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Design Report on a 10-in. Multiwire Proportional Chamber (MWPC) and Associated Electronics

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DESIGN REPORT ON A 10-in. MULTIWIRE PROPORTIONAL CHAMBER (MWPC) AND ASSOCIATED ELECTRONICS

by

D. W. MacArthur

ABSTRACT

We discuss the design and specifications of a 10-in. x 10-in. active area wire chamber. Several of these chambers will be combined with polyethylene converters to make a large volume detector intended for use as a high-energy detector displaying moderate energy resolution. We also discuss the amplifiers and discriminators that have been designed for these chambers. This report only concerns the wire chambers and electronics.

INTRODUCTION

We describe the design and construction of multiwire proportional chamber (MWPC) planes of the type shown in Fig. 1. Each plane has an active area of 10 in. x 10 in.; additional details of the chamber's design parameters are given in Table I. These chambers will be interleaved with aluminum and polyethylene sheets in the final design. The polyethylene serves to convert incoming neutrons into protons, by way of (n,p) elastic scattering reactions, which can be detected by a subsequent MWPC layer, and the aluminum serves as a range filter to discriminate against the lower energy recoil protons.

The energy of a proton will be determined by observing how many layers of a detector stack are penetrated by the particle. Higher energy neutrons will give rise to higher energy recoil protons in the polyethylene, and these energetic protons can generate signals in several successive MWPCs at some location within the stack. Note that (n,p) reactions can occur in any of the polyethylene layers; thus, the desired signature will be several adjacent counters firing in coincidence at any depth in the stack.

The MWPC design is modular so that chambers, converting plates, and range filters can be changed easily. The chambers will not be gas tight until the entire stack is assembled. The gas seal on an individual chamber will be made by the thin aluminized Mylar on one side and by the polyethylene pressing against the O-ring on the other. The MWPC is square so that successive chambers can be aligned with their wires either parallel or perpendicular to each other. Chambers will be strung with 1-mil, 2-mil, and 5-mil gold-plated tungsten wires so that the effect of wire size can be investigated. Gold-plated tungsten wire is commonly used in wire chamber design. We also plan to investigate the effects of gas mixtures, converter thickness, and range filter thickness on MWPC operation. Our purpose will be to optimize the stack for detection of neutrons while keeping the low detection efficiency for photons and other minimum ionizing particles. Wire chamber design is discussed in more detail in Refs. 1-20.

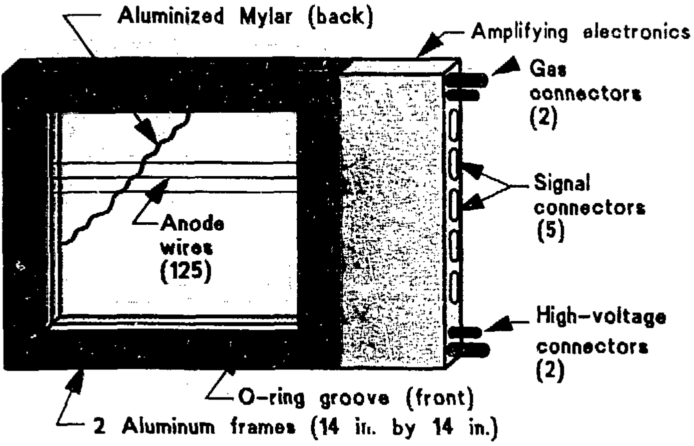


Fig. 1.
A single wire chamber layer. These chambers will be stacked along with aluminum and polyethylene plates to create the finished detector. The electronics package will plug directly into the chamber in order to minimize the signal path length. This package will be coplanar with the chamber in order to facilitate chamber stacking.

TABLE I

SPECIFICATIONS FOR THE 10-in. MWPC DESIGN

The final detector will be made up of 10 of these chambers stacked with aluminum and polyethylene layers between them. The gas seal is provided by the aluminized Mylar back window and the similar window of the chamber stacked above it. Pressure windows are provided by thicker pieces of polyethylene on the ends of the detector stack. Sets of five adjacent wires will be read by a single amplifier, giving a spatial resolution of 0.375 in. and a single detector element volume of 1.875 cu. in. Both the amplified analog signal and a logic signal generated by a discriminator will be available on the output connector. Each set of five amplifiers (25 wires) will be on a separate circuit board, so each plane will be served by five amplifier boards generating a total of 25 output signals. These amplifier boards will also be modular so they can easily be changed in the event of technology advances.

Detector size	14 in. x 14 in. x 1/2 in.
Active area	10 in. x 10 in.
Gas mixture	various
Gas fittings	1/4 in. Poly-flo®
Electronics package size	14 in. x 6 in. x 1/2 in.
Number of wires per plane	125
Wire sizes to be tried	1 mil, 2 mil, and 5 mil
Wire spacing	0.075 in.
Active volume surrounding 1 wire	0.375 cu. in.
Anticipated detector thickness	10 layers
O-ring groove	1/16 in.
High voltage	about 3 K
High-voltage connectors	SHV

PART 1

CHAMBER DESIGN

I. DESIGN SPECIFICATIONS

The chambers were designed to have the following attributes:

1. The chambers and plates should be modular.
2. Some chambers should be strung with each of several wire sizes.
3. No specific gas mixture should be required.
4. The chambers should be capable of being oriented so that the wires in adjacent planes run either parallel or perpendicular to each other.
5. Any resistors and capacitors needed to isolate the signals from the high voltage (HV) should be located as close as possible to the wires themselves.
6. The first stage of amplification should be located close to the wires with no long cables between them.
7. The chamber frames should be fairly lightweight and made of aluminum.
8. There should be very little material permanently attached to the front and back surfaces of the chambers.

Some explanation and clarification of these specifications is in order. Requirement 1 states that the aluminum and polyethylene plates should be modular. By this I mean that these plates should be a standardized size and should be easily interchangeable. These requirements will allow one to quickly check the effects of plate parameter changes. Requirements 1 and 2 would enable one to check the effect of changing wire diameter without building a new detector. We plan to have two chambers, each strung with 1-mil, 2-mil, and 5-mil wire. After the optimum wire size is determined, 8 more chambers will be strung with that wire for a total of 10. Requirement 3 allows experimentation with the gas mixture without disturbing the rest of the apparatus. All of the above requirements will allow various elements of the design to be changed without affecting the other parameters. Requirement 4 is intended to make the effects of different orientation and placement of the chambers observable.

Requirements 5 and 6 will insure that the sensitive front ends of the amplifiers are exposed to as little noise and hum as possible. In another design such pickup proved to be one of the major limitations of the system.[21] If specification 5 is followed, it will also lessen the risk of exposure to high voltage. Aluminum is currently the material of choice for wire chamber designs, hence, the second part of requirement 7. The chamber frames will be lightweight to minimize gamma-ray interactions. What few interactions there are can be calculated. Finally, requirement 8 ensures that most of the material between the chambers consists of the converters and range filters, which have a carefully calculated and known density.

The chambers and other elements of the stack will be square and will be held together by a series of symmetrically positioned bolts. This symmetry will allow the components of the stack to be positioned and repositioned as desired. Each chamber will be made of two aluminum frames glued together with the sense wires sandwiched between them. The bolt pattern and other features of these frames are shown in Figs. 2 and 3. The metallic nature of the chamber frames will require that the wires be maintained at high voltage. This will necessitate an individual resistor/capacitor (R/C) isolation network for each wire as shown in Fig. 4. The R/C networks will plug directly into the chamber, and the amplifiers will plug into the R/C networks, so there will be no sensitive, exposed signal cables.

II. WIRE CHAMBER DESIGN

The chamber was designed to satisfy the requirements delineated in the previous section. This chamber is shown schematically in Fig. 1, and more detailed drawings of the two halves of a chamber are given in Figs. 2 and 3. These frames will be machined out of aluminum, and two frames (one of each type) will be glued together around a printed circuit board (the larger of the two chamber boards) to form a single chamber. As both frames will be 1/4 in. thick, the total chamber thickness will be 1/2 in. The sense wires will be mounted on the etched boards between the frames. The wires and mounting scheme are described in more detail below. Thin (0.5-mil) aluminized Mylar will be glued to the back side of each chamber assembly. The front surface will have a 1/16-in. O-ring groove cut so as to surround the active chamber area. Thus, a complete chamber will be formed when the back side of another frame, or some other conducting material, is pressed against the O-ring. The pressure windows will be made of thicker pieces of plastic on the outside of the outermost chambers. One possible configuration of a detector stack is shown in Fig. 5.

The etching pattern of the chamber printed circuit (PC) boards is shown in Fig. 6, and Fig. 7 shows how the boards will be assembled to form a complete chamber. Most of the larger circuit board (including the portion that will be between the chamber frames) will be covered with a pressed-on layer of Kapton for insulation. As mentioned before, using aluminum frames requires that the sense wires be at high voltage. Thus, every wire will have a resistor to isolate it from the high-voltage bus and a capacitor to isolate the amplification stages from the high voltage. This arrangement of resistors and capacitors is shown in Fig. 4. Each signal then will go to the output jack. Five 25-pin D connectors will be used for the outputs from the 125 signal wires. The HV bus and a few other wires are etched onto the opposite board surface from the signal wires.

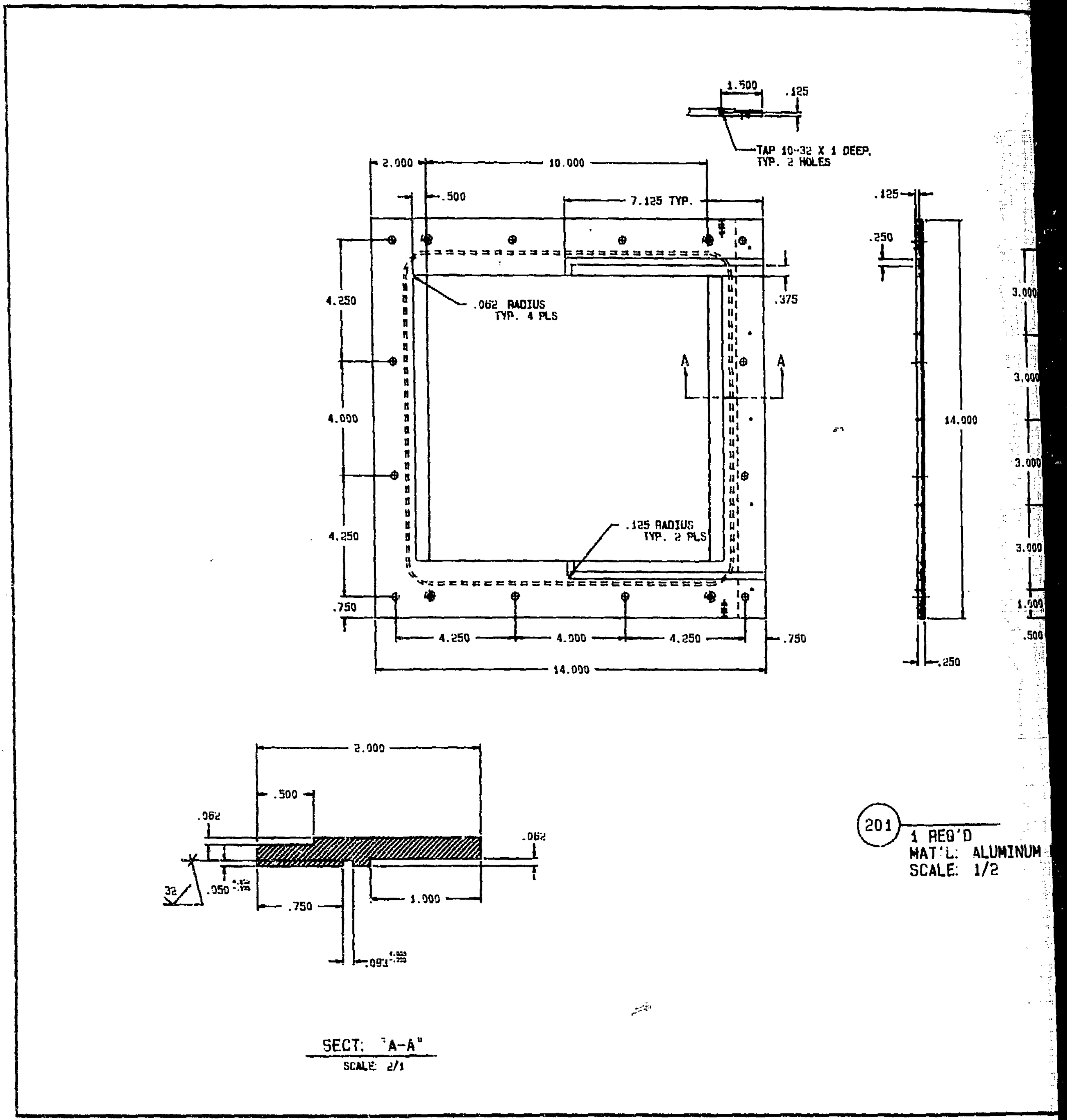
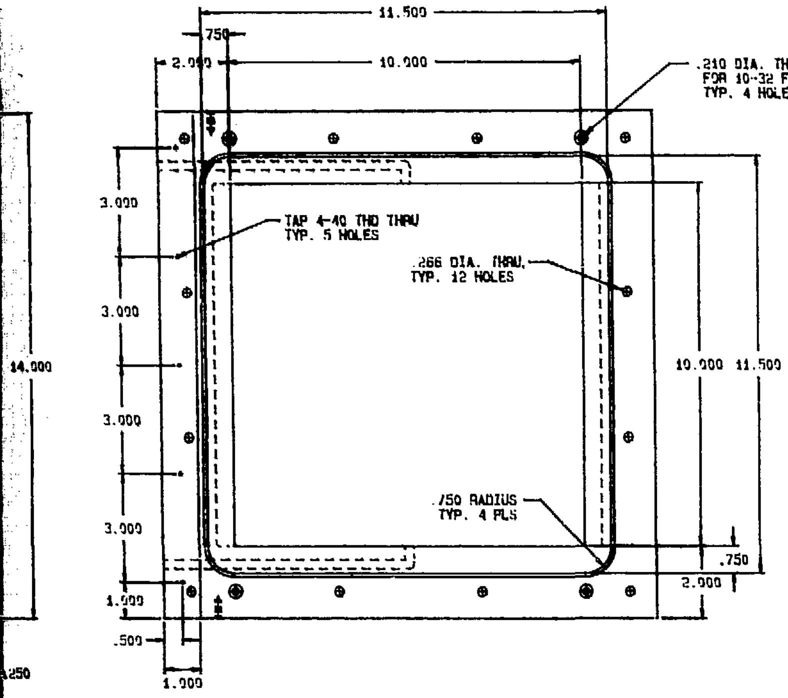


Fig. 2.

Top wire chamber frame detail. One of these frames, along w frames shown in Fig. 3, will be glued together to form a si The top frame will have an O-ring groove milled into it. Th gas seal between the chamber and the next layer. The holes the frame will be repeated in every other component of the s holes will be used to support the detector and to align the



EQ'D
'L: ALUMINUM PLATE, .250 THK
LE: 1/2

LOS ALAMOS
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545

PART 201. TOP PLATE

	SIGNATURE	DATE	GROUP
ORIGINATED	MACARTHUR	6/3/86	Q-2
DRAWN	J.ORTIZ	6/3/86	Q-2
CHECKED			Q-2
PROJ. ENGR.			Q-2
APPROVED			Q-2
RELEASED			Q-2

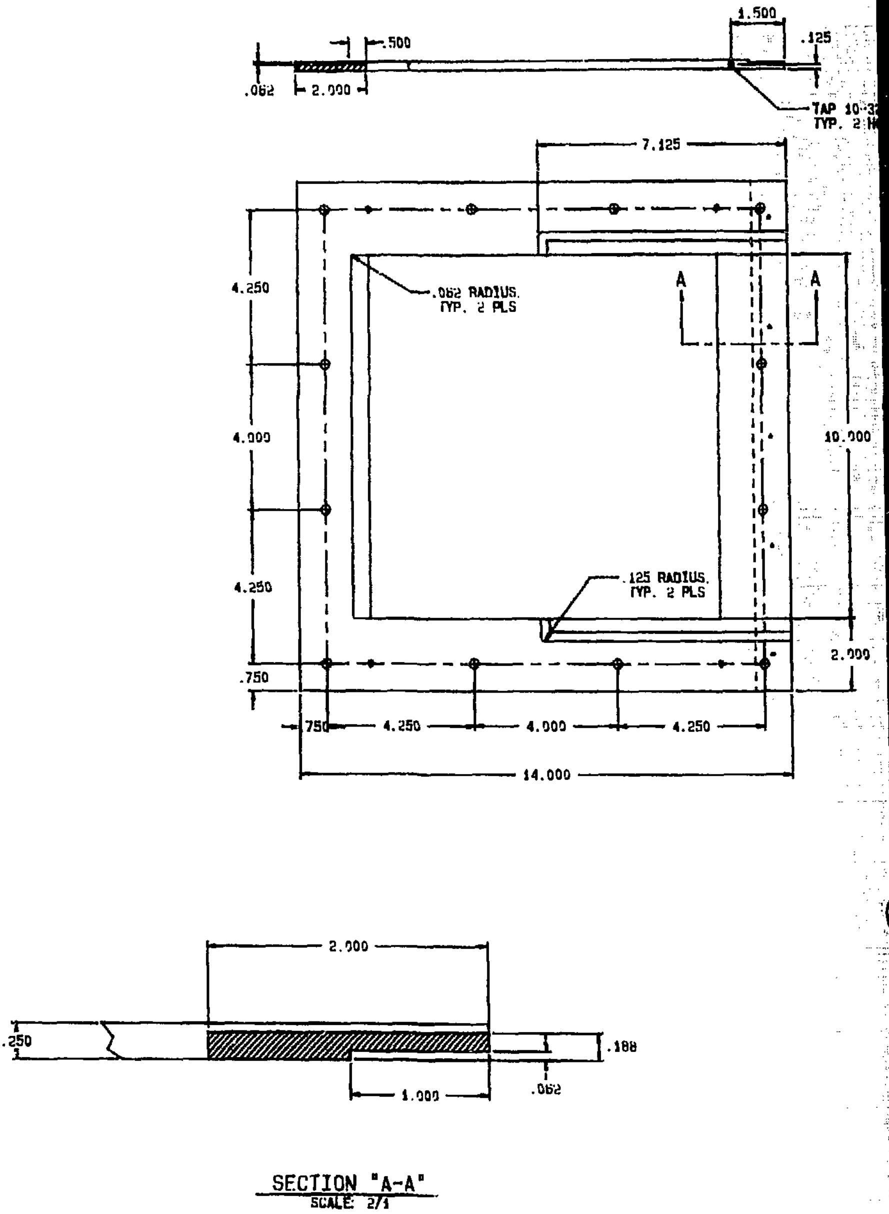
CLASSIFICATION OF DRAWING: U
NOTE: U
TITLE BLOCK: U

TITLE
MULTI-WIRE
NEUTRON DETECTOR
ASSEMBLY

ALL DIMENSIONS ARE IN INCHES

SCALE NOTED
TOTAL SHEETS
DRAWING NO. Q2-2177
SIZE D
SHEET NO. 5

s, along with one of the bottom form a single wire chamber layer. to it. This O-ring will make the The holes shown around the edges of t of the stack. Bolts through these align the various layers.



Fig

Bottom wire chamber frame detail. One of
to form a single wire chamber layer. The
glued to it to form the rear gas-tight sea
in every other layer of the stack. Bolts
detector and align the various components.

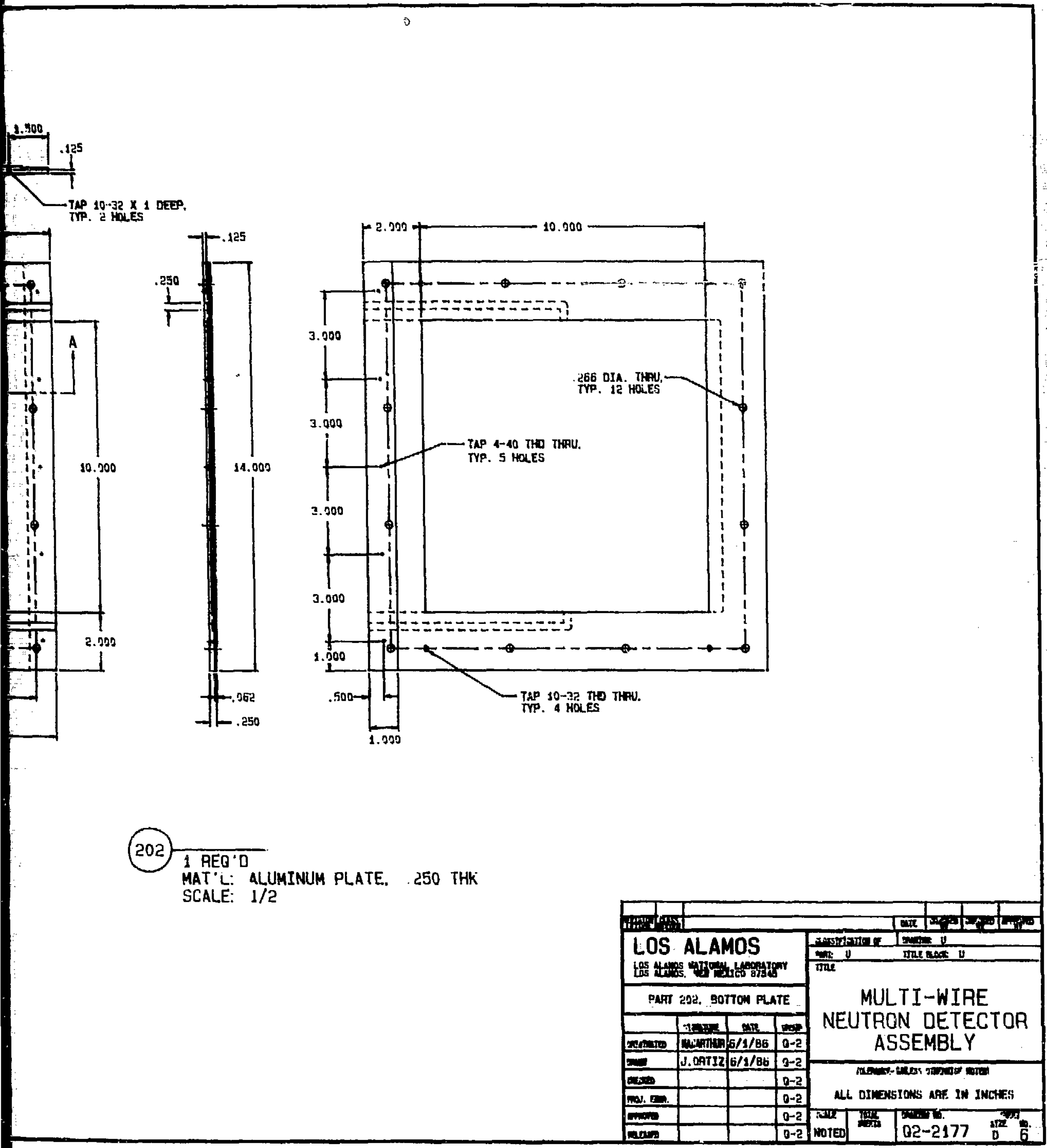


Fig. 3.

. One of these frames will be glued to the top frame
yer. The bottom frame will have thin aluminized Mylar
-tight seal. The holes in the frame will be present
k. Bolts through these holes will support the
omponents.

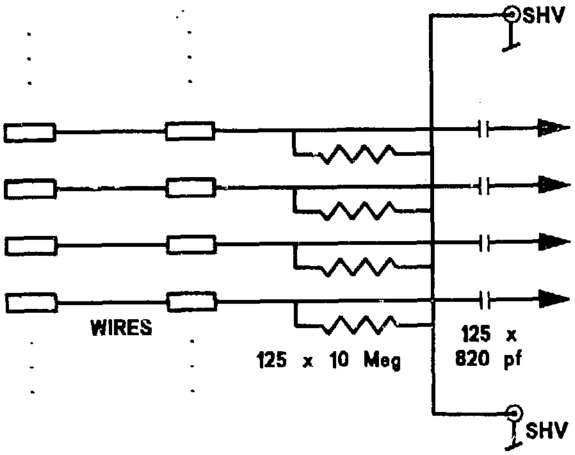


Fig. 4.
Schematic of a portion of the R/C isolation networks on a wire chamber. Every wire (125 per chamber) will be isolated from the high voltage by a resistor and from the amplifier by a capacitor. Four of the R/C networks, typical of the remaining 121, are shown here. Each chamber will be powered from a single high-voltage supply (for simplicity and to conserve space) or from two separate supplies (for additional current capability). The high-voltage components and the PC board are permanently attached to the chamber, minimizing the risk of personnel exposure.

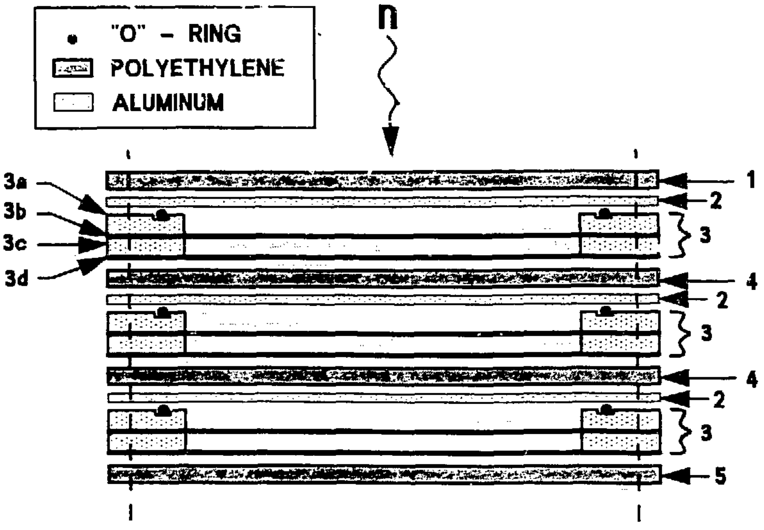


Fig. 5.
Diagram (not to scale) of one possible stack assembly showing the iterations of the converter/filter/chamber layers. The final conversion will have 10 layers. The components of the stack are identified below. (1) Polyethylene converter and front pressure window. (2) Aluminum range filter and front conductor plane for the chamber. (3) Wire chamber layer. (4) Polyethylene converter. (5) Polyethylene rear pressure window. Each chamber layer can be further divided into its component parts. (3a) The front aluminum frame holding the O-ring groove (Fig. 2). (3b) Sense wires soldered in place between the two frames. The two frames will be glued together with a thin layer of epoxy. (3c) The rear aluminum frame (Fig. 3). (3d) Thin aluminized Mylar glued to the rear frame. The chamber dimensions are given in Table I, and the converter and filter dimensions will be adjustable. Bolts through the alignment holes will support the entire detector and line up the various components. The chambers will be square so that they can be mounted with several different orientations within the stack.

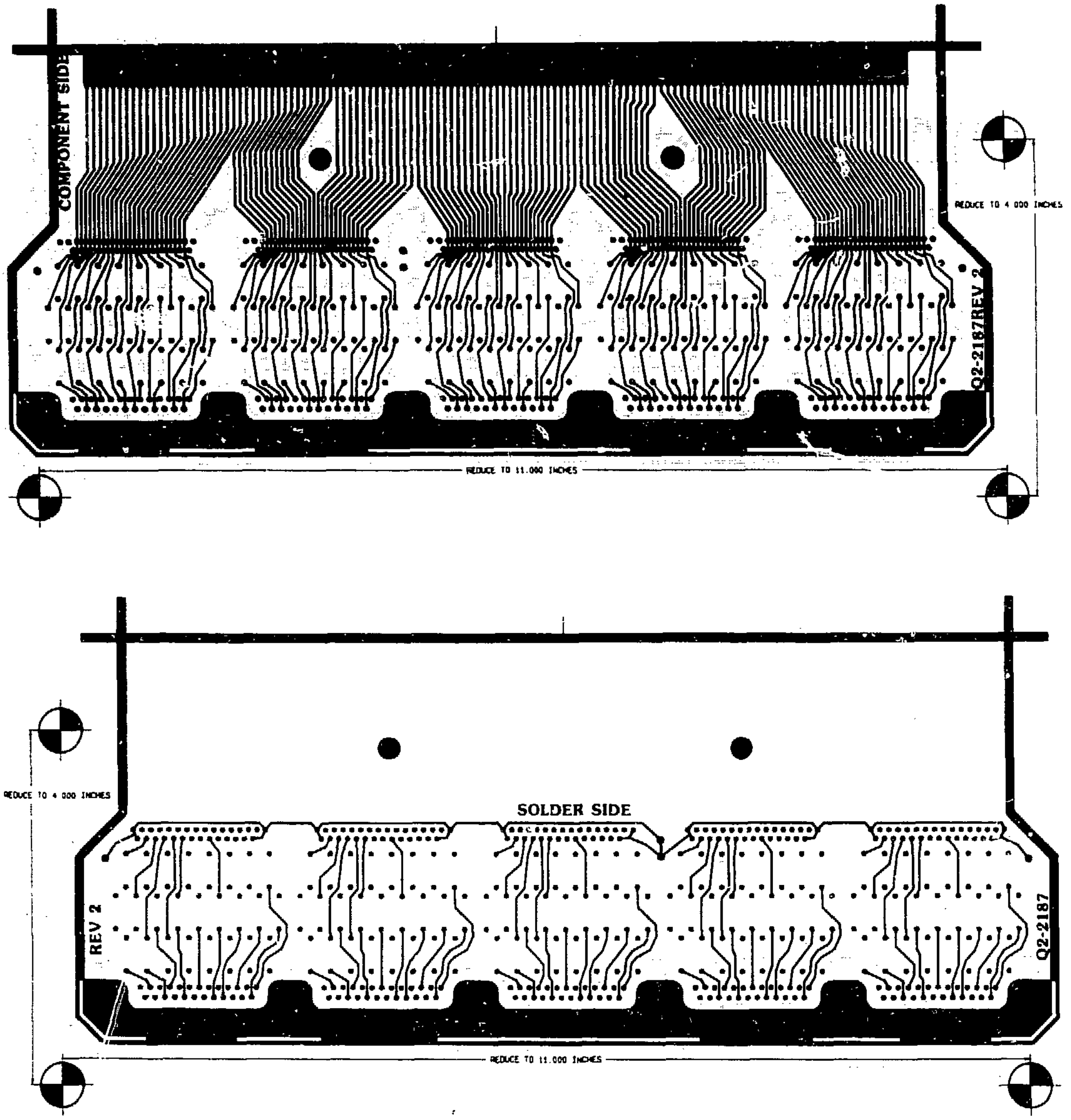


Fig. 6.
Etching pattern for the two circuit boards specified for a chamber. The chamber will be built around a large and a small etched board. One end of each sense wire will be soldered on to the small board (glued on one side of the aluminum frame), and the other end of the wire will be soldered to one edge of the larger board. This large board will give the signals a path out of the chamber and will also have the R/C isolation networks mounted on it. Both boards will be constructed of 1/16-in. fiberglass material.

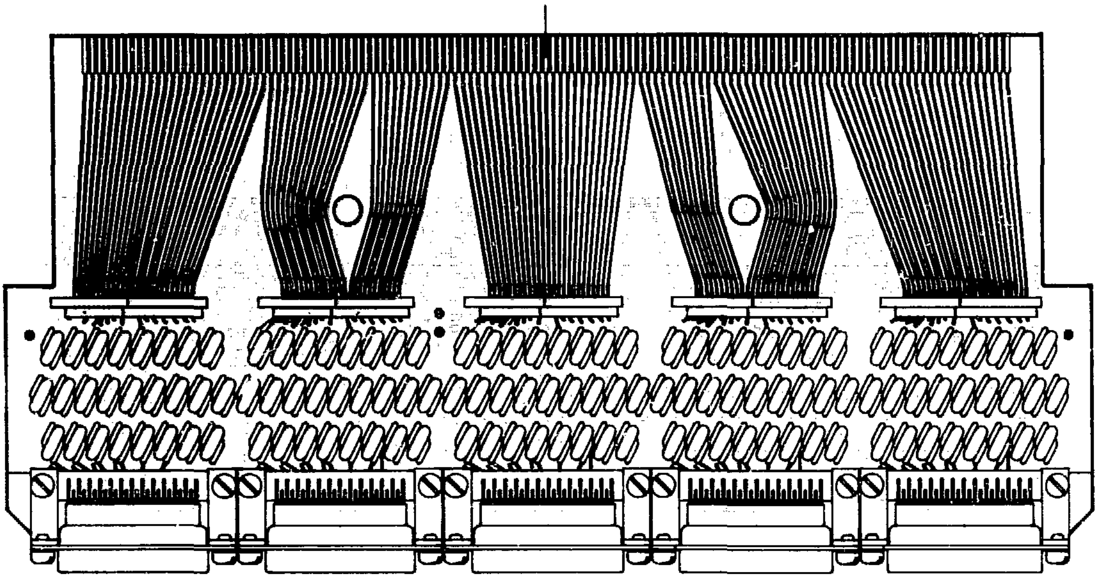


Fig. 7.
Assembly of the chamber PC boards. This figure shows how the circuit boards shown in Fig. 6 will be assembled into a single chamber package.

One end of the board will be clamped between the frames. The D connectors will be soldered and bolted to the other end of the board and will also be bolted to the framework surrounding the output components (Fig. 8). This framework is also aluminum and will entirely enclose the signal lines and the HV bus. The framework will provide shielding for the signal path and totally protect the high-voltage circuits from accidental contact. The only HV connections to the outside will be the two SHV connectors mounted on the shielding frame. Also mounted on this framework will be two gas line feedthroughs. The gas will enter and leave each chamber through 1/4-in. square grooves cut into the chamber frames (Figs. 2 and 3). Short pieces of 1/4-in. copper tubing will be glued into these grooves and will extend out to the front of the shielding. There the tubing will connect to 1/4-in. bulkhead feedthrough/adapters, which will accept 1/4-in. Poly-flo® tubing. The chambers can be connected to the gas handling system with polyethylene tubing. All of these connections are shown in more detail in Fig. 8.

High voltage will be supplied to the wire chambers by a LeCroy* HV4032A (or similar) modular high-voltage system. The blocking capacitors in the chambers can only withstand 3 kV, so the supply will be limited to this value. The LeCroy +3.3 kV modules seem ideal for this system. These modules can be used to create up to 32

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*LeCroy Research Systems Corp., 700 South Main Street, Spring Valley, NY 10977.

separate HV supplies from a single main frame. Thus, if 10 chambers are to be instrumented, only one main frame will be needed. These main frames can also accommodate higher voltage or current supplies if desired. This modular high-voltage system can be expanded to work with the next generation of chambers at a later date. The system can be used to supply up to 512 separate high voltages. Notice (Fig. 4) that each chamber can be powered by either one or two high-voltage supplies. The second option will be used only if a single supply proves to be inadequate.

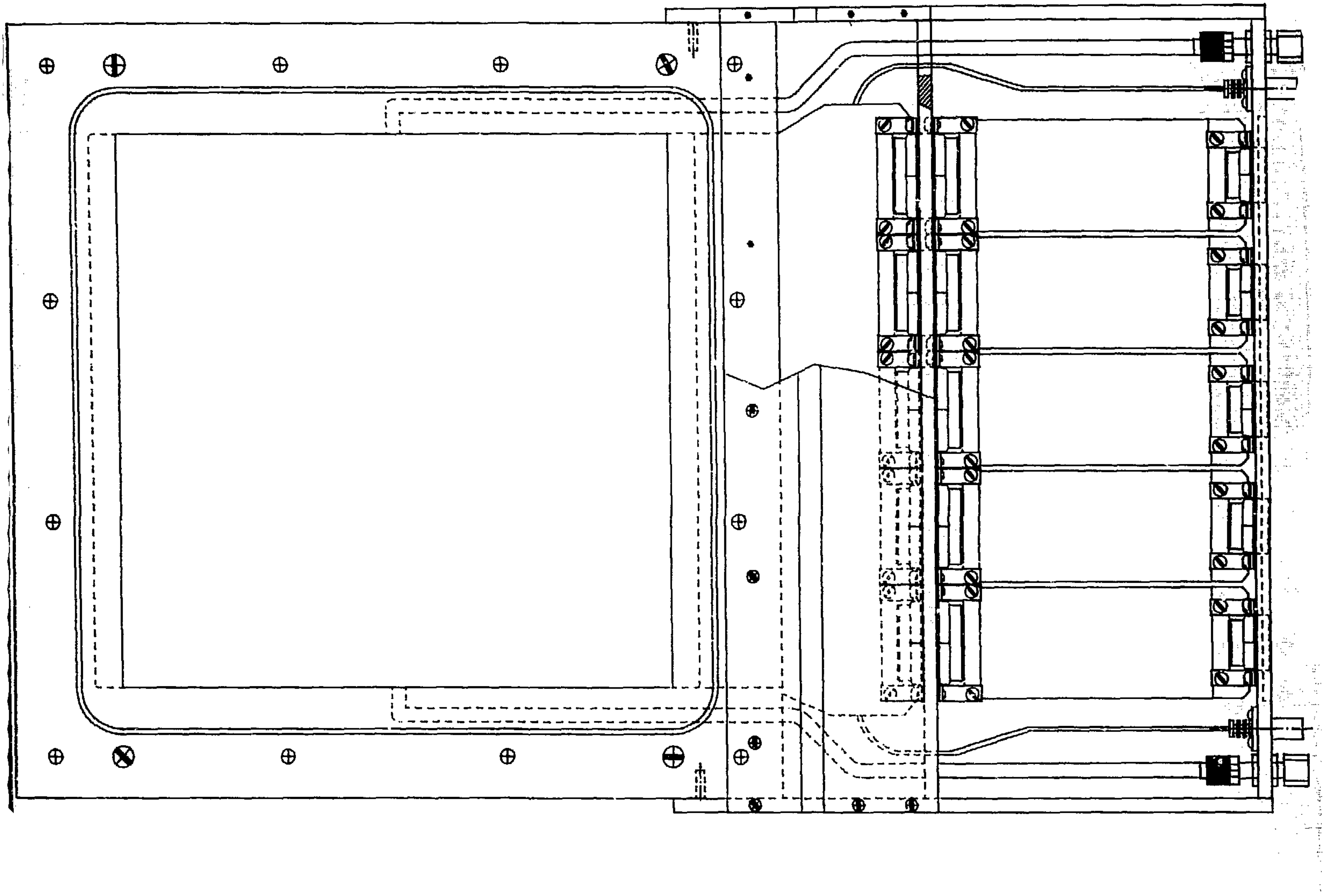


Fig. 8.
Mechanical assembly. The shielding frame holding the chamber, the R/C networks, and the gas and high-voltage connectors. The frame will support the chamber PC boards through the output D connectors. The frame will shield all of the signal wiring and will connect both the connector shields and the chamber assembly to ground. The SHV connectors will also be screwed to this frame so their shields will be grounded. Note that an extension of the shielding framework will support and partially shield the amplifier boards.

PART 2

CHAMBER ELECTRONICS

I. ELECTRONICS REQUIREMENTS

The overwhelming concern in designing the electronics packages was to keep the length of the low-level signal wiring between the chamber wires and the first stage of amplification as short as possible. This wiring should also be kept far away from cables that are carrying signals. These specifications will keep noise pickup and cross talk to a minimum. We desired the amplifiers to be constructed in a modular fashion so that different types of amplifiers could be accommodated with a minimum of difficulty. Also, handling all 125 signals from a chamber on a single board presented significant problems. As the chamber itself has 5 output connectors of 25 pins each, we decided to design each amplifier board to amplify the signals from a set of 25 wires.

Clearly, for a multiple amplifier design such as this the amplifiers themselves must be small. Also, we wanted to have both a linear and a discriminator output from each set of wires. Because of the very large number of signals, it was impractical to have a separate threshold setting for each signal—a common voltage must control the set points for all the discriminators. Similarly, there should be no variable controls on the individual amplifiers, and the design should not depend on gain controls that are individually set or on individual output offset adjustments. In particular, the threshold settings of the discriminators should not depend on the offsets of the amplifiers. The linear outputs may prove to be unnecessary and may be reduced or deleted in a later design. This initial amplifier design was kept general so that it could be used to answer as many questions as possible.

The amplifiers should be moderately fast (rise time < 100 ns) and low noise (equivalent input noise voltage << 5 mV p-p). In addition, the amplifying devices must be readily available, off-the-shelf devices. This constraint rules out the use of custom hybrid amplifiers, although such hybrids might be used at a later date. The easy exchange of amplifier types is one of the advantages of the modular concept.

II. ELECTRONICS DESIGN

To meet the requirement of small size, the design had to be based on integrated circuits (ICs). The purchase time requirement restricted our choices to commercially available operational amplifiers (op-amps). The only op-amp that, on paper, met the speed requirement was the Signetics NE5539.[22] This IC is specified to have a rise time (at low gain) of 5 ns and even at 30 dB gain to have a bandwidth of 40 MHz. This capacity is excessive and, therefore, if time permits, other amplifiers will also be investigated. The NE5539 is specified to have an input noise of 4 nV per square root of bandwidth. If the bandwidth is assumed to be 40 MHz, then the total input referenced noise becomes 25 mV. This is comfortably below the 5-mV level required.

However, there are three major problems with the NE5539. First, this amplifier can only deliver an output of about 2 V into a high-impedance load or about 0.4 V into 50 Ω. This is not a severe problem in our application, but it must be recognized. Another problem is that, although the NE5539 has an enormous gain-bandwidth product (1.2 GHz), its dc gain is only 52 dB. Thus, the closed loop gain of any NE5539-based amplifier must be kept relatively low if amplifier speed is to be maintained. The amplifier bandwidth is 80 MHz at 20 dB (x10) gain, 40 MHz at 30 dB gain, and 15 MHz at 40 dB (x10).

The third difficulty is that the NE5539 is rather large. A single amplifier is contained in a 14-pin dual inline package (DIP). This difficulty would be another reason to try other, more densely packed amplifiers. A sensitive volume of 30.7 cm^3 is acceptable for this application, and a spatial resolution of 1 cm is adequate so the signals from every set of five adjacent wires will be summed and sent to a single amplifier. This reduces the amplifier and discriminator requirement to 5 per board or 25 per chamber. The number of signals that must be processed is similarly reduced. If five amplifier boards are to fit across a single 10-in. chamber, then each board must be <2 in. wide. Five DIP packages will just fit into 2 in. Therefore, each board is laid out as shown in Fig. 9.

The schematic for a single amplifier is given in Fig. 10. A similar amplifier (shown in Fig. 11) is structured to have a gain of 40 dB (rather than 30 as is specified here) and to be very fast (being made up of two 20-dB gain stages rather than a single one). This amplifier has an output noise of about 12 mV p-p into a high-impedance load. This output noise corresponds to an input referenced noise of 110 mV p-p, or if the bandwidth is taken to be 80 MHz, a noise per square root of bandwidth of 4.4 nV rms. This input referenced noise level agrees well with the 4-nV rms specification. Representative input and output signals of the 40-dB amplifier are shown in Fig. 12. The rise time of this circuit is about 15 ns, which agrees well with the expected 80-MHz bandwidth. These results indicate that the 30-dB wire chamber amplifiers will work as expected.

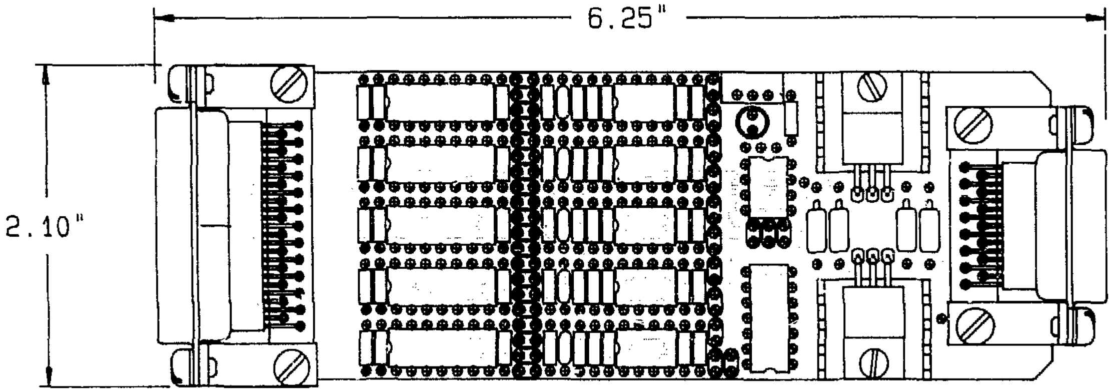


Fig. 9.
Layout of the parts on an amplifier board. Five of the NE5539 amplifiers can just be fitted across a 2-in. board. Thus, this design specifies five channels of amplification per board and five amplifier boards per channel. The small (unamplified) signals will not pass near the amplified ones. The NE5539s are ideal in this respect in that their inputs are located at one end (pins 1 and 14) and their output at the other (pin 8). However, any further miniaturization of this board will probably require the use of custom hybrid amplifiers in place of the NE5539s. Each channel also has a discriminated TTL output. All inputs will be through the 25-pin D connector at one end of the board, and all outputs will be through a 15-pin D connector at the other.

The discriminators also need to meet the 100-ns speed requirement. As in the case of the amplifiers, size and availability requirements make commercial integrated circuits the most viable for the alternatives. Again, the initial unit chosen is somewhat more than adequate. At a later date this IC may be replaced, but because we know it will work, we are using it for the first design. For the discriminator we specify the National LM360 comparator.[23] This circuit comes as a single unit in an 8-pin DIP package; it is not as compact as we would like but is better than the amplifier. Its response time is specified as <16 ns, and experience shows this to be true as long as one condition is met. The outputs of the LM360 comparator will not handle large currents and hence cannot directly drive capacitive loads such as coaxial cables; therefore, some kind of buffer must be placed between the LM360 and a useful output. The National LM361 is a similar comparator with a built-in buffer, but it is housed in a 14-pin package. Five LM360s and a single 74LS04 hex inverter will take up less space than five LM361s.

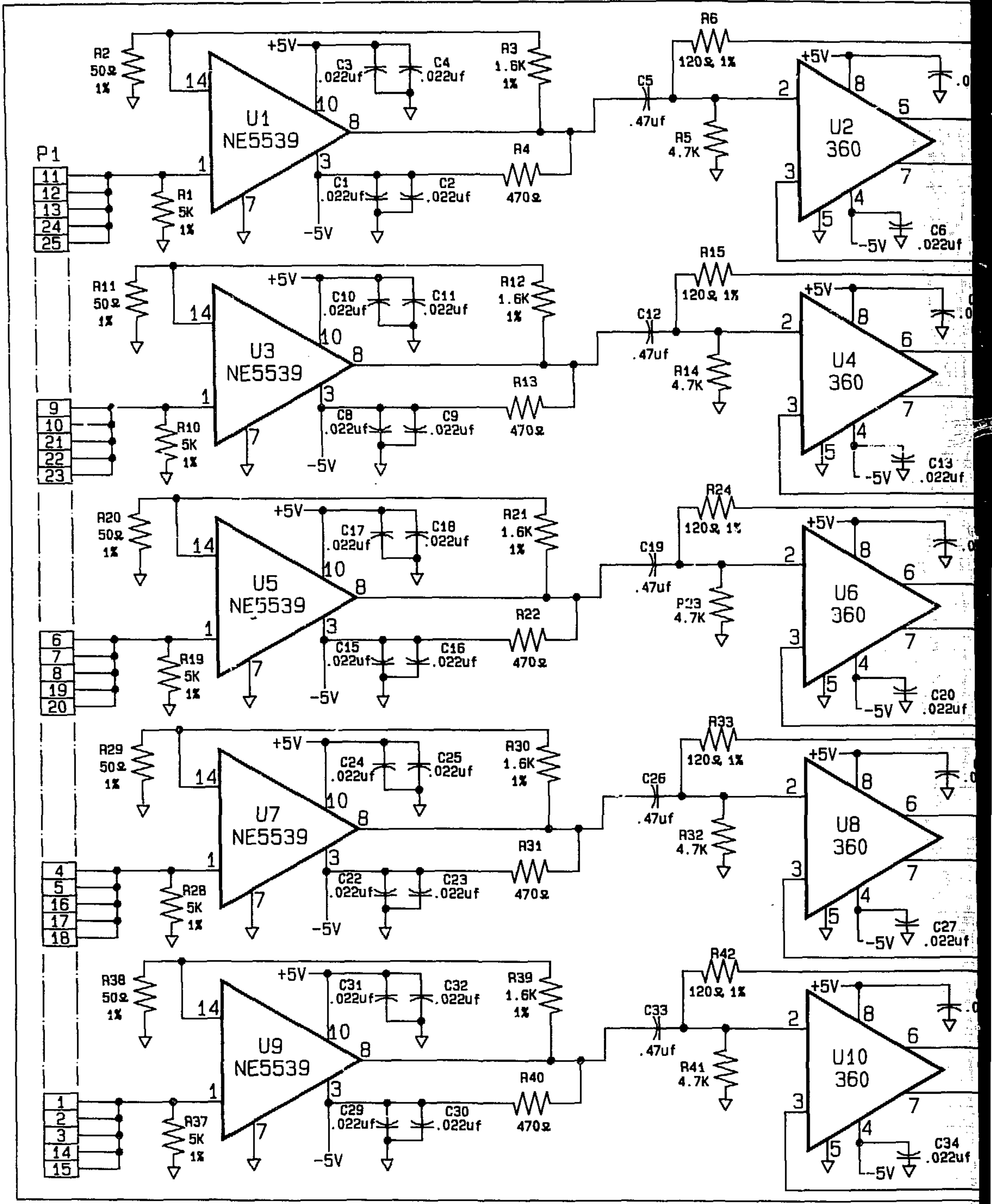
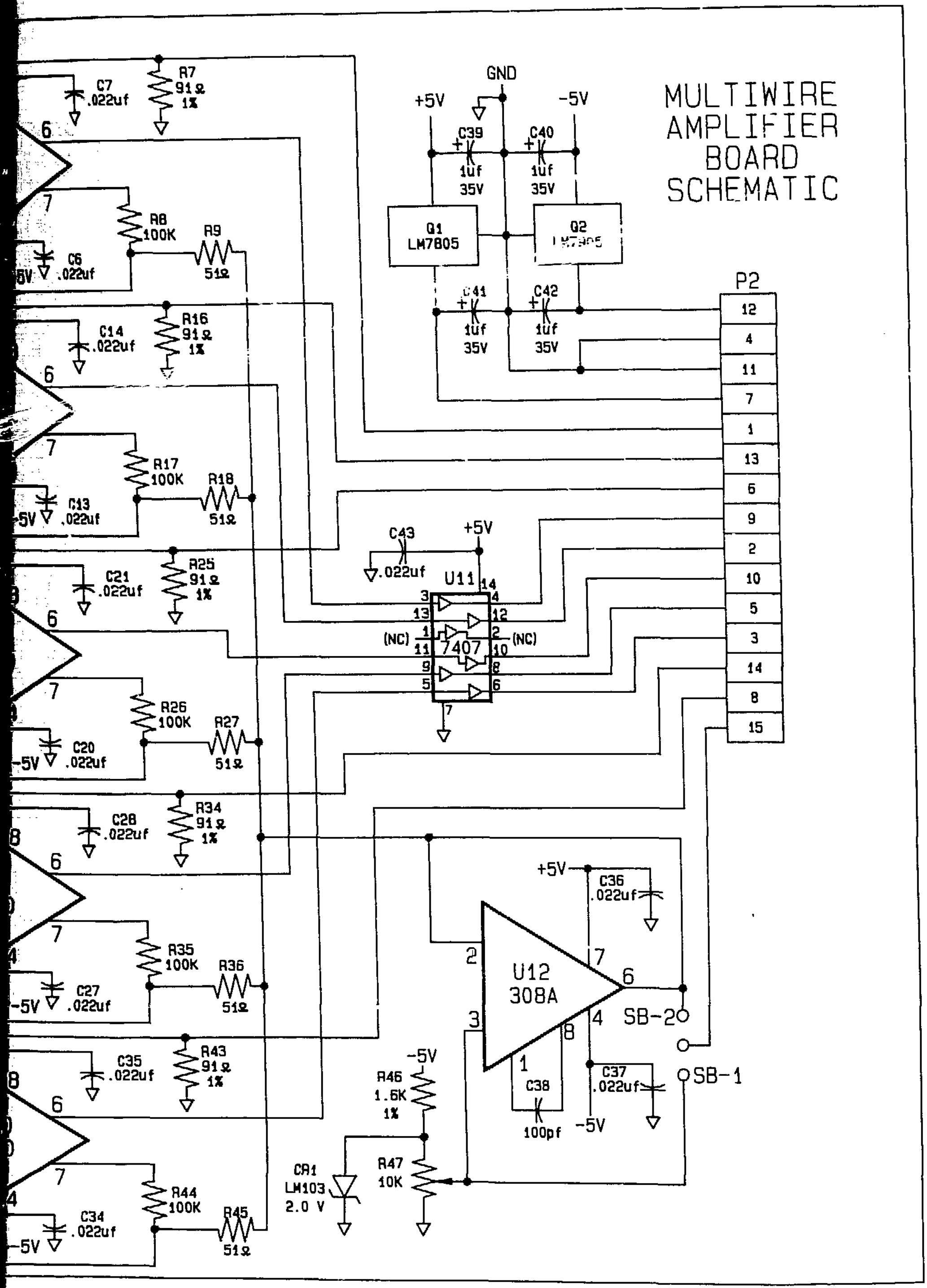


Fig. 10.

Schematic of a single wire chamber amplifier. This schematic also
voltage circuitry. Each of the amplifier boards, shown in Fig. 9,
circuit, but five signal amplifiers and five discriminators. All
single reference set point. If the jumper wire is in position 1,
generator and output this reference voltage. If the wire is in po
a "slave" voltage follower on the input reference voltage. Normal
as a master and all the rest as slaves. In this case the referenc
the one master reference generator.



. 10.

tic also includes the power supply and threshold reference
Fig. 9, contains one power supply and one reference
s. All the discriminators in the system operate on a
tion 1, then the circuit will act as a "master" reference
is in position 2, then the reference circuit will act as
Normally, only one reference generator will be configured
reference level for all the discriminators will be set by

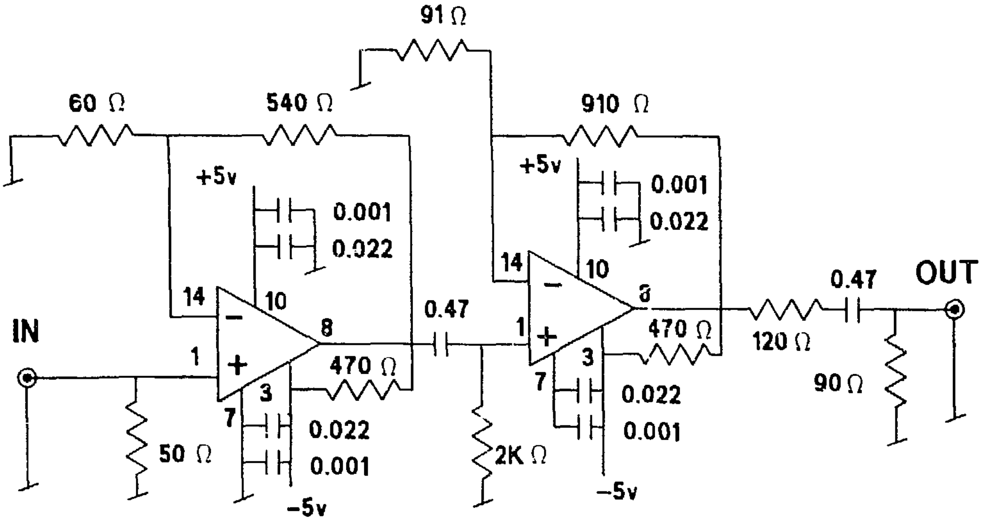


Fig. 11.
Schematic of the 40-dB amplifier. This amplifier has been built and tested and is the basis for the wire chamber amplifier shown in Fig. 10. The topology of the two amplifiers is very similar, the major difference being the number of stages used in the amplifier. The 40-dB amplifier uses two 20-dB stages in order to achieve 40 dB of gain at very high frequencies. The response of the 40-dB amplifier to a tail-pulse input is shown in Fig. 12.

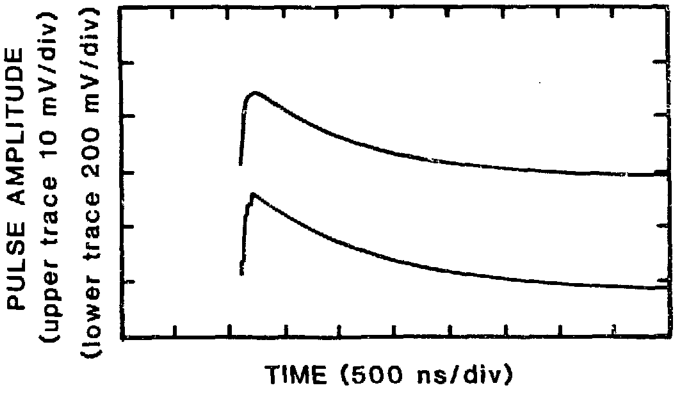


Fig. 12.
Response of the 40-dB amplifier. The upper trace is the input to the amplifier from a tail-pulse generator. This input has a rise time of about 100 ns and a peak amplitude of 16 mV. The lower trace is the output from the amplifier. The rise time here is 100 ns, indicating an amplifier rise time of less than 100 ns. A 50-Ω output network was in place, therefore the gain was only about 20 rather than 100.

The discriminator threshold level is set for all the comparators by a single adjustable circuit based on an LM308 (Ref. 23) voltage reference diode. The amplifier gives the low impedance necessary to drive all of the comparators, and the diode provides some isolation between the set point voltage and the power supply voltage. Only one voltage reference circuit will be used at a time. The other boards obtain their reference from the master controller. On these boards the LM308 will be used as a voltage follower to strengthen the master reference signal. Hence, one adjustment will set the thresholds for every discriminator.

Each board has its own regulation. Separate regulators on each board will reduce the cross talk between boards and will place a smaller load on each regulator, allowing the use of less expensive regulators. The NE5539, LM360, and LM308 are all TTL compatible. Thus, only plus and minus 5-V supplies will be required. A 15-pin D connector links the amplifier board and any further data processing electronics. Five of these pins carry the linear signals, five the outputs of the discriminators, one the discriminator threshold voltage, one the positive voltage, one the negative voltage, and two the signal and power grounds.

III. DETAILS OF THE ELECTRONICS

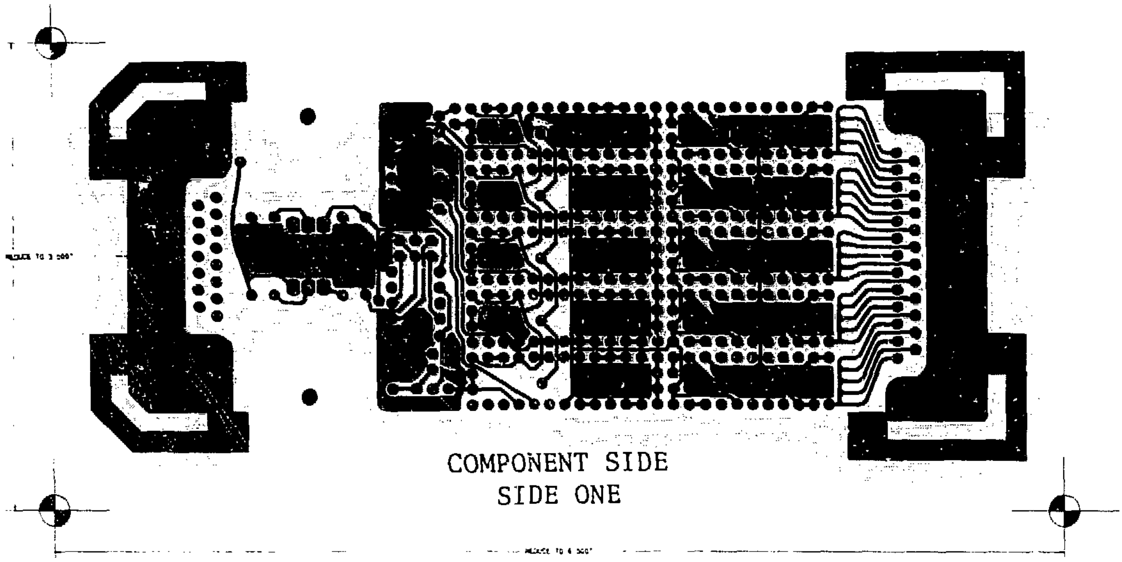
It may be useful when reading this section to refer to the amplifier board schematic, Fig. 10, and the PC board layout, Fig. 13.

A. Signal Amplifiers

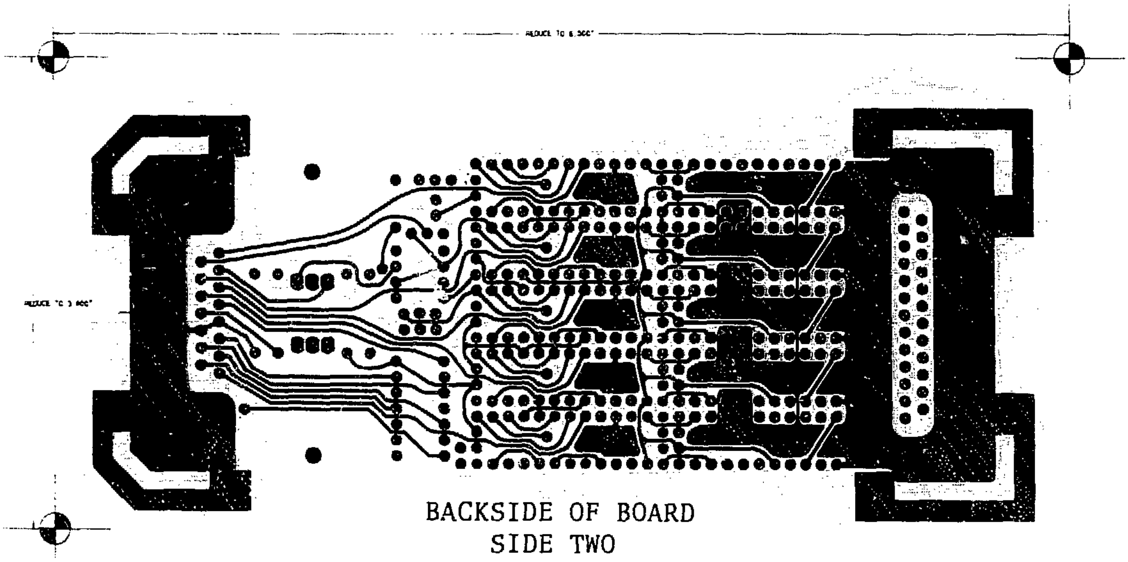
The current pulses from five wires will be summed across R37 to produce a single voltage pulse. The voltage gain of the NE5539 will be set by the resistors R38 and R39 to be 33 (30 dB). The 0.47-μF capacitor will block any dc generated by the amplifier, making offset adjustments unnecessary. The optional output resistor network will be needed to drive 50-Ω loads but will be ignored otherwise. The NE5539 will drive 50 Ωs through this network at the cost of a factor of 5 reduction in gain. The 470-Ω resistor (R40) on the op-amp output is specified[22] to increase the maximum negative output of the NE5539.

B. Signal Discriminators

Discrimination of the five analog signals will be accomplished by five LM360 comparators. These will form leading edge discriminators with the threshold set by the reference voltage as described above. There will be a small amount of positive feedback around each comparator to give hysteresis to reduce triggering on noise. As mentioned before, the outputs of the LM360 are directly TTL compatible but require buffering. This buffering will be provided by a 74LS04 hex inverter. Its outputs will go to the 15-pin D connector, so the discriminator outputs from the board will also be TTL levels.



COMPONENT SIDE
SIDE ONE



BACKSIDE OF BOARD
SIDE TWO

Fig. 13. Etching plan for the amplifier board. Each set of five amplifiers will be built on this modular board. Each amplifier board will handle 25 signals.

C. Discriminator Reference

The circuit that will generate the threshold voltage for the comparators has also been used before. If the jumper wire is in position 1, the reference diode will be used, and the reference circuit will produce an isolated voltage between 0 and 2.0 V. In this case, the circuit will consist of an LM103-2.0 voltage reference diode and an LM308 amplifier. The resistor, R46, sets the current through the diode to 1 mA. The voltage across the diode will then be 2.0 V; any threshold between 0 and -2.0 V can be selected using the potentiometer, R. The LM308 will be configured as a voltage follower to isolate the diode/potentiometer circuit from loading caused by the reset of the circuitry. If the jumper wire is in position 2, the reference diode will not be used, and the LM308 will serve as an additional voltage follower for the externally generated reference signal. Thus, each set of five comparators will be driven by an LM308 buffer. The LM308s will all be driven by a common reference voltage.

D. Power Supply

Each board of five amplifiers will draw 140 mA from the negative supply and 248 mA from the positive (see Table II). The 7805 positive and 7905 negative regulators have been specified for this design. Compared with adjustable regulators, these are cheaper and require fewer auxiliary components. The advantages of adjustable regulators (precision and setability) are of little use in this application. As mentioned below, the high-current "raw" power supplies will be regulated, so elaborate on-board regulation will not be required. The 7805 is specified to have a maximum dropout voltage of 2.3 V and the 7905 1.1 V.[24] Thus, the raw supply voltages to the regulators must be at least +7.3 V and -6.1 V. Raw voltages of +9 V and -8 V were chosen to allow for some part-to-part variation. The positive regulator will be dissipating 1 W and the negative regulator 0.4 W. A small sheet metal heat sink will be sufficient for each regulator, given this power dissipation. The current drain for 50 amplifier boards (10 chambers) will be 12.5 A from the positive supply and 7 A from the negative. The small capacitors on the regulators are specified by the manufacturer.[24] A suitable raw power supply is the Kepco* model JQE 15-25 M. This supply has a variable output of 0-15 V at 0-25 A. This much power is again an overkill but has the advantage that it will run a large number of amplifier boards of almost any design. Two of the Kepco supplies will be needed to provide both positive and negative voltage.

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*Kepco Inc., 131-138 Sanford Avenue, Flushing, NY 11352.

TABLE II

CURRENT LOAD OF THE CIRCUITRY ON A SINGLE BOARD

Both regulated voltages will be 5 V. If the positive "raw" supply voltage is 9 V (4-V regulator drop) and the negative "raw" supply is 8 V (3-V regulator drop), then each positive regulator will dissipate 1 W and each negative one 0.4 W. Fifty boards will draw 12.5 A from the positive supply and 7 A from the negative.

Number Per Board	Chip	Negative Supply Current (mA)	Positive Supply Current (mA)
5	NE5539	55	70
5	LM360	80	160
1	74LS04	--	7
1	LM308	1	1
1	LM103	1	--
1	7805	--	10
1	7905	3	--
	TOTAL	140	248

E. Output Signals

The five analog signal outputs will be buffered and can be made to drive 50 if desired. The 50-Ω outputs will be needed if the analog outputs are connected to long cables. If the signal outputs are to be plugged directly into another circuit board, then high-impedance outputs will suffice. The discriminator outputs will be buffered TTL level (0 to +5 V) signals. These outputs will not tolerate 50-Ω termination but are capable of driving a significant load. The reference voltage output will be buffered by an LM308, which can supply up to 5 mA of output current.[25] The input resistance of an LM308 is specified[24] to be at least 10 M ; the current drain of this input with a 4-V dc signal applied to it is 0.4 mA. The input offset and bias currents of the LM308 combine to 8 nA; thus, the total current load imposed by each LM308 is at most 410 nA. The maximum current of each LM360 is 10 nA, so the reference-generating LM308 can drive its own set of five comparators plus more than a thousand other LM 308s. The reference generator should be able to drive the 50 amplifier boards specified with no difficulty.

The analog amplifiers will be noninverting, and the discriminators inverting. Thus, for a negative input signal the analog outputs will be positive, and the discriminator outputs will be positive TTL pulses. These pulses will be of random lengths, depending on the lengths of the input pulses, and may require further processing to achieve a more uniform pulse length.

CONCLUSIONS

This report has been compiled from the design specifications and drawings for the 10-in. wire chamber and associated electronics in order to document these designs. We have not addressed the question of how to process the signals after they have been amplified, nor do we present data or results at this time.

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