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MARTIN MARIETTA CORPORATION

DESIGN, MANUFACTURE, AND TEST OF INFRARED CROSS WIRE RESISTANCE MICRO-WELDING SYSTEM

Final Report

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Report Period,
20 June 1967 to 20 March 1968

Contract No.: NAS8-21221

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ILLUSTRATIONS

INTRODUCTION

A definite correlation has been established between the pull strength (tensile strength) of a weld and the peak infrared radiation that a weld emits during the welding process. This correlation was implemented and verified in a feasibility demonstration, Contract NAS8-20339, completed in February 1967. The demonstration included a method of 1) sensing the infrared radiated energy generated at the weld, 2) evaluating the magnitude of the infrared radiated energy, and 3) providing a GO or NO-GO indication by energizing indicator lamps. The feasibility demonstration system is shown in Figure 1.

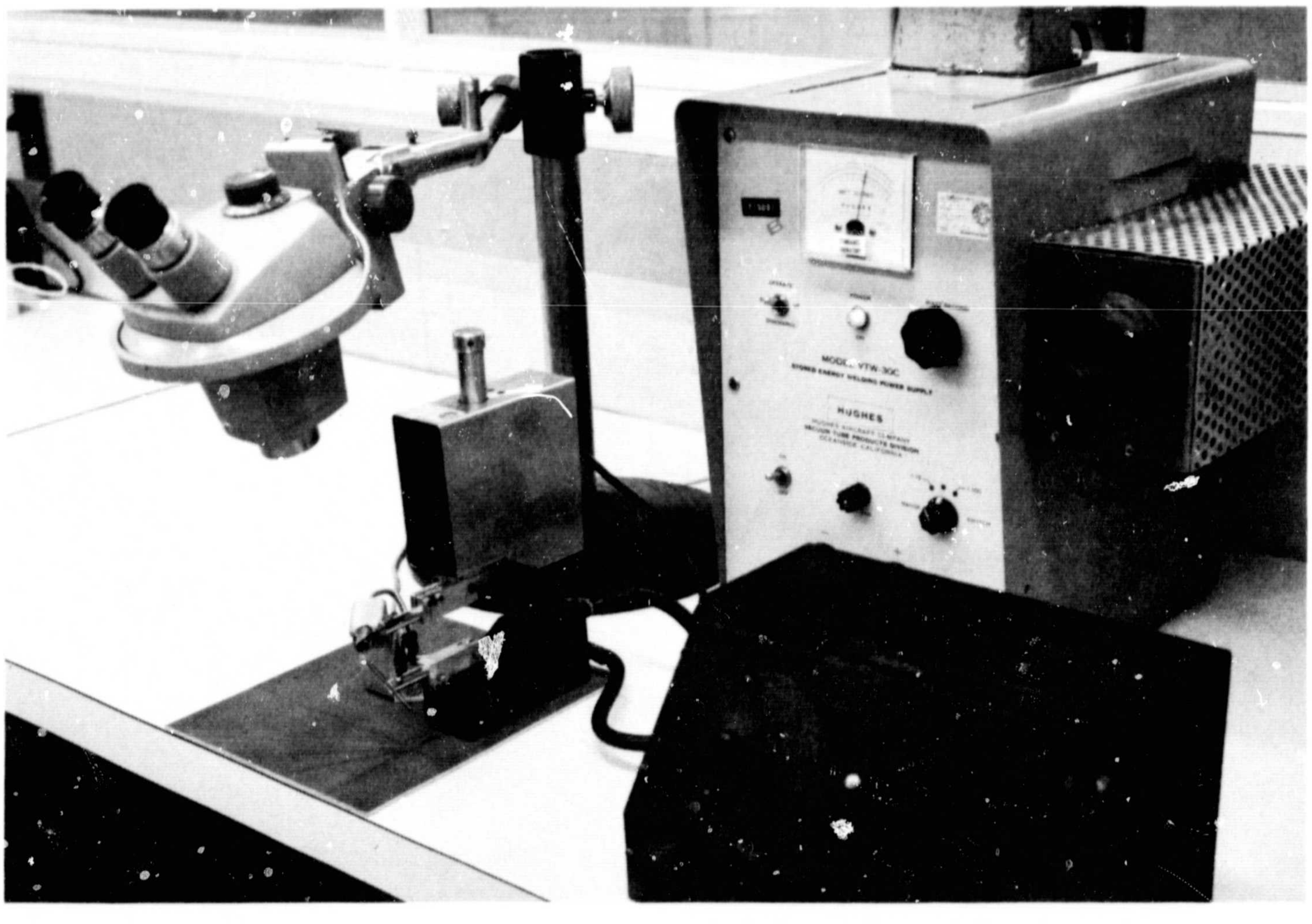

Figure 1. Infrared Radiation Weld Evaluator Feasibility Demonstration System

The present contract, NAS8-21221, provided for an engineering prototype weld evaluator that would demonstrate 1) immunity from power line noise, 2) a method of calibration, 3) a method of self test, and 4) an interlock to prevent additional welding after a NO-GO indication. The complete system is shown in Figure 2.

Figure 2. Infrared Radiation Weld Evaluator Engineering Prototype System

I. PROGRAM PLAN

At the beginning of the program a critical path diagram (see Figure 3) was constructed to ensure 1) that each requirement was accomplished in the time allotted, and 2) that all aspects of the program were considered.

II. FACTORY NOISE STUDY

The breadboard system generated in the preceding contract was sensitive to the noise generated by local equipment and by variations on the line. A passive tandem filter (design center 60 and 420 Hz) was used with a storage oscilloscope. The filter characteristics are shown in Figure 4. The power line of the microweld area and two adjacent areas were monitored. Figure 5 shows the noise in the weld area (the figure shows both normal and expanded scale on the oscilloscope).

Recharging the storage capacitors in a Hughes Weld Supply containing vacuum tubes caused the noise shown in Figure 6. Figure 7 shows the repetitious noise in the Chassis Fabrication Area. (The double spike area, expanded, is shown on the right side.)

Figure 8 shows both the normal and expanded noise, positive and negative spikes, in the wiring harness fabrication area. The rise time shown is 1.0 microsecond.

III. SYSTEM BREADBOARD

The basic circuits for a completely operating system were built in breadboard fashion (see Figure 9) using external power supplies. Component selectivity aided in reducing the sensitivity to noise. The breadboard was enclosed and was operated in the microweld area to determine sensitivity to factory noise (see Figure 10). The results were encouraging, but noise rejection was not sufficient. By carefully grounding and shielding the unit, plus the compactness in the final configuration, susceptibility to noise was not detectable.

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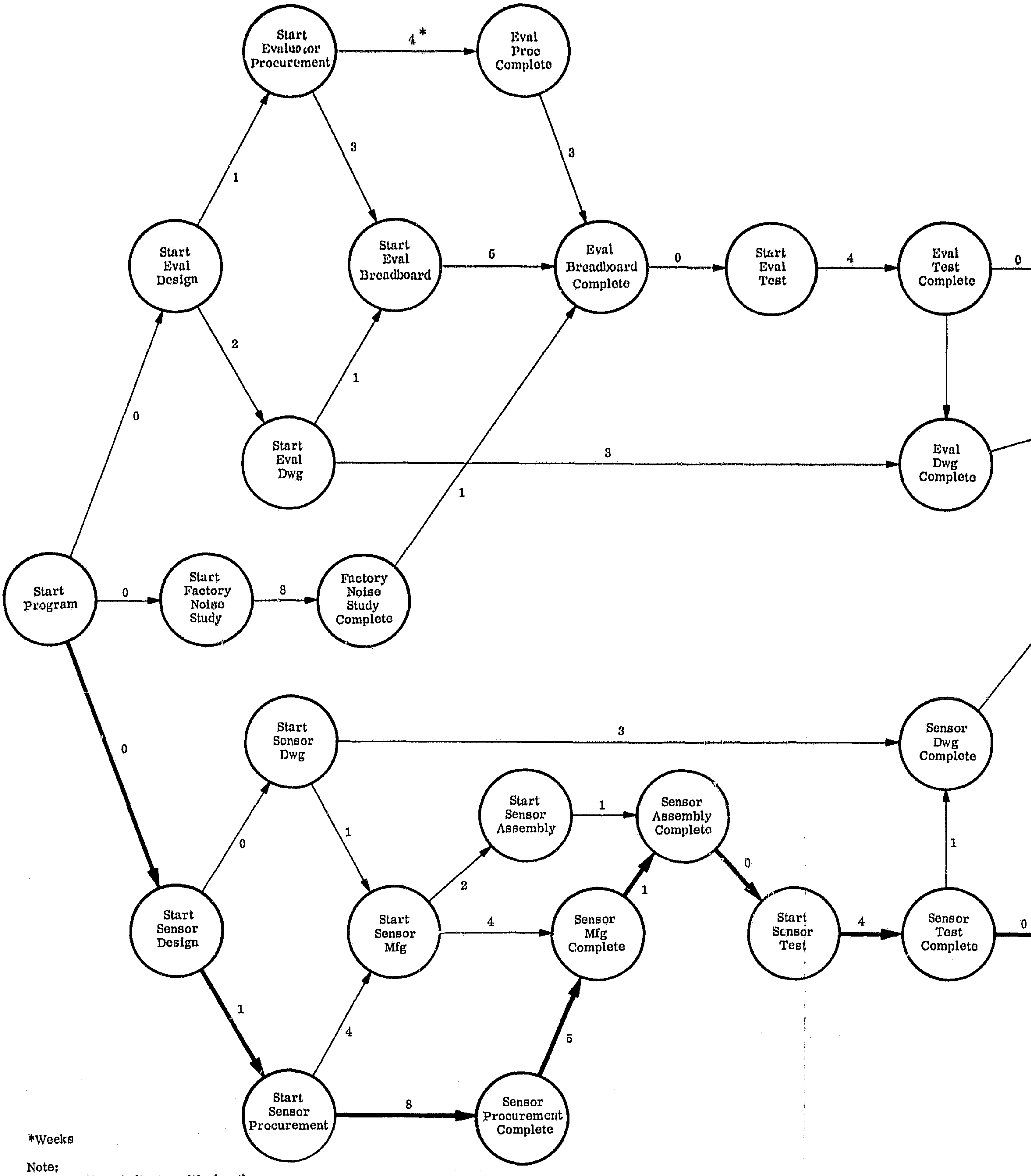

*Weeks

Note:
Heavy lines indicate critical path.

Figure 3. Critical Path Diagram

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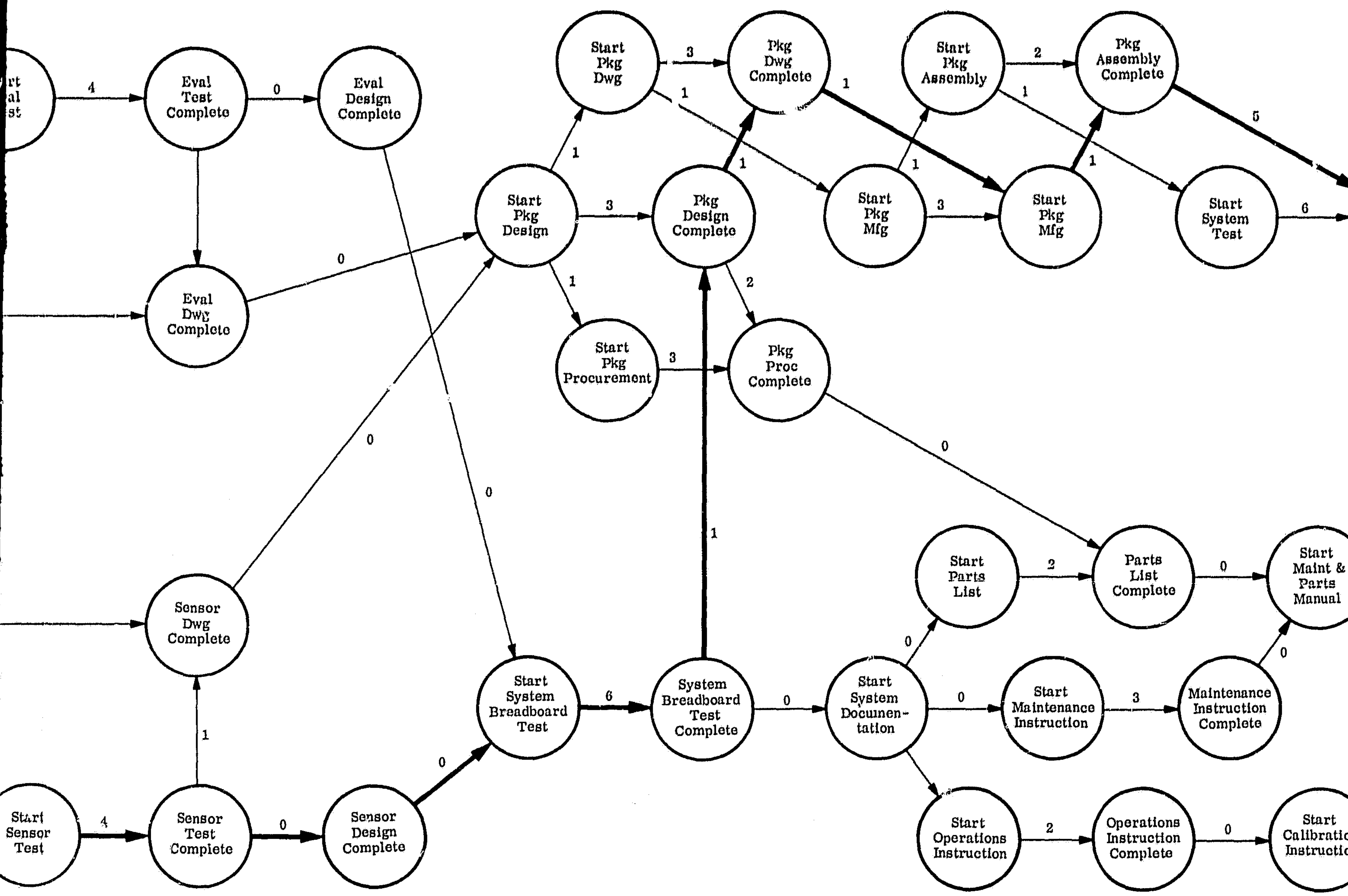

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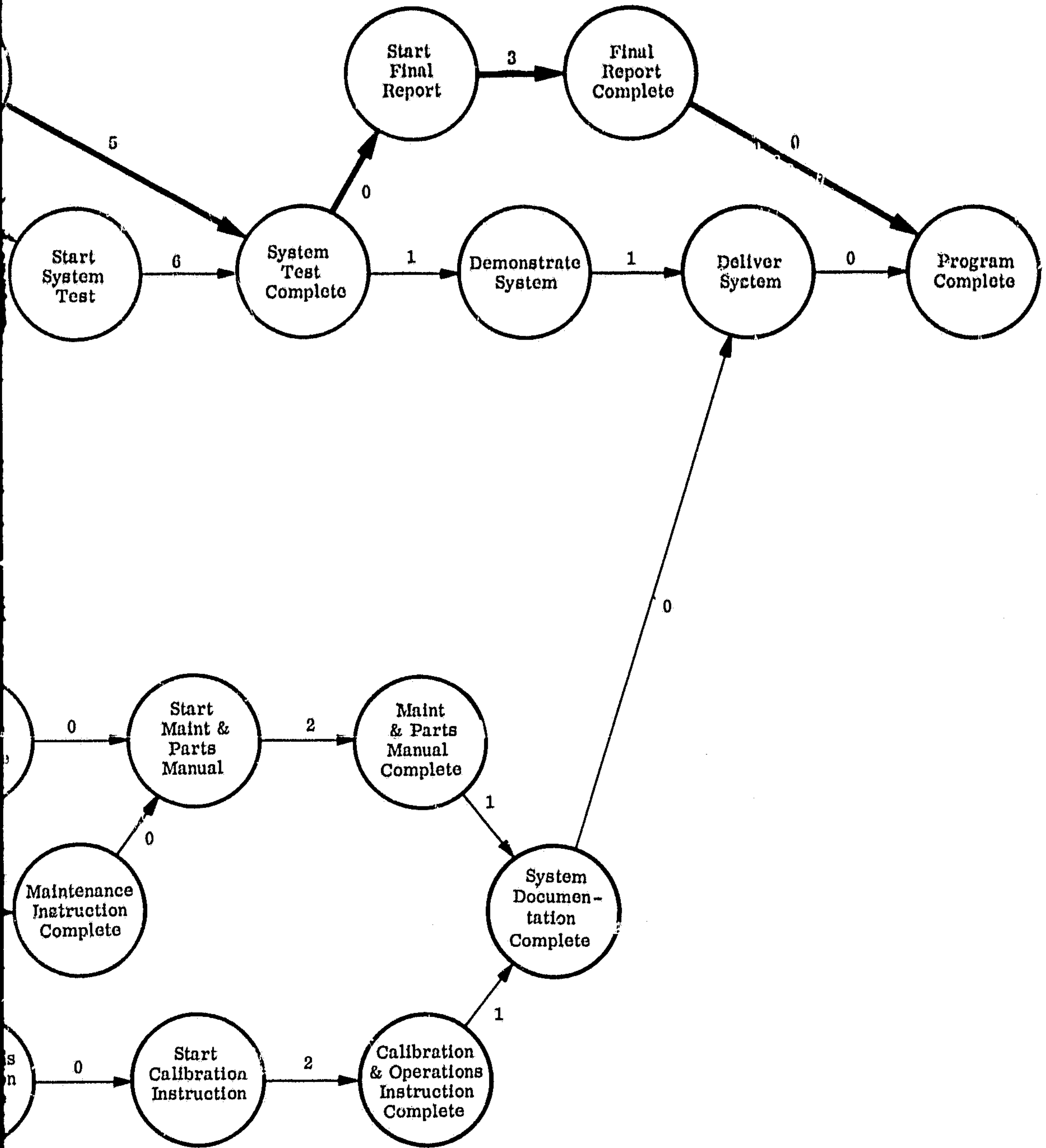


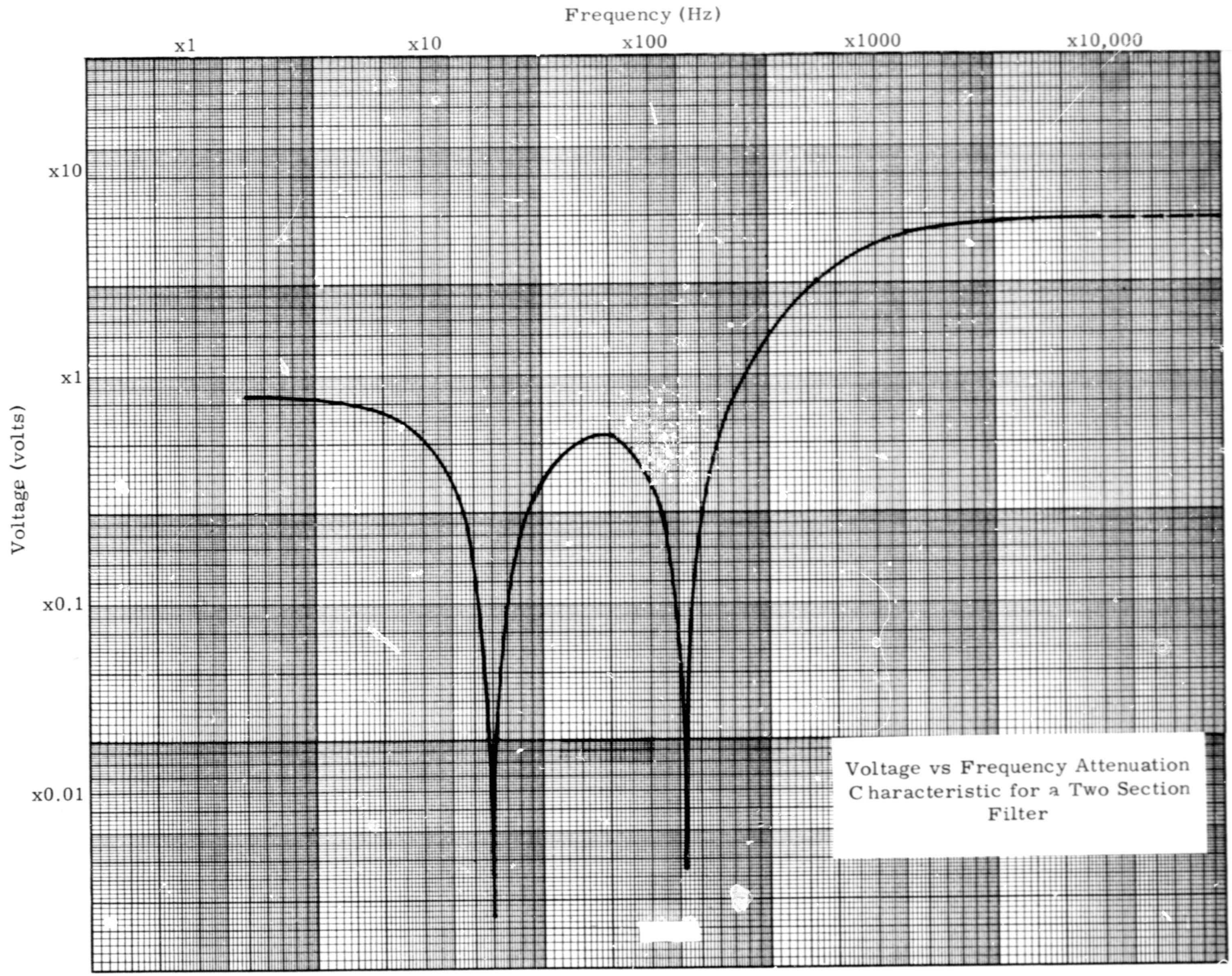
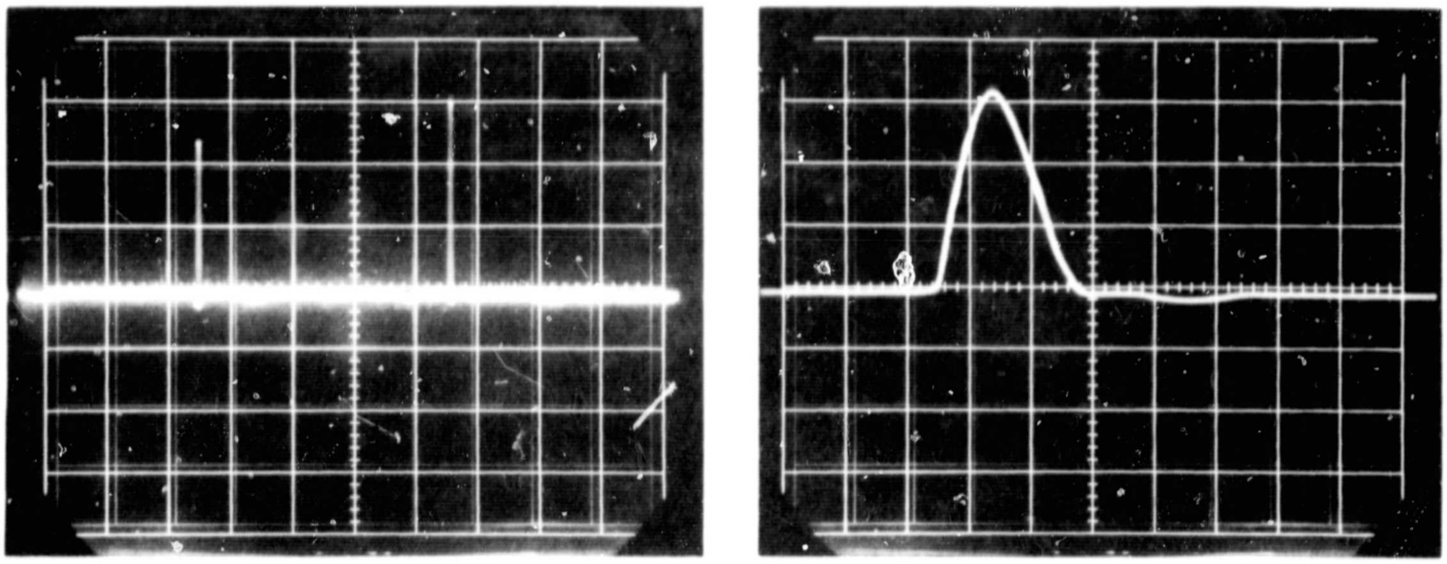


Figure 4. Attenuation Characteristics of Passive Tandem Filter



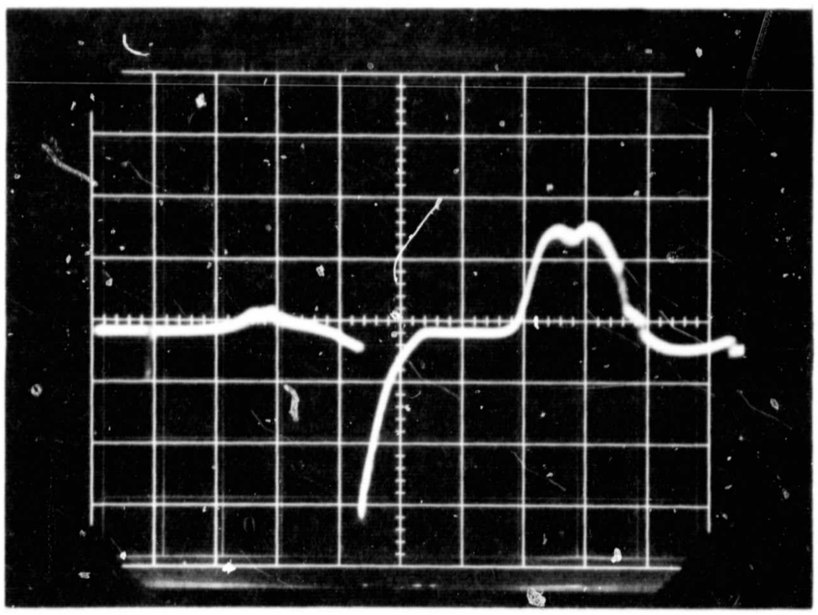
Vertical 0.5 V/cm
Horizontal 2 ms/cm

Normal

Vertical 0.5 V/cm
Horizontal 10 μs/cm

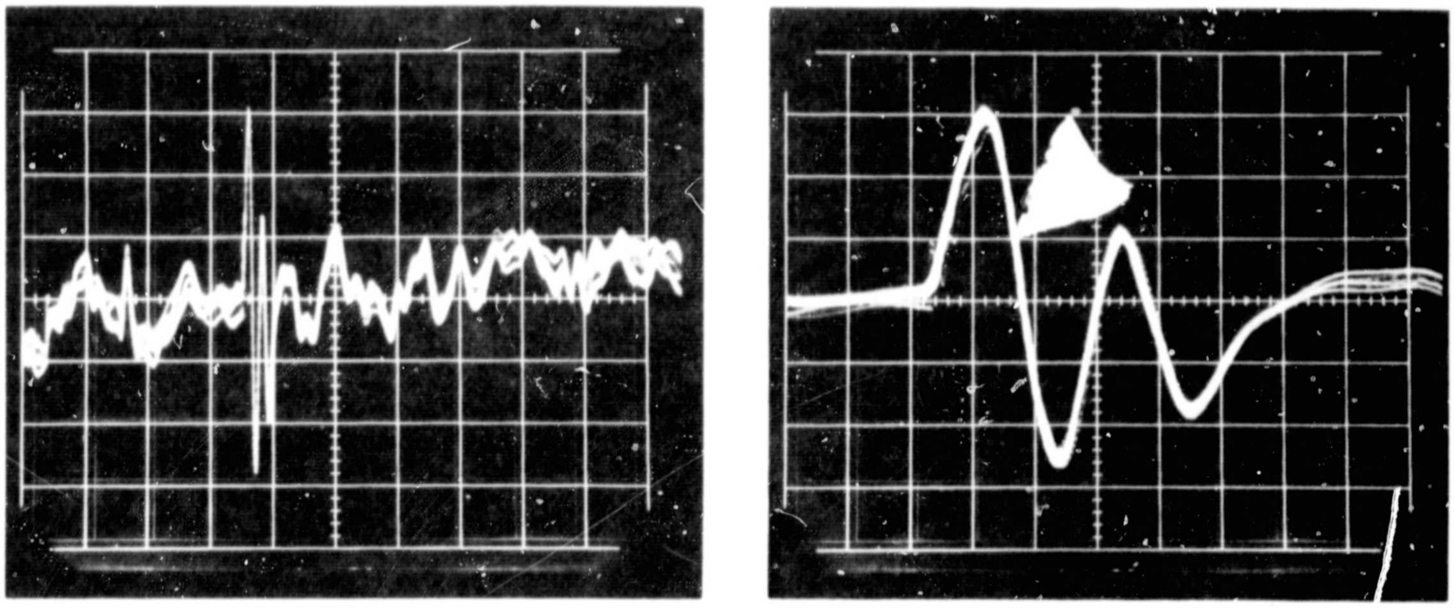
Expanded

Figure 5. Oscilloscope Traces of Noise on Power Line in Weld Area



Vertical 0.1 V/cm
Horizontal 0.5 ms/cm

Figure 6. Oscilloscope Traces of Noise Caused by Recharging Storage Capacitors in Hughes Weld Supply



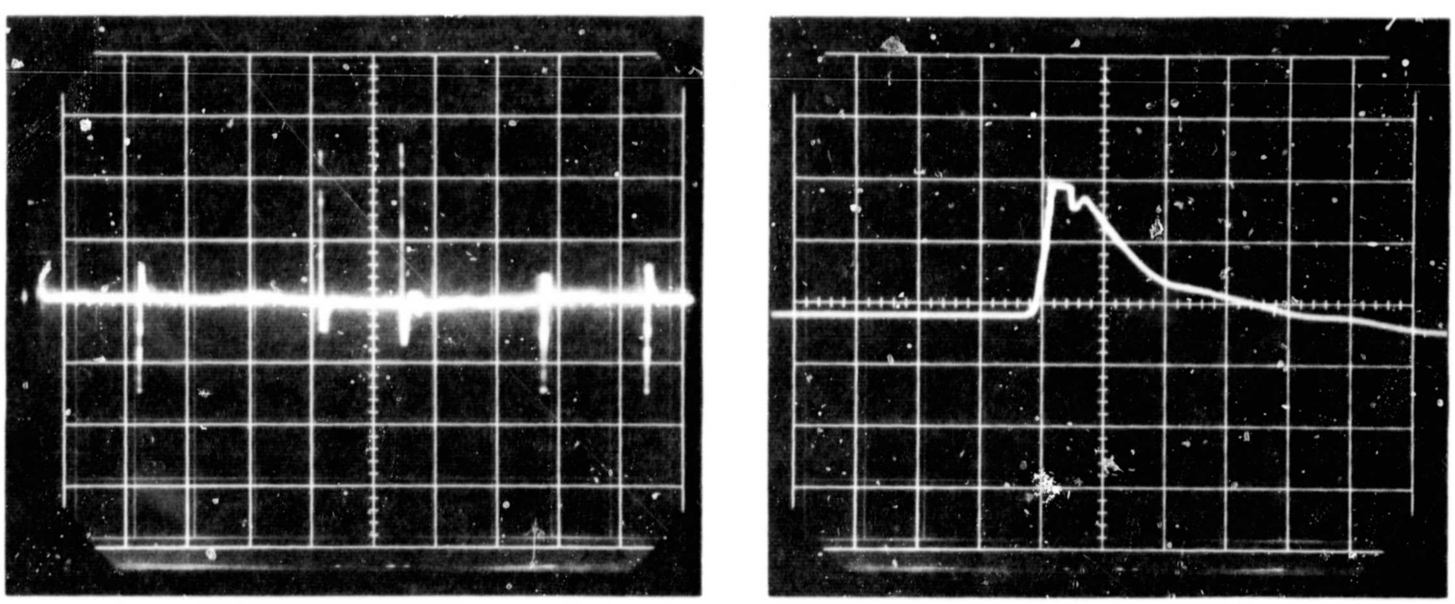
Vertical 0.2 V/cm
Horizontal 0.5 ms/cm

Normal

Vertical 0.2 V/cm
Horizontal 50 μs/cm

Expanded

Figure 7. Oscilloscope Traces of Noise in Chassis Fabrication Area



Vertical 5 V/cm
Horizontal 2 ms/cm

Normal

Vertical 5 V/cm
Horizontal 10 μs/cm

Expanded

Figure 8. Oscilloscope Traces of Noise in Wiring Harness Fabrication Area

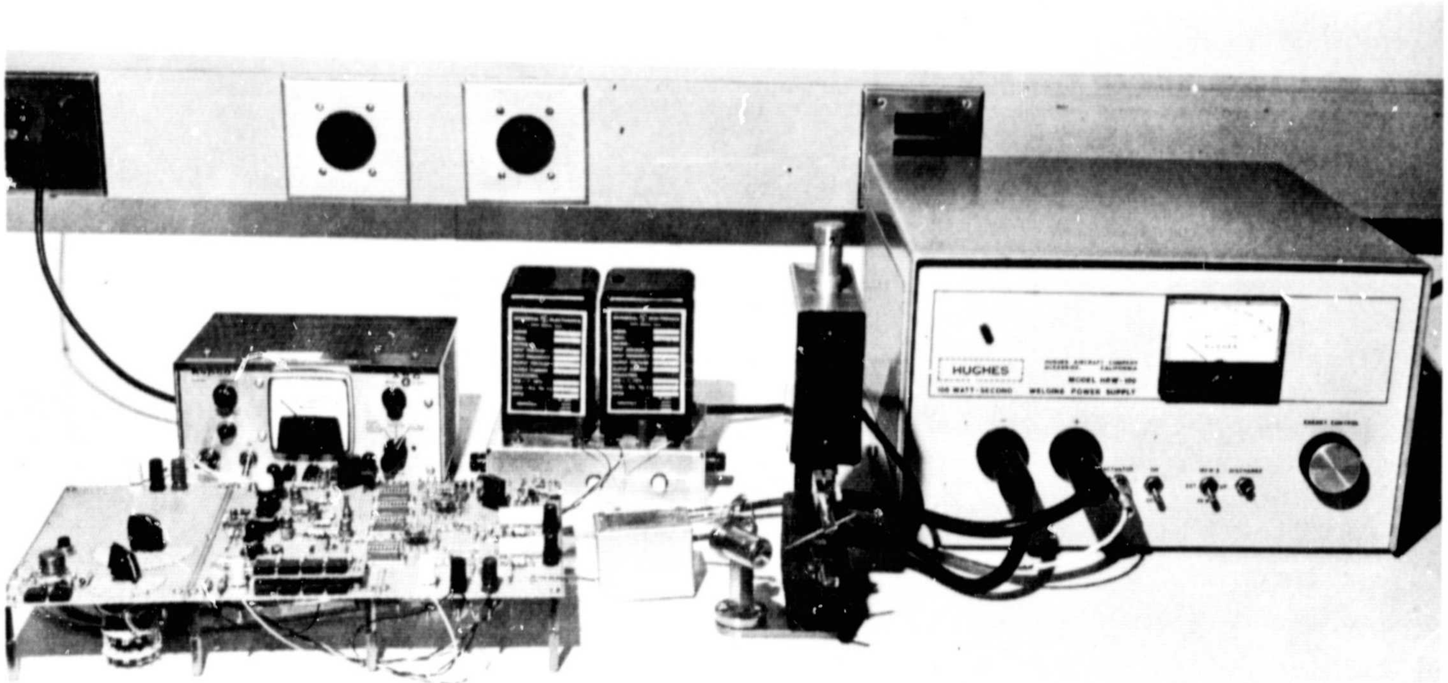


Figure 9. Weld Evaluator System Breadboard

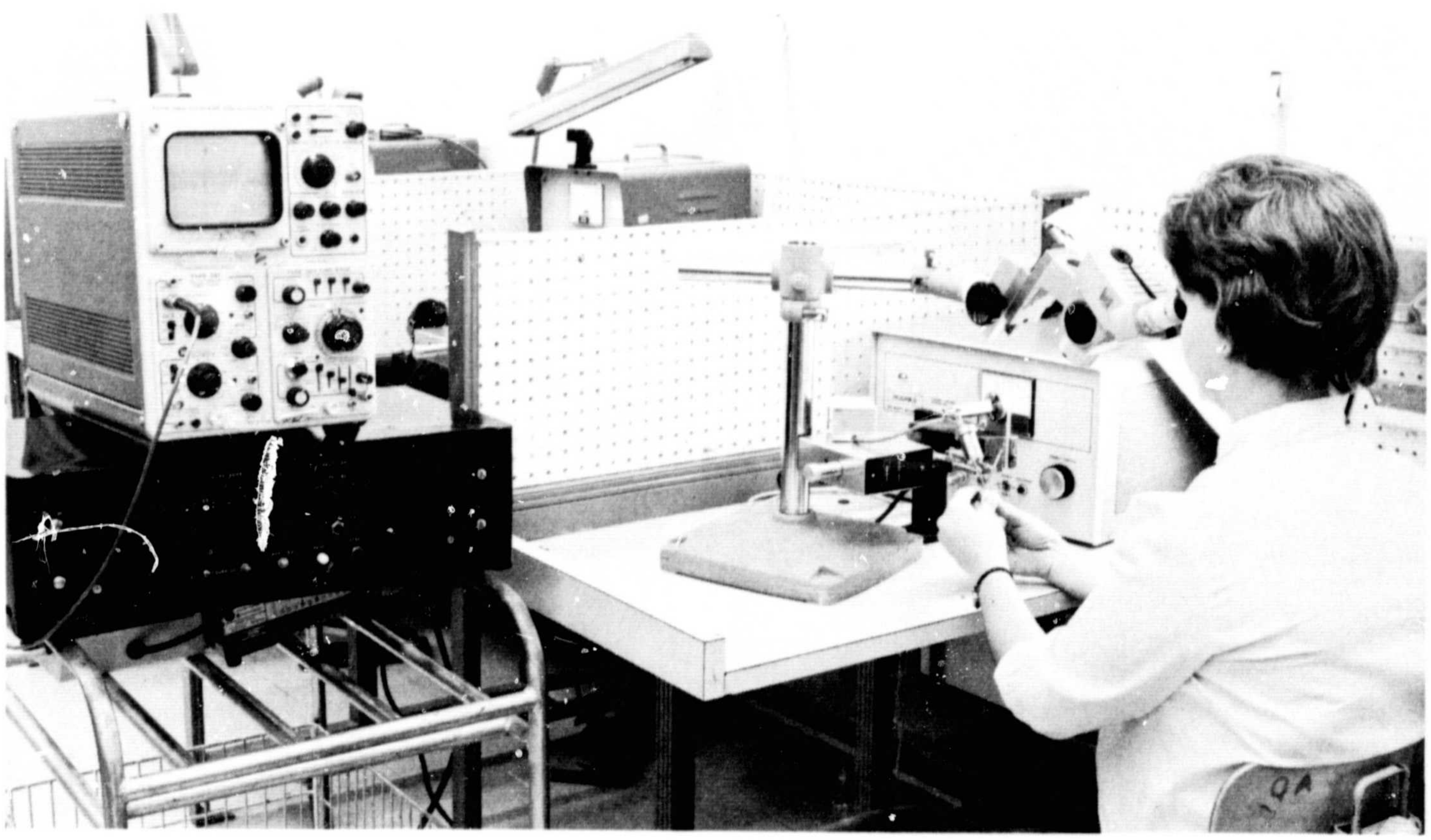


Figure 10. System Operation of Breadboard in Microweld Area

IV. CONTRACTUAL REQUIREMENTS

In accordance with contractual requirements, Advanced Manufacturing Technology has furnished the necessary facilities, engineering capability, personnel, materials, and other support as required to successfully accomplish:

1 Design, manufacture, test, and deliver one prototype microwelding system for cross wire resistance welded connections, utilizing the infrared radiation emitted from the weld zone during welding;

2 Primary design requirements with variation as required utilizing design concepts similar to those in Contract NAS8-20339.

The system includes an infrared radiation detector and its optics with its holding device. The electronic control system includes:

1 Electrical capability to discriminate between acceptable and unacceptable infrared radiation pulses;

2 A method for showing by means of indicating lights whether infrared pulses are acceptable or unacceptable;

3 Circuits for interlocks with welding equipment to prevent further welding operations following an indication of an unacceptable pulse until reset from remote reset controls;

4 Circuits for provisions of calibrations and adjustments;

5 Adequate filtering to prevent erroneous operation due to the presence of electrical interference under normal factory environments;

6 A self checking calibration;

7 Acceptance to human engineering standards.

AMT has furnished a complete set of operation, calibration, and maintenance instructions containing photographs, drawings, and schematics, a list of spare parts, and a sensor alignment tool.

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V. DESIGN REQUIREMENTS

The following additional requirements were established by the task leader at the beginning of the program. The weld evaluator must:

1 Operate unaffected in a factory environment;

2 Have an inherent long term stability and reliability;

3 Be easily calibrated and maintained;

4 Use integrated circuits where practical;

5 Operate in a +65°F to +85°F temperature environment;

6 Contain only off-the-shelf components and assemblies;

7 Contain minimum cost components and assemblies.

VI. COMPONENT SELECTION

A. INFRARED RADIATION DETECTOR

The detector for the breadboard system in Contract NAS 8-20339 was of lead sulfide and was manufactured by Kodak. (Kodak discontinued manufacturing this detector.) A search revealed that the lead selenide detector made by Santa Barbara Research Center had essentially the same characteristics as that made by Kodak. The greatest difference was the sensitivity. The Kodak detector was approximately five times more sensitive than the detector manufactured by the Santa Barbara Research Center.

B. OPERATIONAL AMPLIFIER

Of the many integrated circuit operational amplifiers capable of being externally connected to form a stable low-gain amplifier and a stable level detector, the Fairchild μ 709C was selected for its price, availability, and reliability.

C. LOGIC GATE

Of the many integrated circuit logic gates capable of performing the required logic, the Amelco 321CJ (four two-input gates) and Amelco 322CJ (two five-input gates) were chosen primarily for their high noise rejection. Cost and reliability were also considered.

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VII. SYSTEM DISCUSSION

A. SENSOR ASSEMBLY

The final configuration of the sensor assembly is shown in Figure 11. The front portion, which is the sensor, contains a quartz window, two plano-convex quartz lenses, and a 1 mm by 1 mm lead selenide infrared radiation sensitive detector. The large rear portion contains the impedance matching network. The complete assembly is positioned with respect to the fixed electrode of the weld head with the aid of a sensor alignment tool.

B. WELD EVALUATOR

The final configuration for the weld evaluator is shown in Figure 12. The operator controls include wire combination selection, self test for each evaluation channel, and power control. All lamps are press-to-test. The line leader has the key to control reset. Cable connectors and fuse holders are shown in Figure 13. The power supply for the weld evaluation is located in the enclosure, Figure 14. This figure also shows the placement of the printed circuit boards.

The components for the four portions of the weld evaluator are shown in Figure 15; the figure shows arrangement for the digital portion, the voltage reference generator, the analog portion, and the pulse generator and time delay portion, respectively.

The schematic of the weld evaluator is shown in Figure 16.

The human factors group was asked to evaluate the infrared radiation weld evaluator design; the following comments reflect their evaluation of the design with respect to its function:

1 Operationally, the unit is straight forward and should present no difficulties in either performing the tests or interpreting the results, with one minor exception; i.e., the requirement to move the "wire combination" selector to "test" position before performing self test is not optimum in that it presents an additional sequence and creates a potential error of returning the control to a different (wrong) "wire combination" selector position for the subsequent weld.

2 The control/display relationships are satisfactory and specific conditions are easily interpreted by scanning the existing panel display.

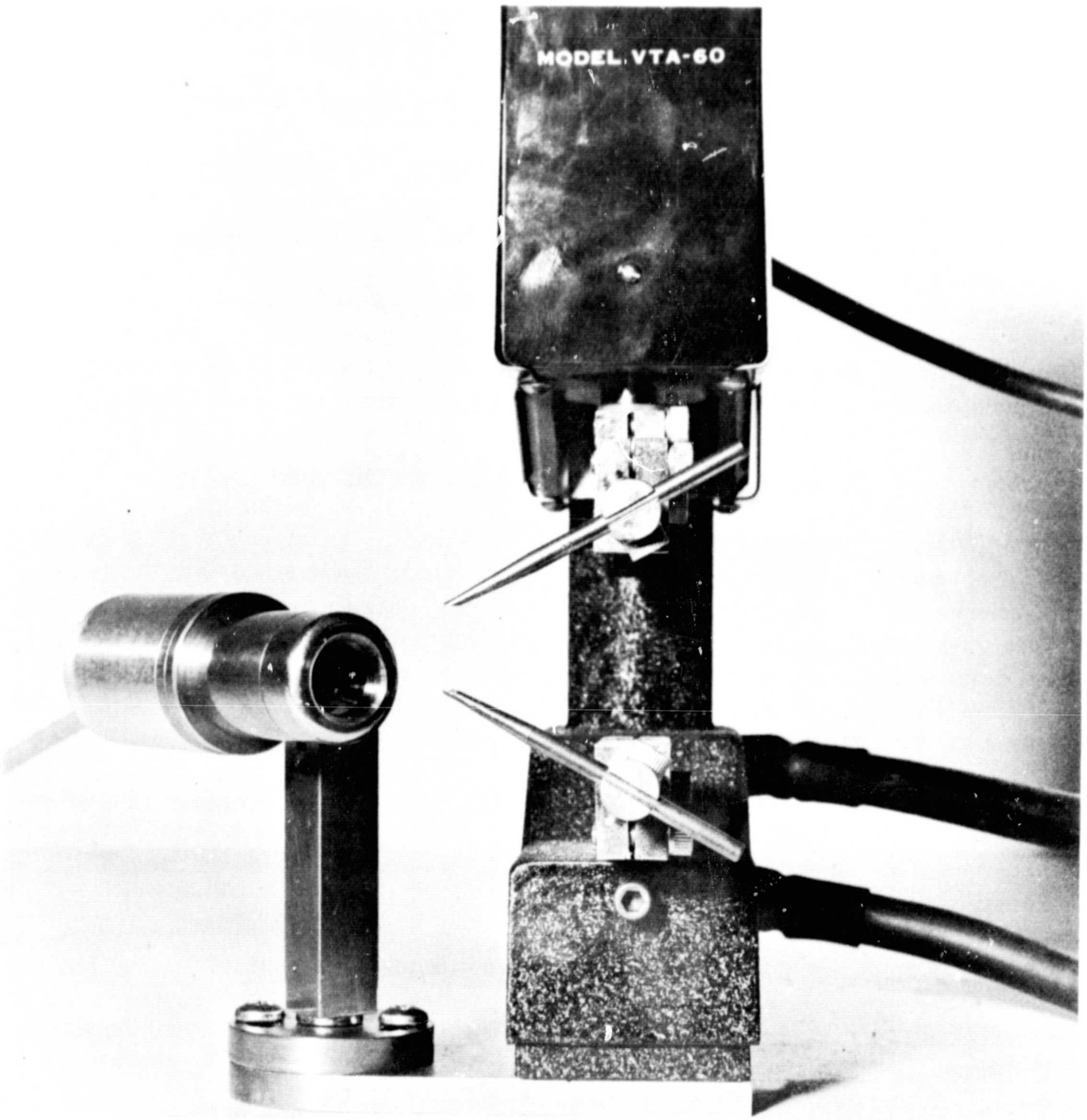


Figure 11. Sensor Assembly Configuration

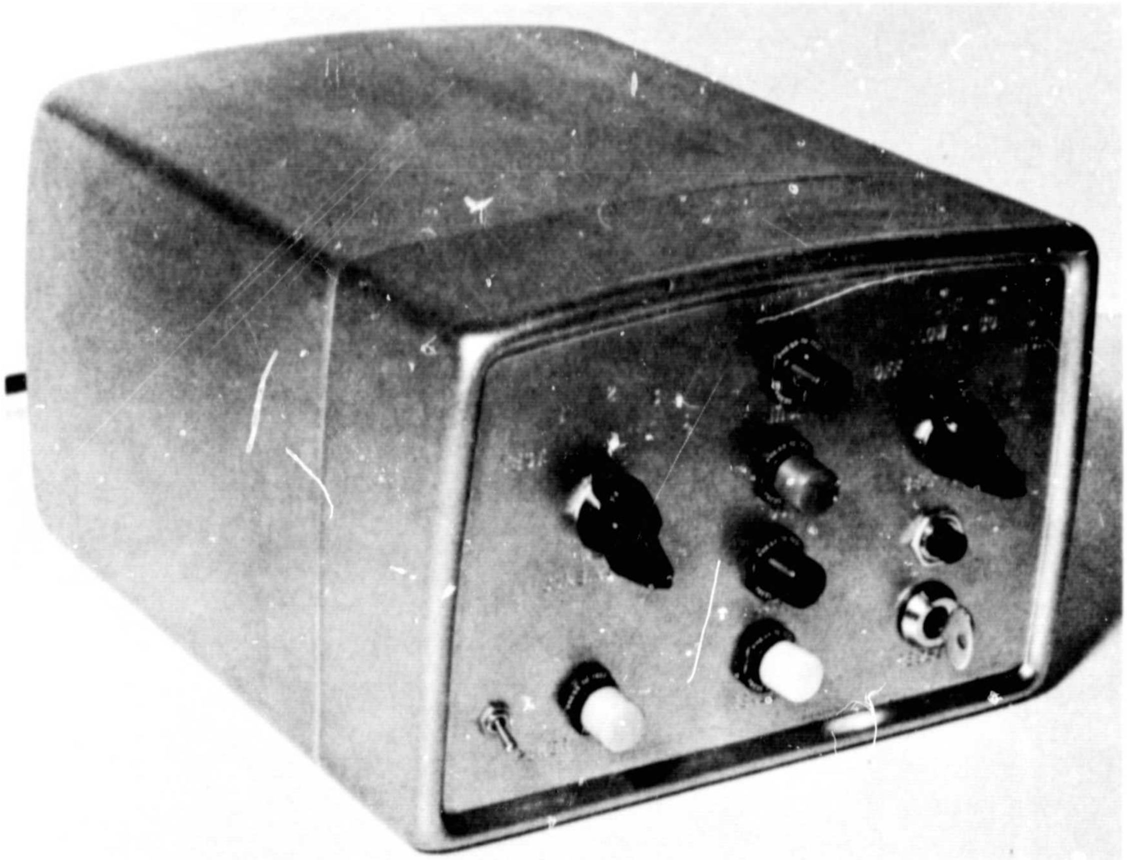


Figure 12. Weld Evaluator Final Configuration

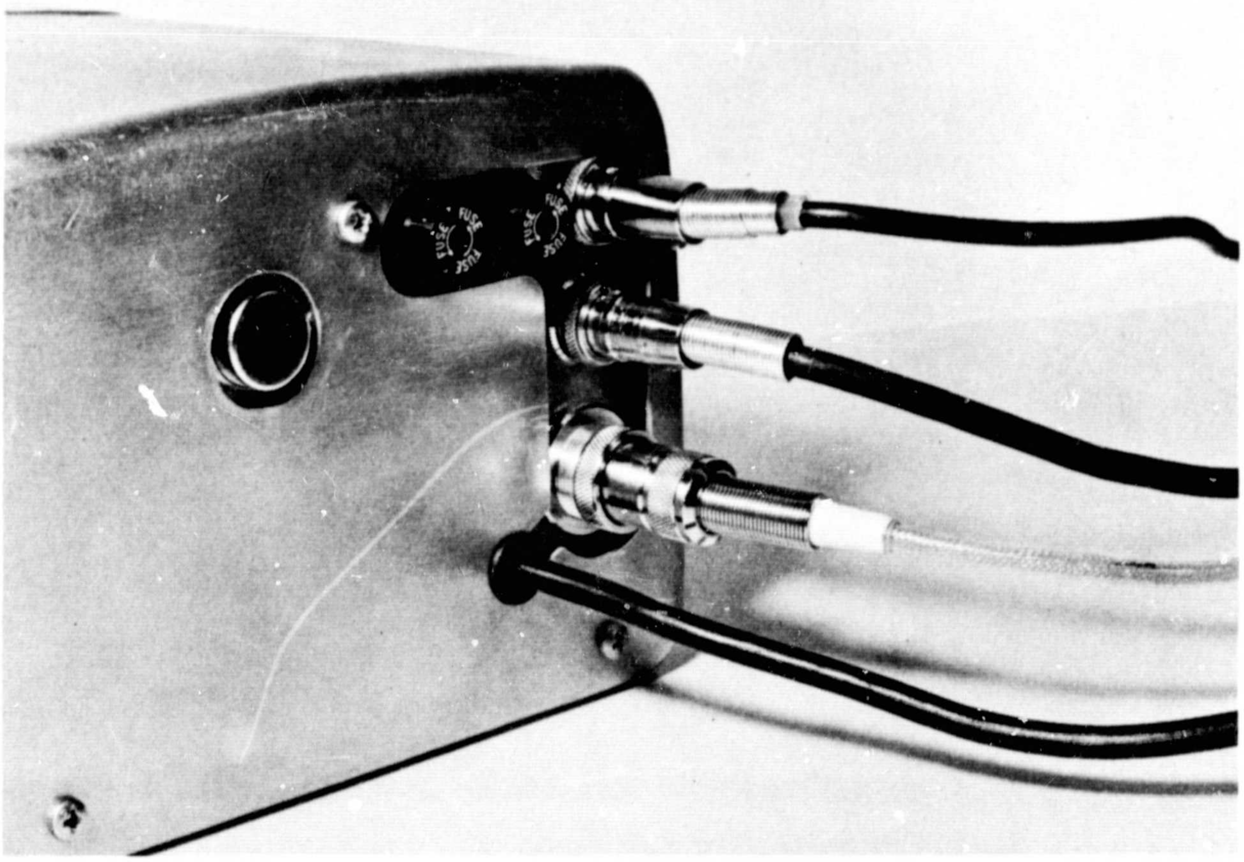


Figure 13. Cable and Fuse Arrangement

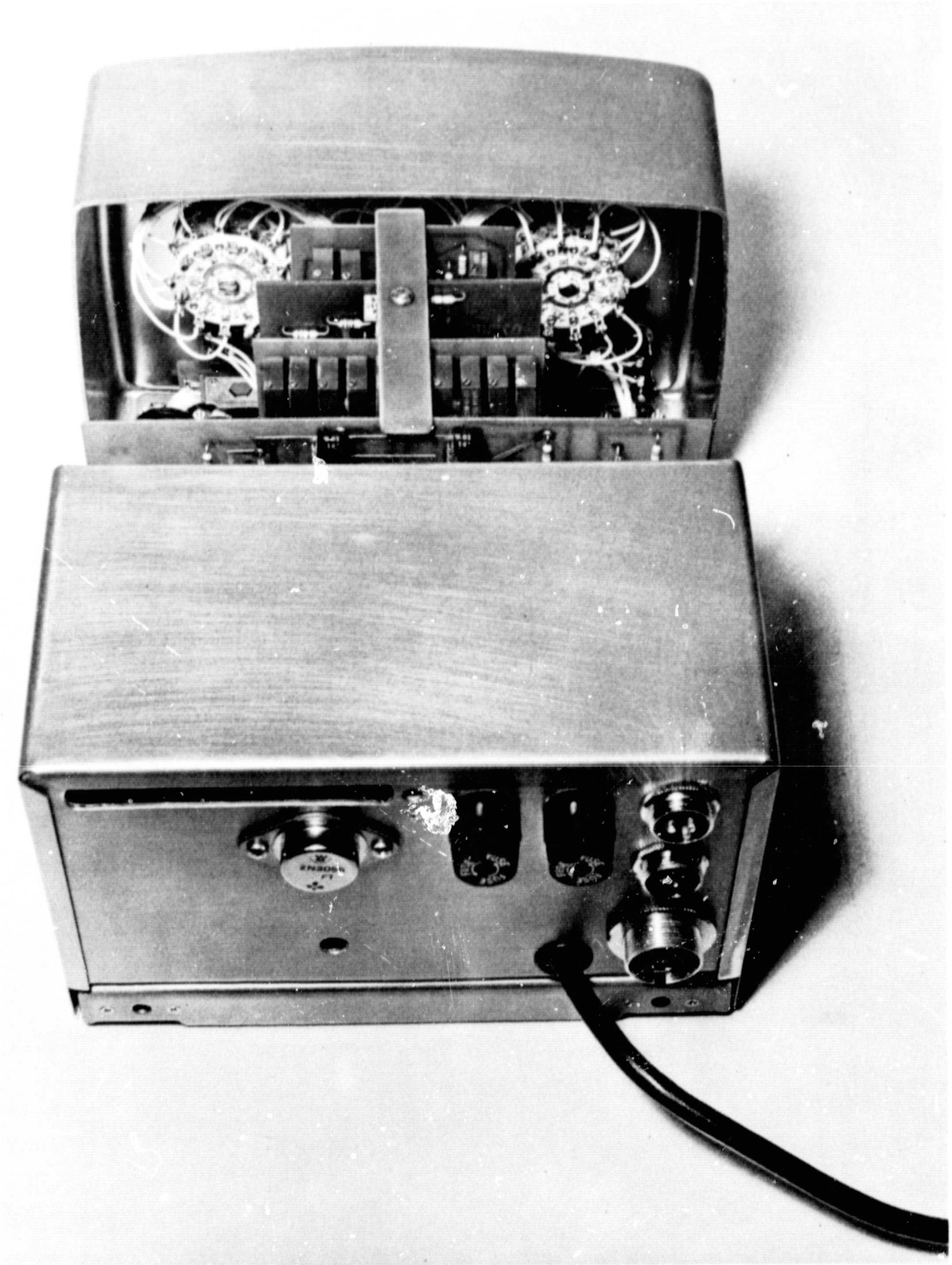


Figure 14. Power Supply Portion of Weld Evaluator

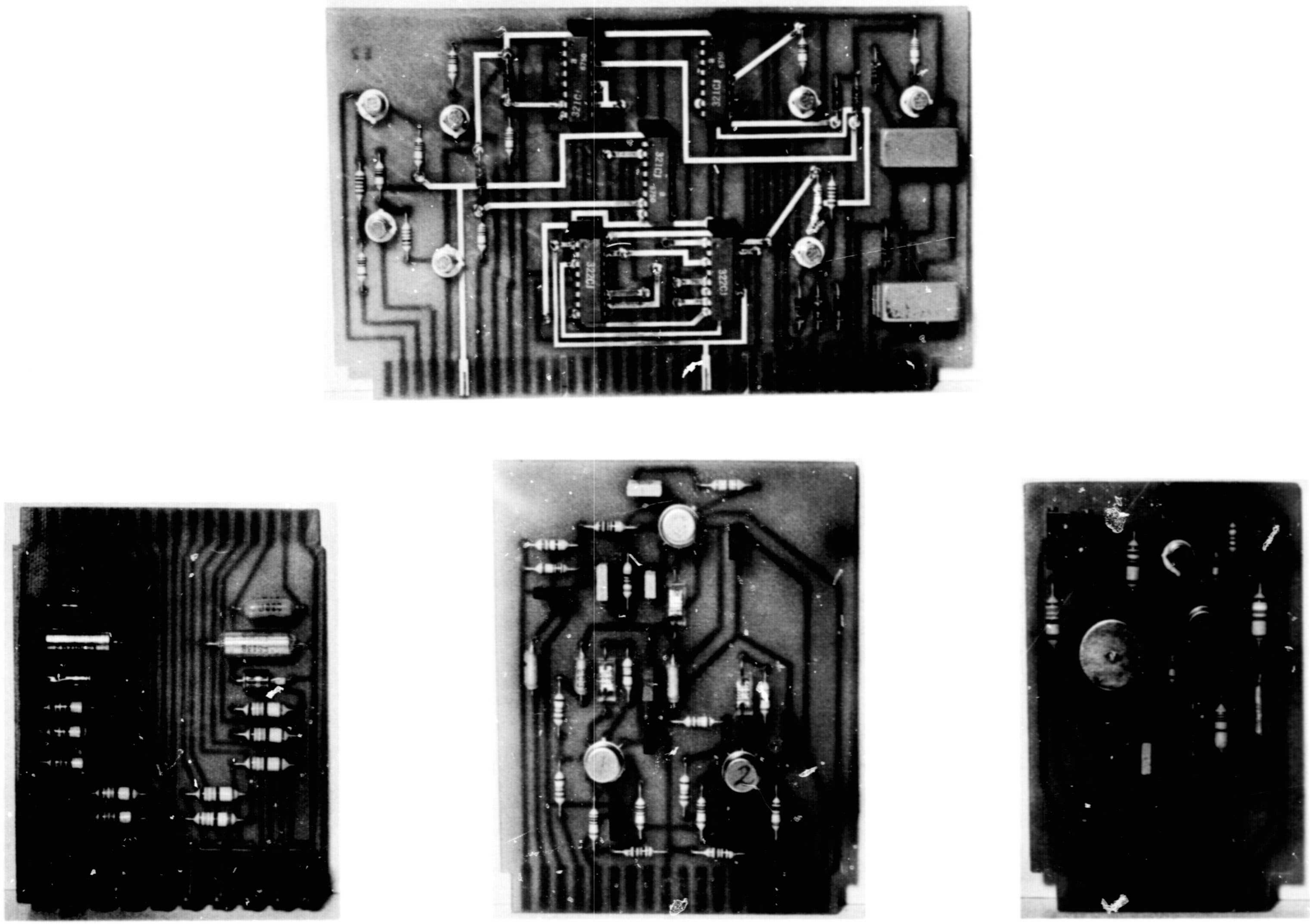
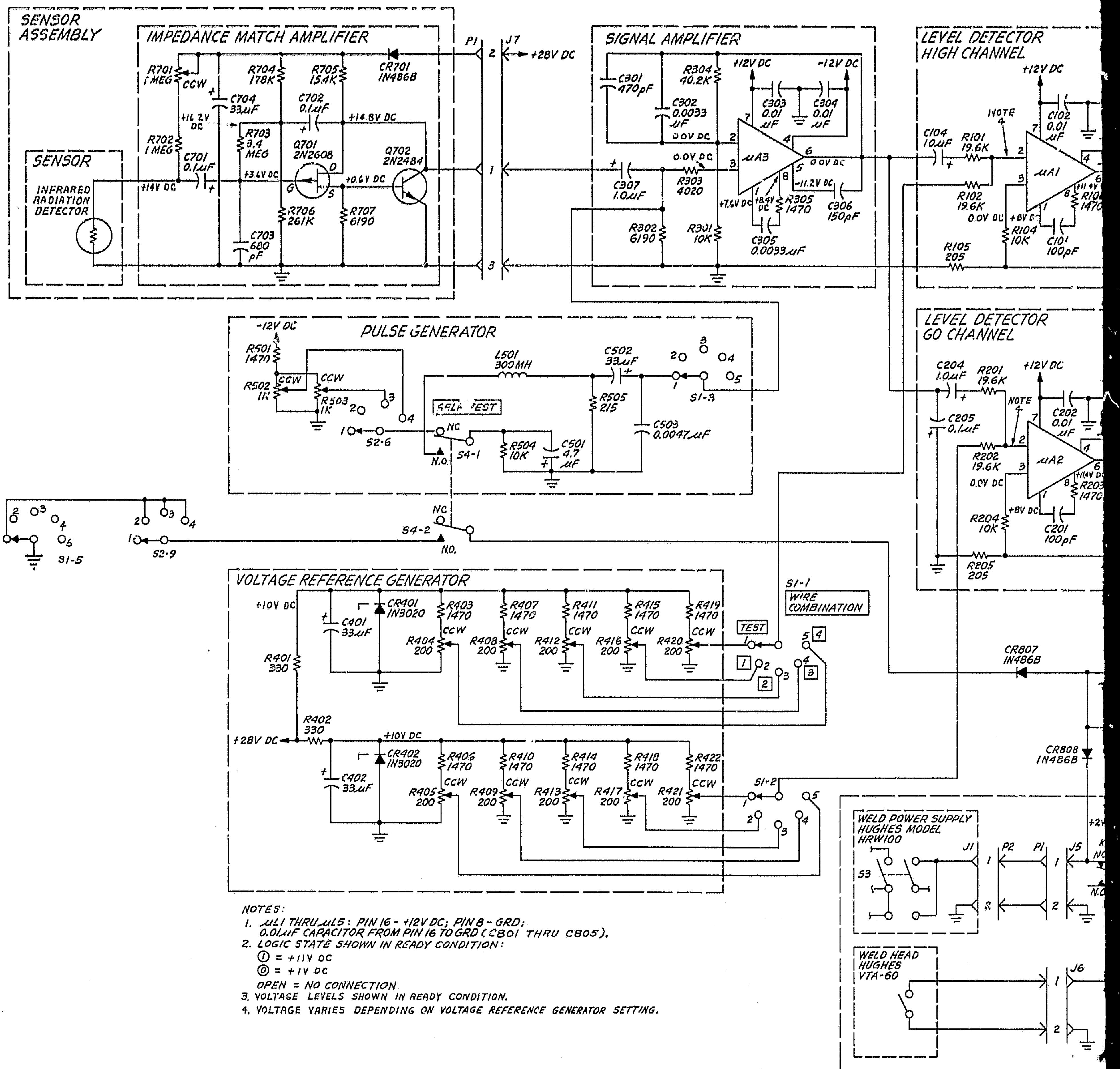


Figure 15. Arrangement of Digital Circuit, Voltage Reference Generator, Analog Circuit, and Pulse Generator and Time Delay Components



NOTES:
1. µL1 THRU µL5: PIN 16 - +12V DC; PIN 8 - GRD; 0.01µF CAPACITOR FROM PIN 16 TO GRD (C801 THRU C805).
2. LOGIC STATE SHOWN IN READY CONDITION:
   ① = +11V DC
   ⓪ = +1V DC
   OPEN = NO CONNECTION
3. VOLTAGE LEVELS SHOWN IN READY CONDITION.
4. VOLTAGE VARIES DEPENDING ON VOLTAGE REFERENCE GENERATOR SETTING.

Figure 16. Weld Evaluator Schematic

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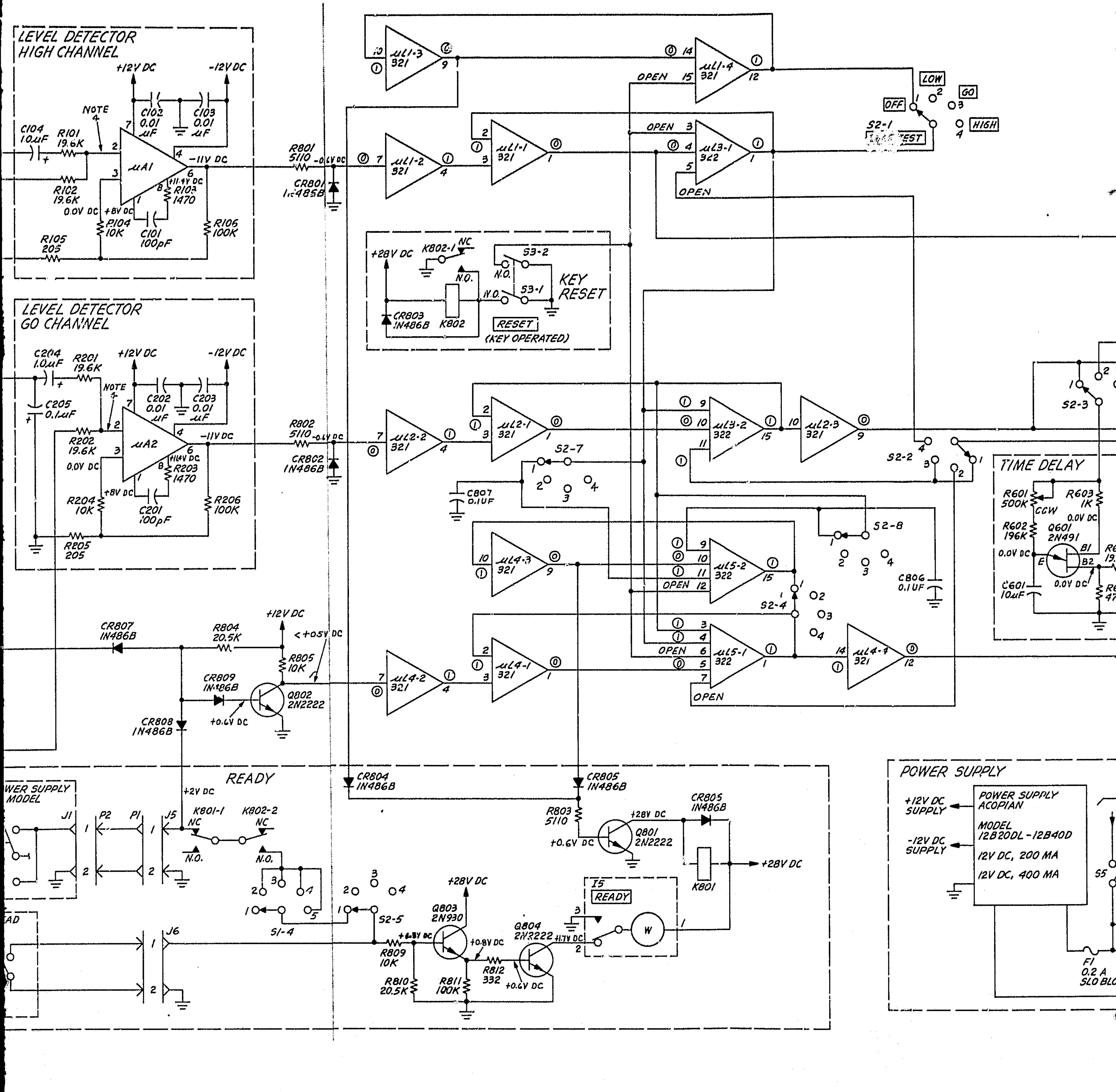

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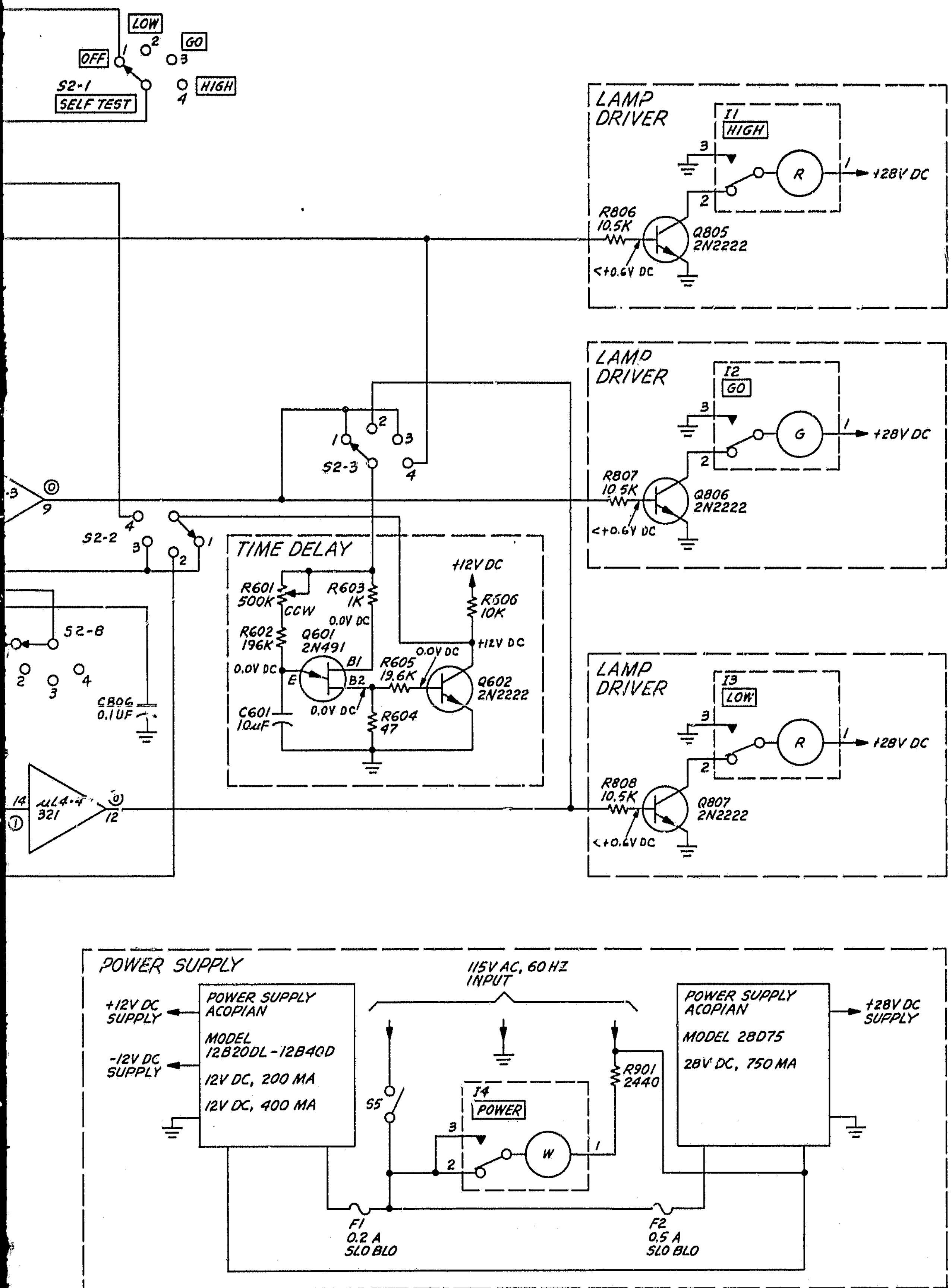

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VIII. INSTRUCTION MANUAL

In addition to the delivery of a weld evaluator, a weld power supply, and a weld head, an instruction manual is furnished to complete the contractural obligations. The manual contains operation instruction, maintenance and calibration instruction, and parts list. Schematics, photographs, tables, and graphs are used in abundance to clarify the instructions.

IX. CONCLUSIONS

The prototype weld evaluator is insensitive to line noise and the operation of near-by high current surge equipment as demonstrated in the Electro-optics laboratory. Shielding, filtering, selection of components, and a cable with low electromagnetic sensitivity contributed to the noise rejection. The weld evaluator was calibrated and adjusted to evaluate welds of nickel ribbon to: Kovar, Dumet, and nickel wire. Unacceptable welds (created purposely) caused a lighted lamp to indicate either too little or too much energy in the weld, and the lockout circuit did not allow additional welding. All components are placed on printed circuit boards for ease of trouble shooting and maintenance. The front panel design was monitored by the Human Factors to ensure that the controls were placed properly. When a high level of confidence is established in the weld evaluator, the use of crosswire welds will become commonplace in the aero and space flight industry.

X. RECOMMENDATIONS

The weld evaluator is an engineering prototype and, to some extent, portions of the assembly were hand built. This unit should be repackaged to facilitate its manufacture.

The sensor configuration is sufficient for classic crosswire welding. Consideration should be given to a versatile weld head, capable of various positions if necessary, utilizing optic fibers if applicable.

An empirical standard, as opposed to a primary standard, is necessary where more than one weld evaluator is used in a given area. This empirical standard would generate calibrated infrared radiation pulses to which all weld evaluators could be calibrated.