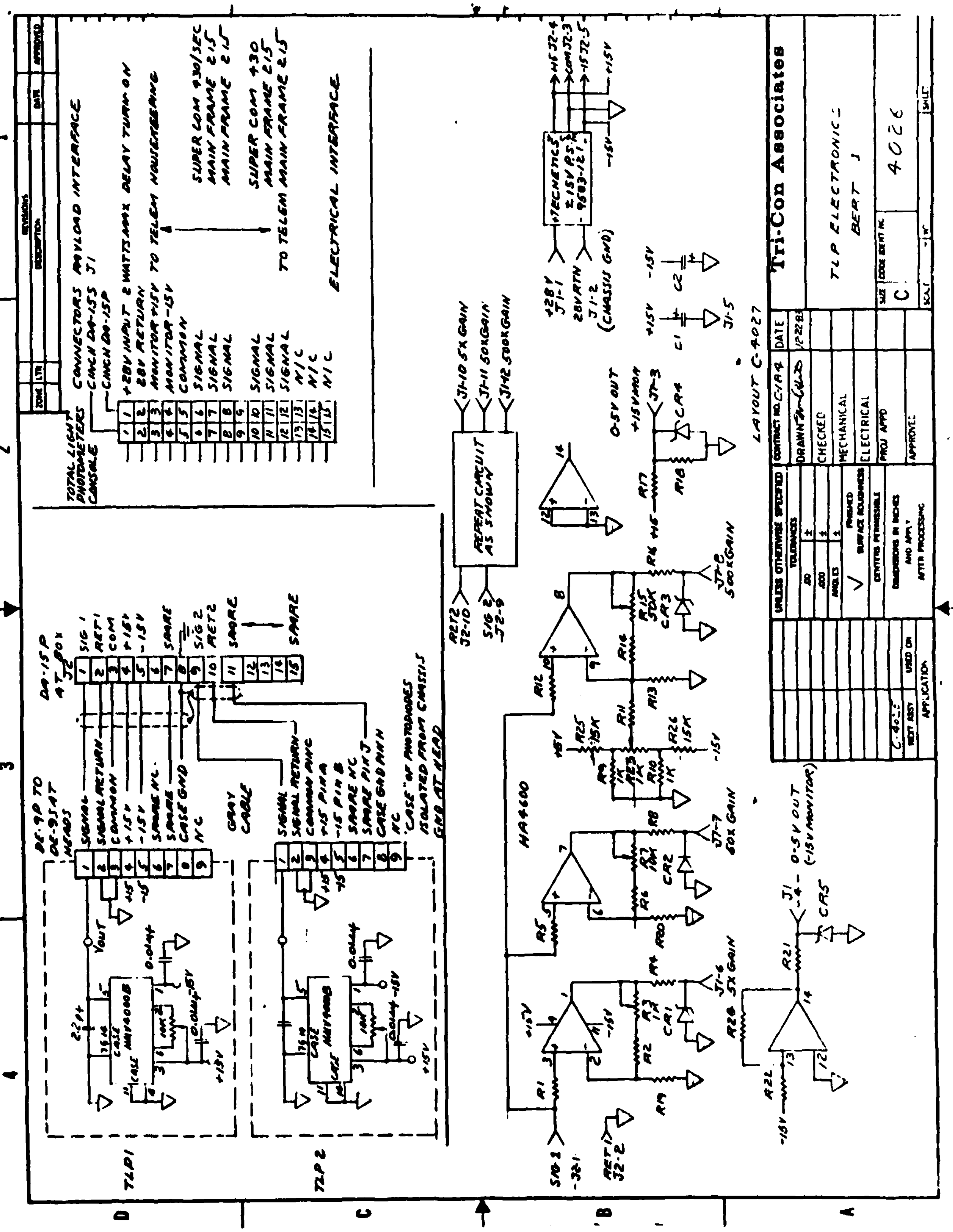

Tri-Con Associates
TLP ELECTRONICS
BERT 1
4026
LAYOUT C-4027
ELECTRICAL INTERFACE
CONNECTORS PAYLOAD INTERFACE
TOTAL LIGHT PHOTOMETERS CONSOLE
REPEAT CIRCUIT AS SHOWN
GRAY CABLE
HA4600
TLP1
TLP2

FIGURE 28

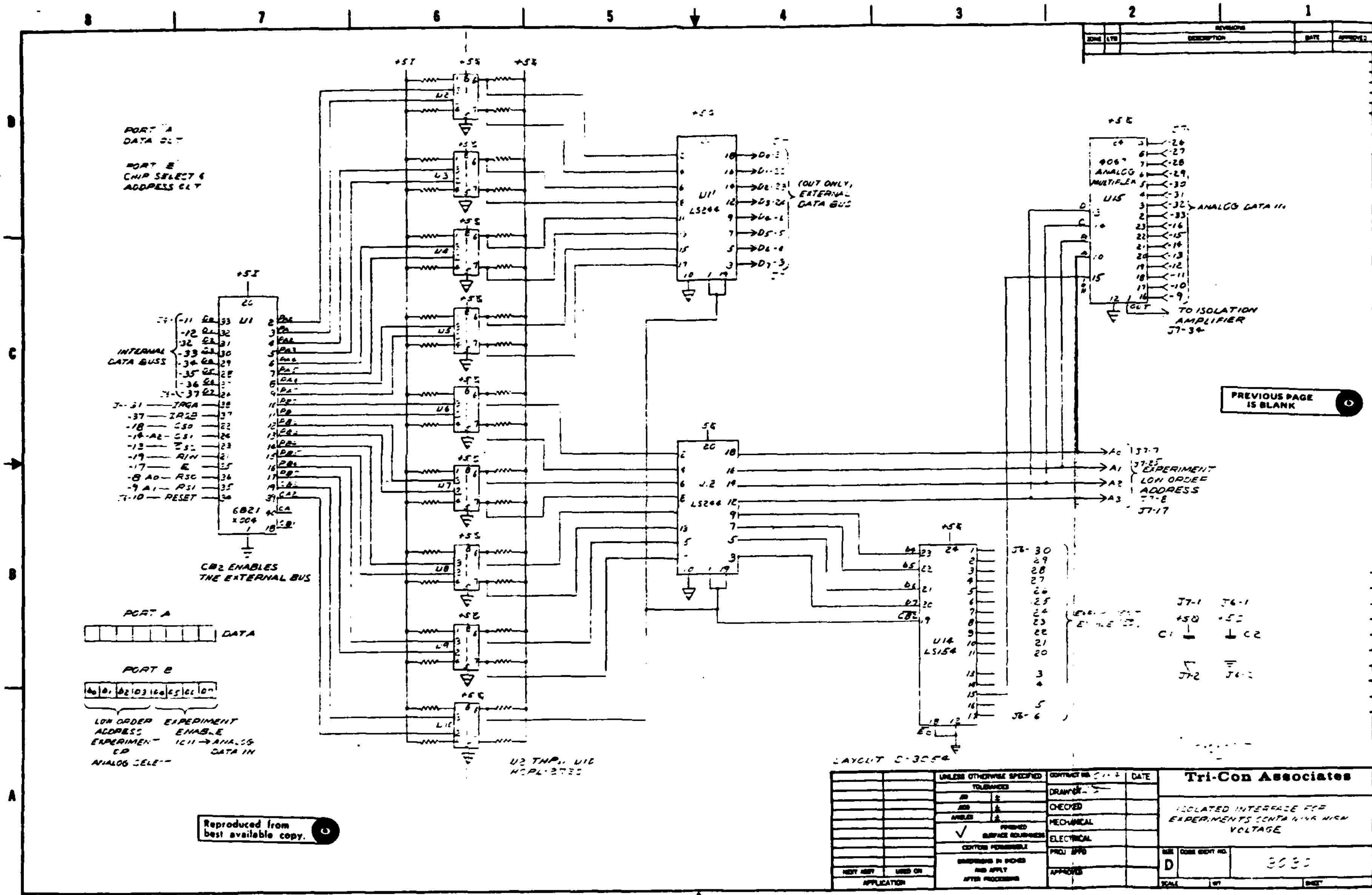

PORT A
DATA OUT
PORT B
CHIP SELECT &
ADDRESS OUT
INTERNAL DATA BUSS
6821
CB2 ENABLES THE EXTERNAL BUS
PORT A
DATA
PORT B
LOW ORDER ADDRESS
EXPERIMENT CP
ANALOG SELECT
EXPERIMENT ENABLE
IC11 → ANALOG DATA IN
U1
U2
U3
U4
U5
U6
U7
U8
U9
U10
U11
LS244
(OUT ONLY) EXTERNAL DATA BUS
LS244
EXPERIMENT LOW ORDER ADDRESS
U14
LS154
U15
4067 ANALOG MULTIPLEX
ANALOG DATA IN
TO ISOLATION AMPLIFIER
J7-34
LAYOUT D-3054
Tri-Con Associates
ISOLATED INTERFACE FOR EXPERIMENTS CONTAINING HIGH VOLTAGE
D
UNLESS OTHERWISE SPECIFIED
TOLERANCES
ANGLES
DRAWN
CHECKED
MECHANICAL
ELECTRICAL
APPROVED
DATE
APPLICATION
Reproduced from best available copy.
PREVIOUS PAGE IS BLANK

FIGURE 29

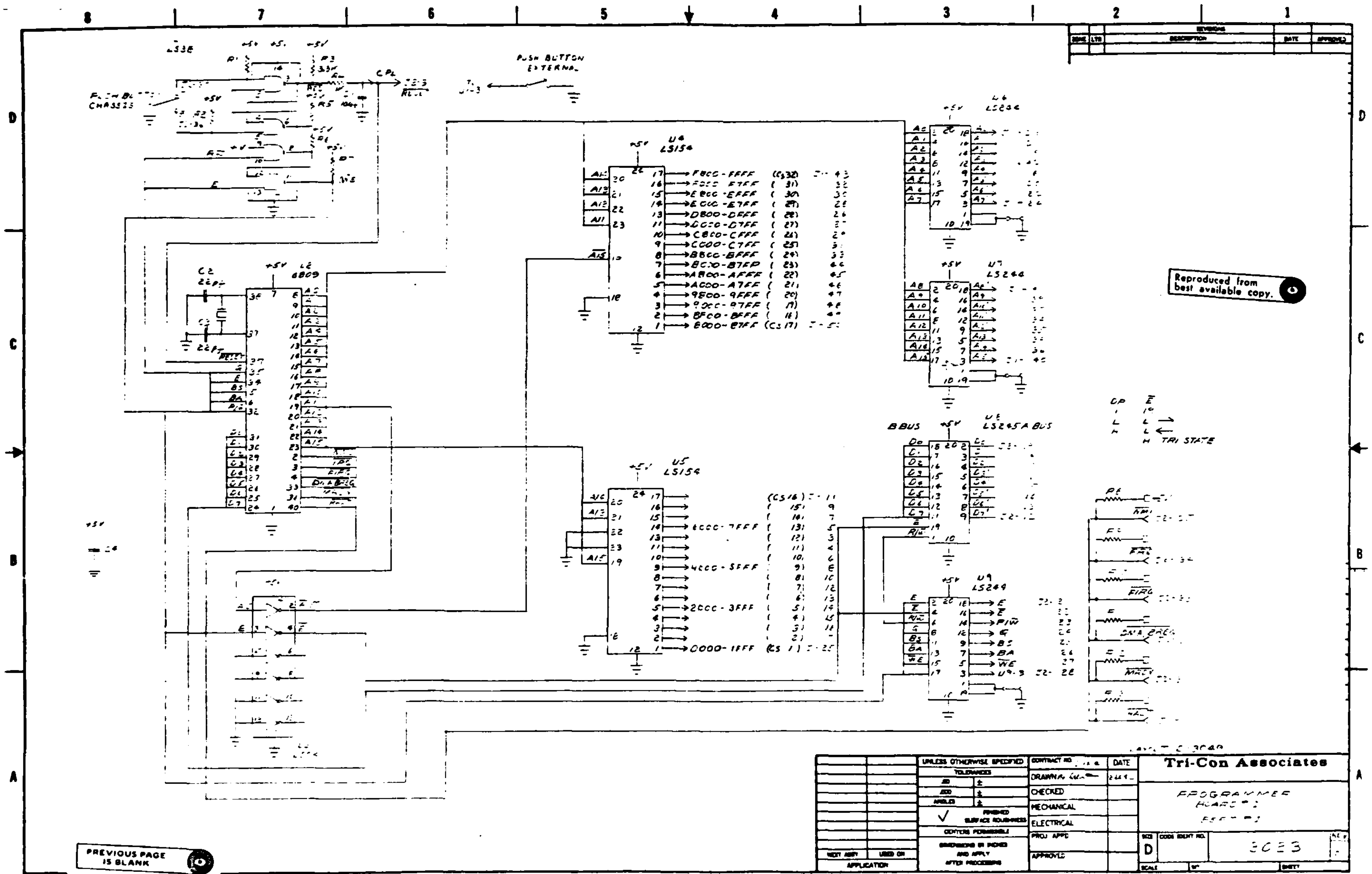

PUSH BUTTON EXTERNAL
U4 LS154
U5 LS154
U6 LS244
U7 LS244
U8 LS245A BUS
U9 LS244
6809
BBUS
TRI STATE
Tri-Con Associates
UNLESS OTHERWISE SPECIFIED
CHECKED
MECHANICAL
ELECTRICAL
APPROVED
APPLICATION

FIGURE 30

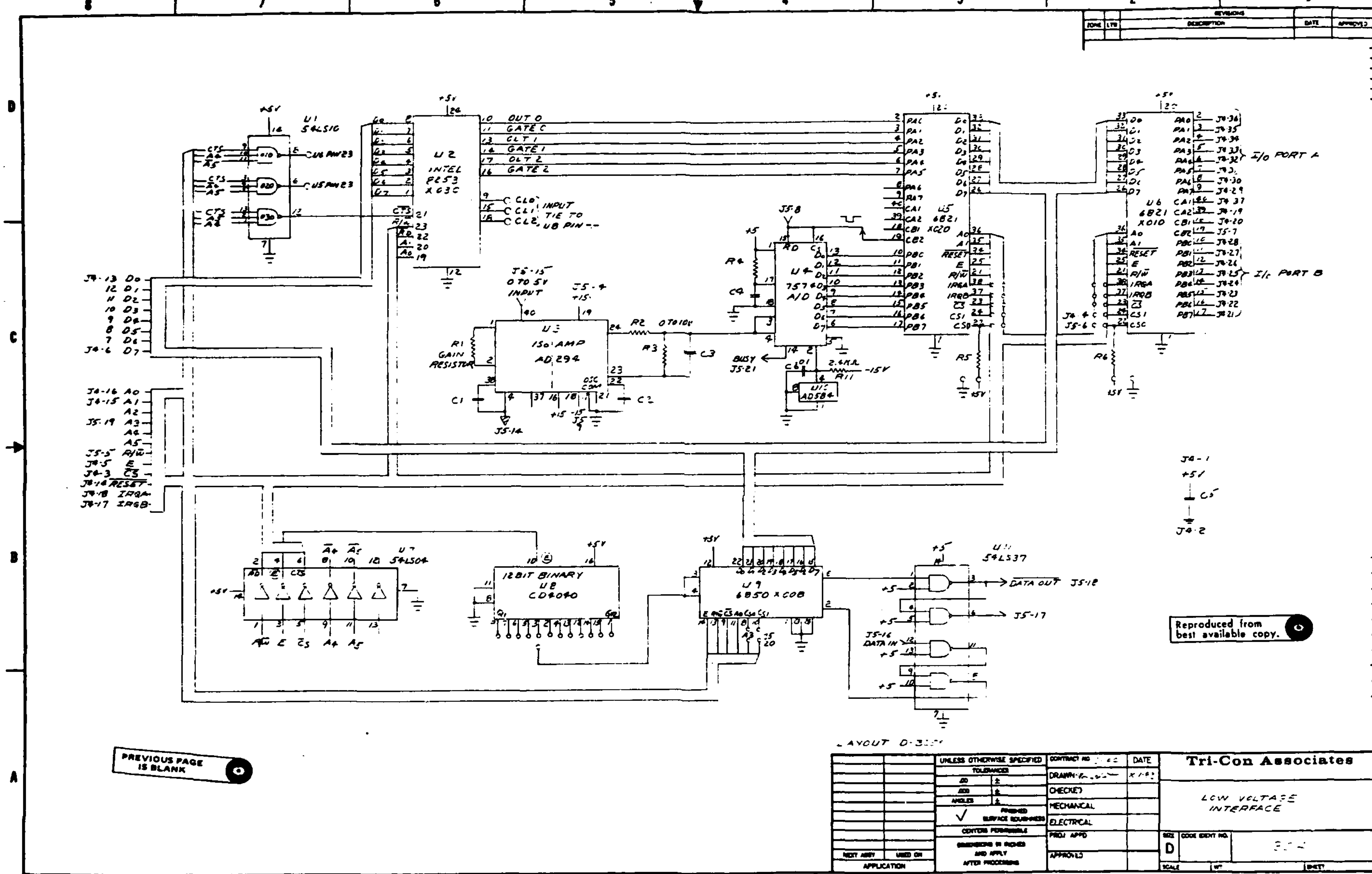

Tri-Con Associates
LOW VOLTAGE INTERFACE
U2 INTEL 8253 X030
U5 6821 X020
U6 6821 X010
U4 7574 A/D
U3 150:1 AMP AD 294
U8 12 BIT BINARY CD4040
U9 6850 X008
U11 54LS37
U7 54LS04
U1 54LS10
I/O PORT A
I/O PORT B
DATA OUT
DATA IN
GAIN RESISTOR
0 TO 5 V INPUT
0 TO 10 V
BUSY
LAYOUT D-3

FIGURE 31

END

FILMED

1-86

DTIC