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1 Introduction to RICH Preamplifier

At PHENIX experiment[1], the RICH (Ring Imaging Čerenkov) detector is a primary device for electron identification. In RICH, 5120 PMT's (HAMAMATSU H7131S) are used to detect Čerenkov photons. The PMT output signal is sent to the RICH FEM (Front End Module) [2] via a coaxial cable with ~9 m in length. The average PMT output per one photoelectron is 1.8 pC in charge and has a pulse height of ~20 mV(at 50 Ω load) with less than 5 ns pulse width. Since the signal is so tiny, additional degradation by external noises will cause a significant problem. To solve this problem, the PMT signal is amplified on the RICH preamplifier card at a gain of ~10 as close to the PMT's as possible. Each card consists of 16 operational amplifier (op-amp) circuit. So, 320 cards are required to amplify the signals from total 5120 PMTs in RICH . From zero to 10 photoelectrons are estimated to come into one PMT, so that the dynamic range of preamplifier output is required to be from zero to 18 pC (from 0 to 200 mV as the pulse height).

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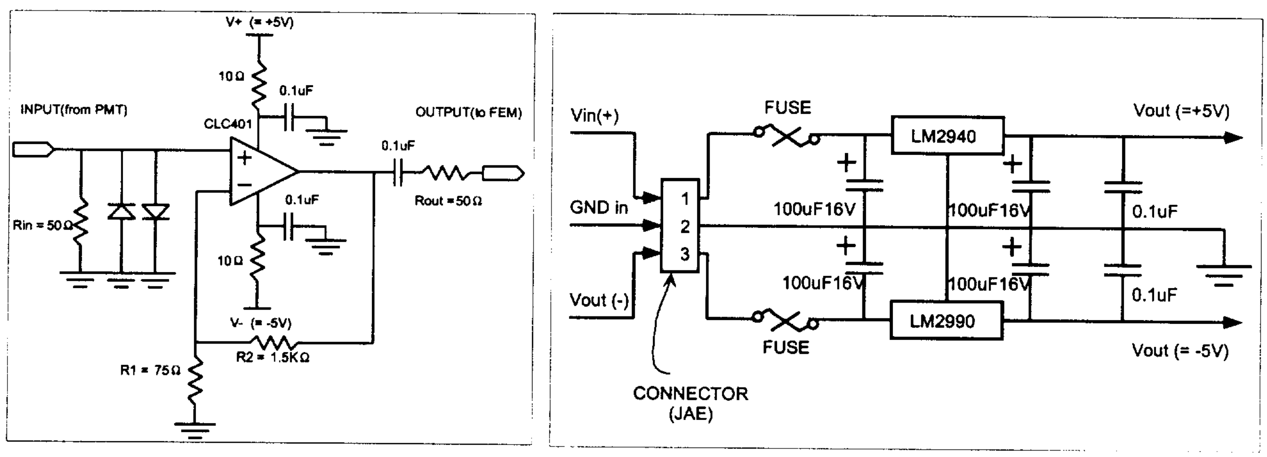
2 Circuit

2.1 Preamplifier Circuit

Each preamplifier card consists of 16 non-inverting gain circuit using a monolithic op-amp(National Semiconductor CLC401) and a power supply unit. The number of channels of 16 was chosen in order to match the physical layout of the PMT array of RICH detector. Fig. 1(a) shows a preamplifier circuit unit. This unit is made of CLC401, protection diodes, resisters and capacitors. The 50 Ω resistors were used for R_{in} and R_{out}, in order to make the impedance matching to 50 Ω. The circuit gain G is decided by, $G = (R_1 + R_2)/R_1$.

The gain of ×20 was chosen with R_1 = 75 Ω and R_2 = 1.5 KΩ, in order to achieve circuit gain of ×10 (Output 50 Ω resister and 50 Ω makes the gain of preamplifier card ×10). In order to reduce the noises, two 10 Ω resistors were used at power supply line both positive and negative. Criteria for op-amp selection was the bandwidth. The CLC401 is a wideband fast-settling (0.1% settling in 10 ns) op-amp with the -3 dB bandwidth of 150 MHz and rise/fall time of 2.5 ns.



(a) Preamplifier Circuit Unit

(b) Power Supply Unit

Fig. 1. (a) Circuit diagram of the Preamplifier Circuit Unit made of CLC401, resistors, capacitors and protection diodes. (b) Circuit diagram of the Power Supply Unit made of LM2940CS-5.0, LM2990S-5.0, fuses, capacitors and connector.

2.2 Power supply

2.2.1 Power requirement

The preamplifier card requires the bipolar power supply (Positive: from +6 V to +8 V, Negative: from -6 V to -8 V). From the above voltages, on-board voltage regulators make ±5 V and supply them to the op-amp circuit units. The current needed per one card is 280 mA (at ±6 V supply) for both positive and negative. Total power consumption per one card when ±6 V are supplied, is around 3.0 W.

2.2.2 Power supply unit

Fig. 1 (b) shows the power supply unit. This unit consists of two voltage regulators (National Semiconductor LM2940CS-5.0 for positive voltage and LM2990S-5.0 for negative voltage), two fuses (HAMAI ROYAL), two 0.1 μF ceramic capacitors (MURATA GRM40F104Z25), aluminum capacitors (NICHICON UWX16V100μF). External positive and negative voltages are supplied via a three-terminal connector (JAE IL3p-S3FP2).

As mentioned above, the preamplifier card requires the 280 mA of current supply. So, over 280 mV of output current is required for the regulators. Regulators have ability to source 1 A of output current with a dropout voltage of typically 0.5 V and maximum of 1 V.

3 Layout of Preamplifier Card

The preamplifier card has an unique five-cornered shape which was determined to facilitate the output cable assembly. So the input and output direction make about 56 degree. Fig. 2 shows board layout of a preamplifier card[3].

There are 16 preamplifier circuit units, an input connector (HONDA MFC-34LFD), an output connector (AMP 4997886-8) and a power supply unit on a card. For the preamplifier circuit, surface-mounted type parts are used. The 16 preamplifier circuits were divided into 4 groups. Each group has the same power supply lines which are one-point connected near the power supply unit[1].

[1] There are detail figures in appendix.

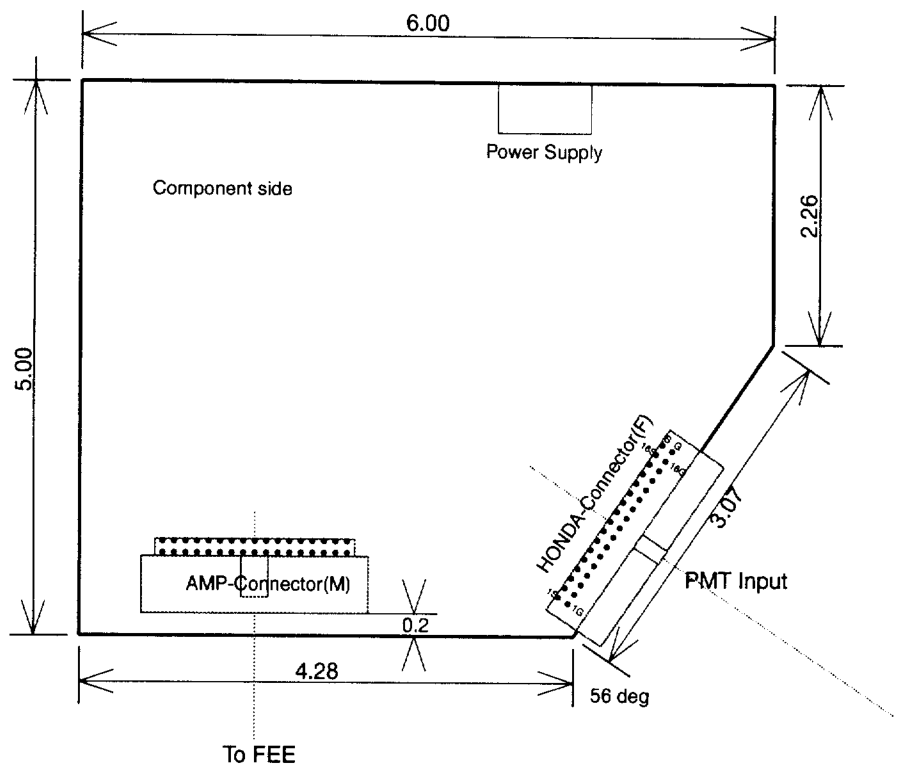


Fig. 2. The layout of Preamplifier Card

The preamplifier card is composed of five copper layers. Four FR4 boards with 0.4 mm of thickness are used and the total thickness of the card is 1.6 mm.

- layer 1 : parts, +5 V, GND
- layer 2 : Signals (input, output)
- layer 3 : GND
- layer 4 : Signals (input)
- layer 5 : -5 V, GND

The layer with signal lines (layer 2 and 4) were sandwiched by the GND layers, in order to guard the signals from outer noises. In order to keep the characteristic impedance Z_0 to 50 Ω the width of the signal lines were decided to be 250 μm, from the relation,

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left[\frac{4b}{0.67\pi(0.8w+t)}\right]$$

where, ε_r is dielectric constant relative to vacuum, b is distance between two GND planes (in mm), t is conductor thickness (in mm) and w is conductor width (in mm).

3.1 Parts

Surface-mounted type parts were used, primarily because of the space limitations of the card. Fig. 3 shows a list of the used parts.

parts	parts number	products	manufacturer	number per card	total
Opamp	U19～U34	CLC401AJE	National Semiconductor	16	5120
Regulator	U17	LM2940CS-5.0	National Semiconductor	1	320
	U18	LM2990S-5.0	National Semiconductor	1	320
Fuse	F1、F2	ROYAL	HAMAI	2	640
Diode	D1、D3、D5、D7、D9、D11、D13、D15、D17、D19、D21、D23、D25、D27、D29、D31	1SS226	TOSHIBA	16	5120
Resister	R1～R4、R20、R22～R24、 R33～R36、R52、R54～R56 R65～R68、R84、R86～R88 R97～R100、R116、 R118～R120	TRN50CF10Ω	TAISEIOHM	32	10240
	R7、R10、R13、R16～R19、R21、R39、R42、R45、R48～R51、R53、R71、R74、R77、R80～R83、R85、R103、R106、R109、R112～R115、R117	TRN50CF50Ω	TAISEIOHM	32	10240
	R29～R32、R61～R64、R93～R96、R125～R128	TRN50CF75Ω	TAISEIOHM	16	5120
	R25～R28、R57～R60、R89～R92、R121～R124	TRN50CF1.5KΩ	TAISEIOHM	16	5120
Capasitor					
ceramic	C1～C4、C6、C8、C10、C12～C16、C21～C24、C26、C28、C30、 C32～C36、C41～C44、C46、C48、C50、C52～C56、C61～C64、 C66、C68、C70、 C72～C76,C84、C88	GRM40F104Z25(0.1uF)	MURATA	50	16000
aluminum	C81、C83、C85、C87	UWX16V100uF	NICHICON	4	1280
tantalum	C89～C96	SVB2 16V4.7uF	NEC	8	2560
Connector	J1	MFC-34LFD	HONDA	1	320
	J2	499786-8	AMP	1	320
	J3	IL3p-S3FP2	JAE	1	320

Fig. 3. Parts List

4 Safety Assurance

Op-amps, voltage regulators, resistors, capacitors and diodes are commercial products. The power connector (IL3p-S3FP2) was made from/of

Pertinet part : INSULATOR
Generic name : 6-6Nylon
Manufacturer : E I Du Pont
Material designation : ZYTEL FR-15
Flame class/File : 94V-0 / E41938

Two fuses are placed for safety minimizing the hazard due to circuit shortening.

5 Test Results

5.1 Pulse Shape

Pulses from a RC circuit were input into a preamplifier channel. The signal from a single photoelectron has 1.8 pC in average, with ~20 mV pulse height. The pulse was made so as to simulate closely the signal for a single photoelectron. Fig. 4 shows an input signal at the top and output signal at the bottom.

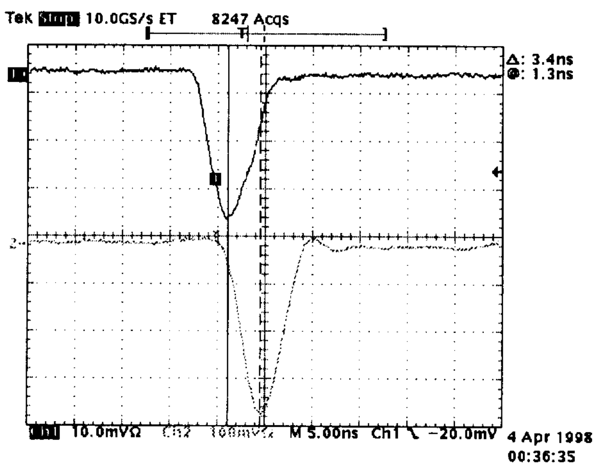
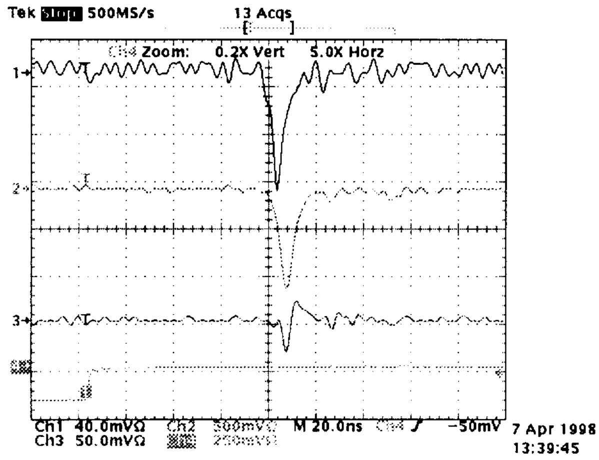


Fig. 4. Pulse Shape. Ch1 shows input signal of preamplifier card, Ch2 shows output signal.

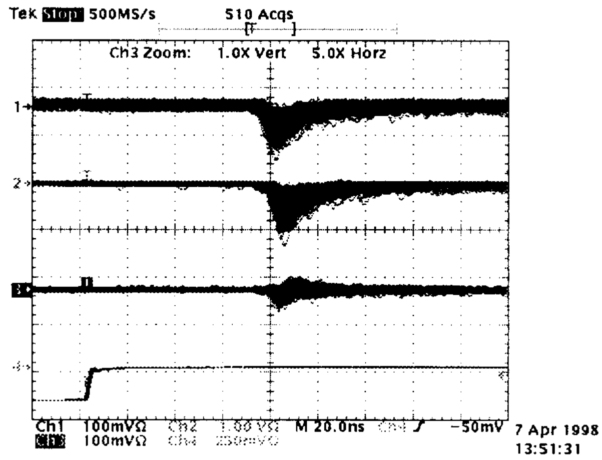
As the figure shows, pulse shape is well kept and the multiplication factor of the pulse height is about 10. Internal pulse delay is around 3.4 ns.

5.2 Cross-talk

Fig. 5 shows a test result of measuring cross-talk. Real signals from a PMT were used to measure the cross-talk. Our test setup consisted of a black box and high voltage power supply



(a) Typical signal shape



(b) Infinite persistence mode

Fig. 5. (a)Typical signal shape. (b) is taken at infinite persistence mode. In these figures, Ch1 is input signal to channel 1 of preamplifier card, Ch2 is output signal from the channel 1, Ch3 is output signal from the channel 2 and Ch4 is gate signal for LED.

system and LED. A PMT was mounted on a PMT mounting case in the black box, and a LED triggered by the TTL signal was used as a light source[4]. The channel (Ch) in the figures are ;

Ch.1: input signal to the channel 1
Ch.2: output signal from the channel 1
Ch.3: output signal from the channel 2
Ch.4: gate signal

The channel 2 of the preamplifier card is adjacent to the channel 1. Ch.3 in Fig. 5 shows the cross-talk of the signal line which have no input signal. As Fig. 5 shows, typical magnitude of the cross-talk signal in adjacent channel (Ch.3) was $\sim 1/30$ of the output signal (Ch2.). On the other hand, the typical magnitude of cross-talk in other channels was $\sim 1/160$. Since the pulse shape of the cross-talk signal is a bipolar one, the signal integrated by the integrator chip[5] should be further reduced.

5.3 Charge Linearity

Each PMT will have a few photoelectrons in average from each Čerenkov hits. With a good margin, the dynamic range of the preamplifier was decided to be zero to ten hits. Fig. 6 shows charge linearity. In this figure, the solid line shows the charge gain of preamplifier card, the dotted line shows the line of gain 10. As this figure shows, the charge gain is not quite linear but the maximum difference is ~5 % in the input range from zero to 18 pC.

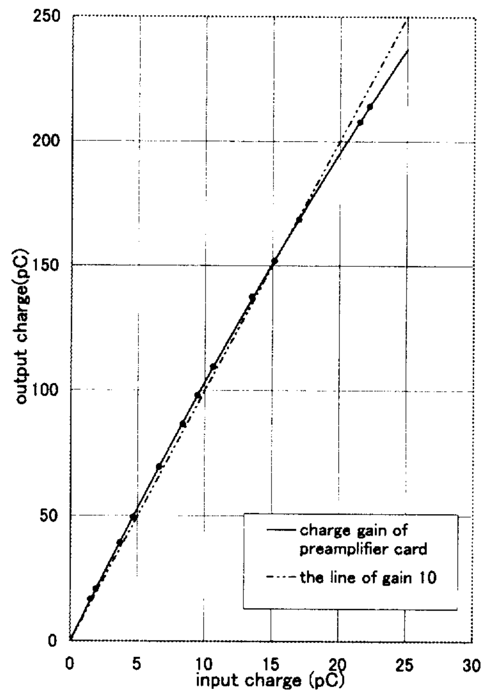


Fig. 6. Charge input vs charge output. Solid line shows charge gain of preamplifier card. Dotted line is the line of gain 10.

6 Summary

This report describes in detail preamplifier card which we developed recently. Each preamplifier circuit unit uses an op-amp CLC401 for amplification at a gain of $\times 20$ with voltage feedback. It is simple non-inverting circuit and has following characteristics, wide-band, low noise and low power consumption.

The preamplifier card is designed to operate with the two supplied voltages of $\pm$(6 to 8) V. On-board voltage regulators make ± 5 V from the supplied voltages. The total power consumption for each card is around 3.0 W.

Test results were also provided. Pulse shape, cross-talk and charge linearity were checked. These test results indicate that this preamplifier card has sufficient performance for RICH.

References

[1] Web page of PHENIX experiment is "http://www.rhic.bnl.gov/phenix"

[2] Web page for the RICH FEM is "http://phenix.cns.s.u-tokyo.ac.jp/~rich/fee"

[3] Web page of preamplifier is "http://phenix.cns.s.u-tokyo.ac.jp/~rich/fee/preamp/preamp.html"

[4] T. Tamagawa, " *Quality Control of Photomultiplier Tubes for PHENIX-RICH*" (Master's Thesis, 1996)

[5] Web page of integrator chip is "http://phenix.cns.s.u-tokyo.ac.jp/~hibino"

Appenix

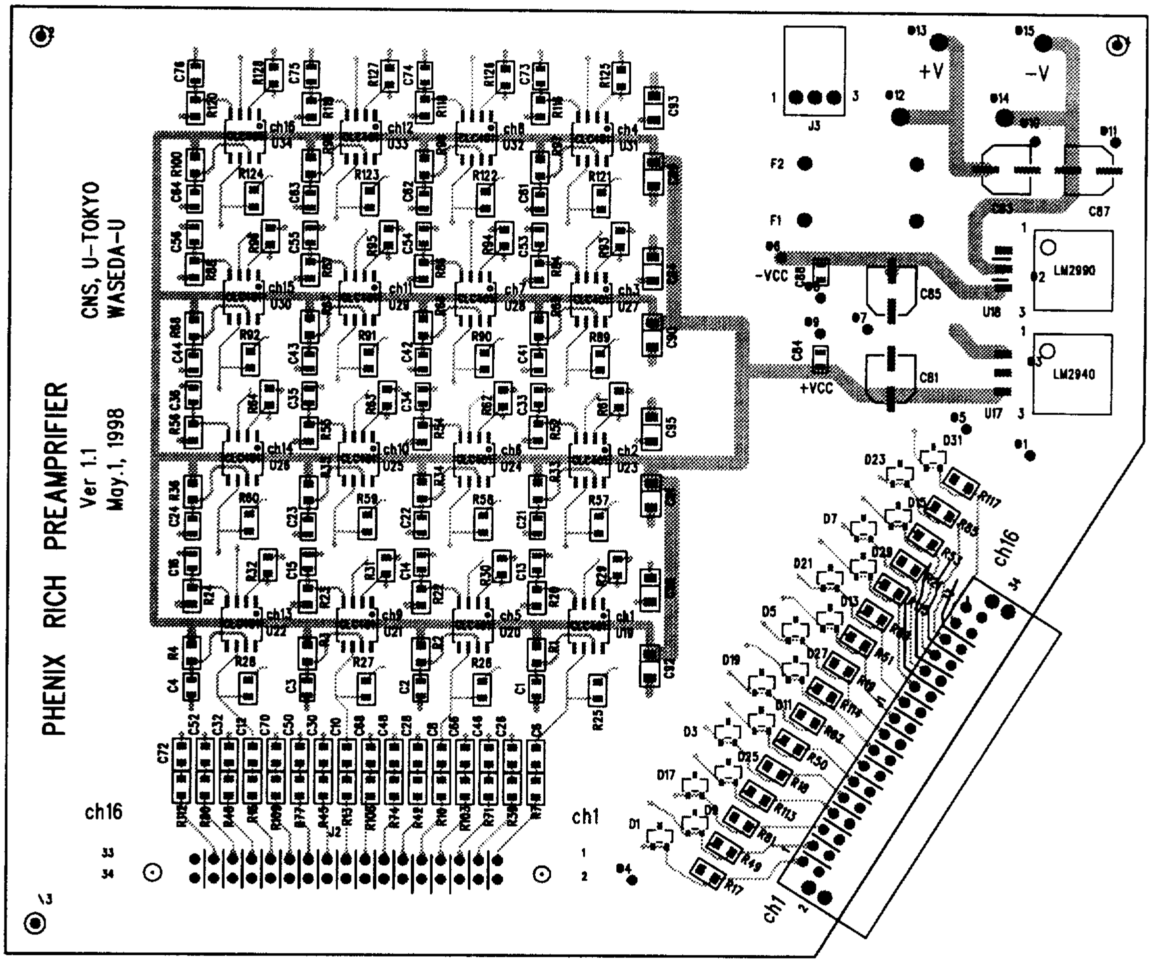


Fig. .1. Silk screen (with signals and soldering pattern).

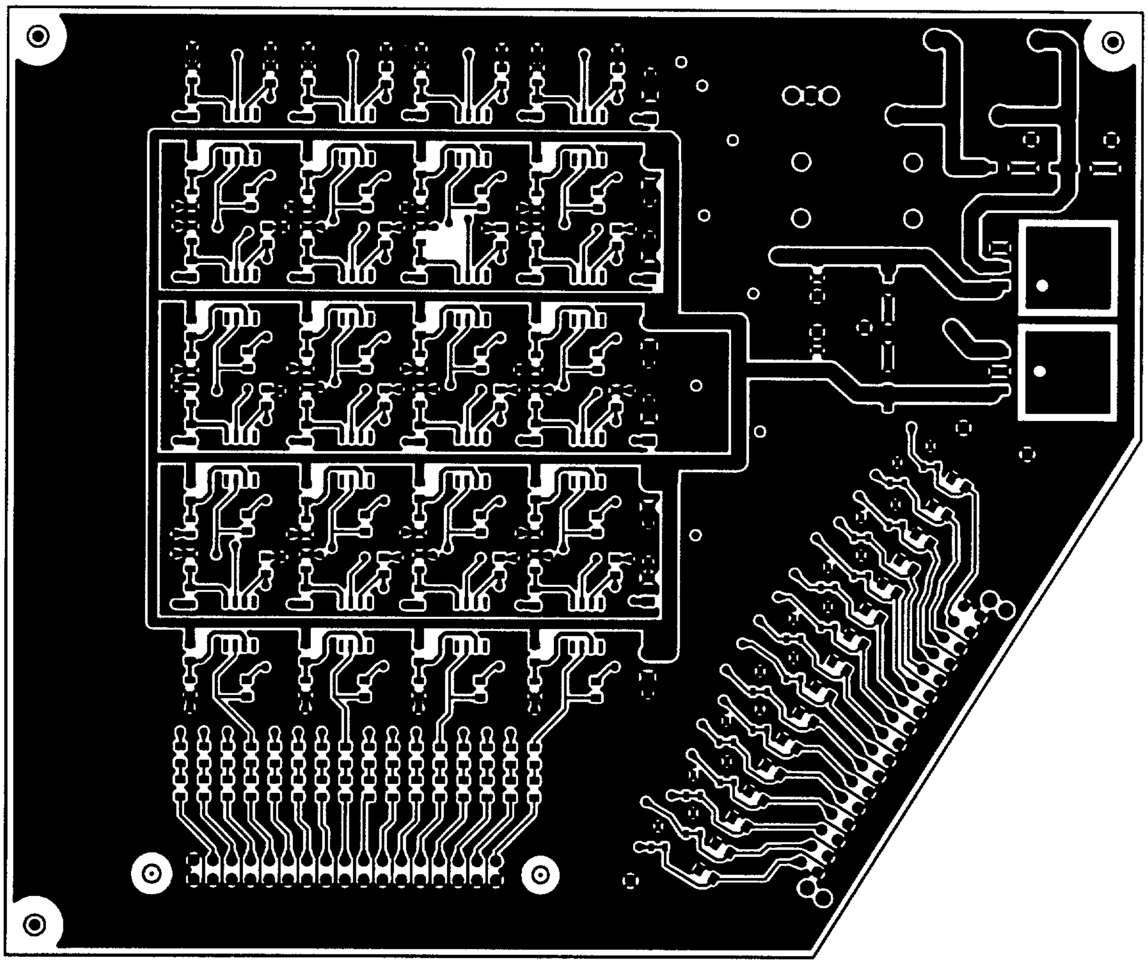


Fig. .2. Layer 1 for parts, GND and +5 V.

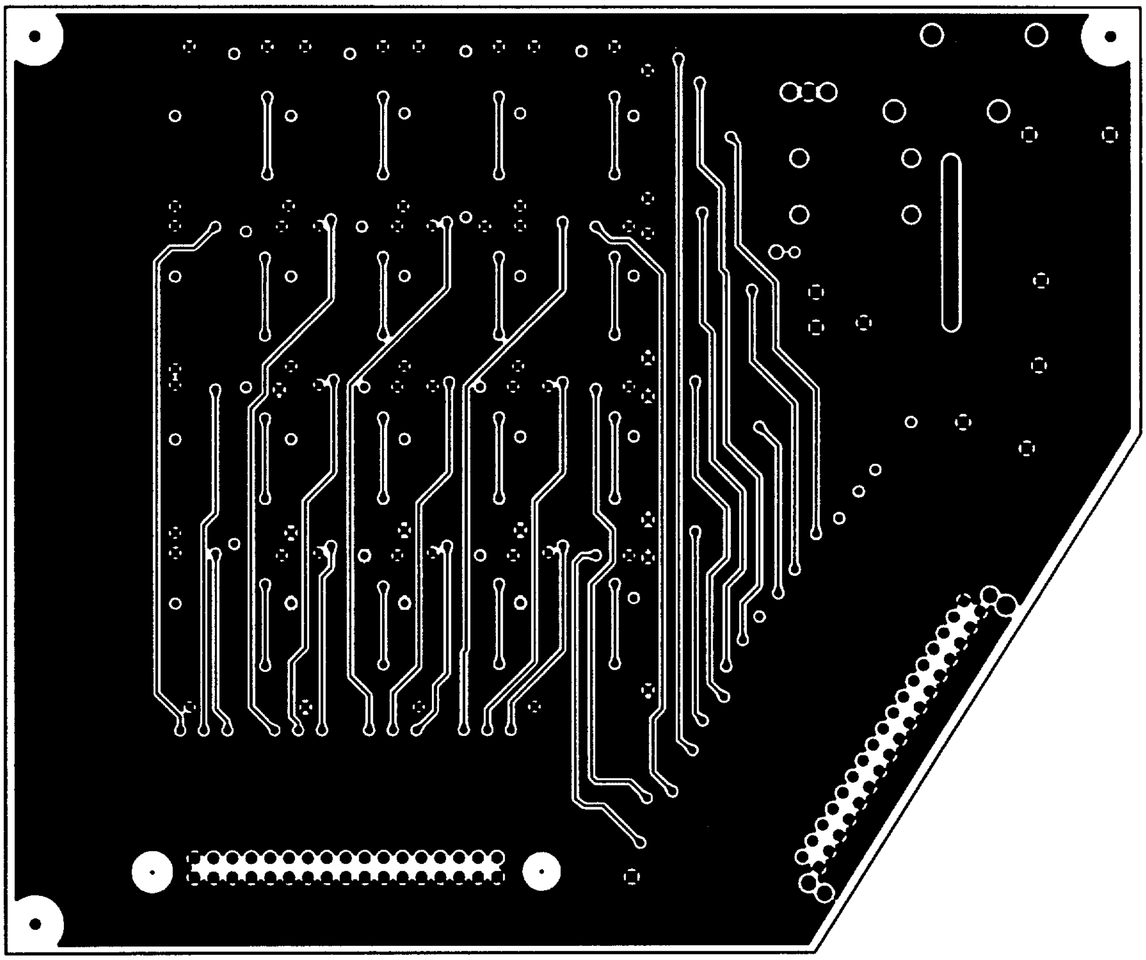


Fig. .3. Layer 2 for signals (input and output).

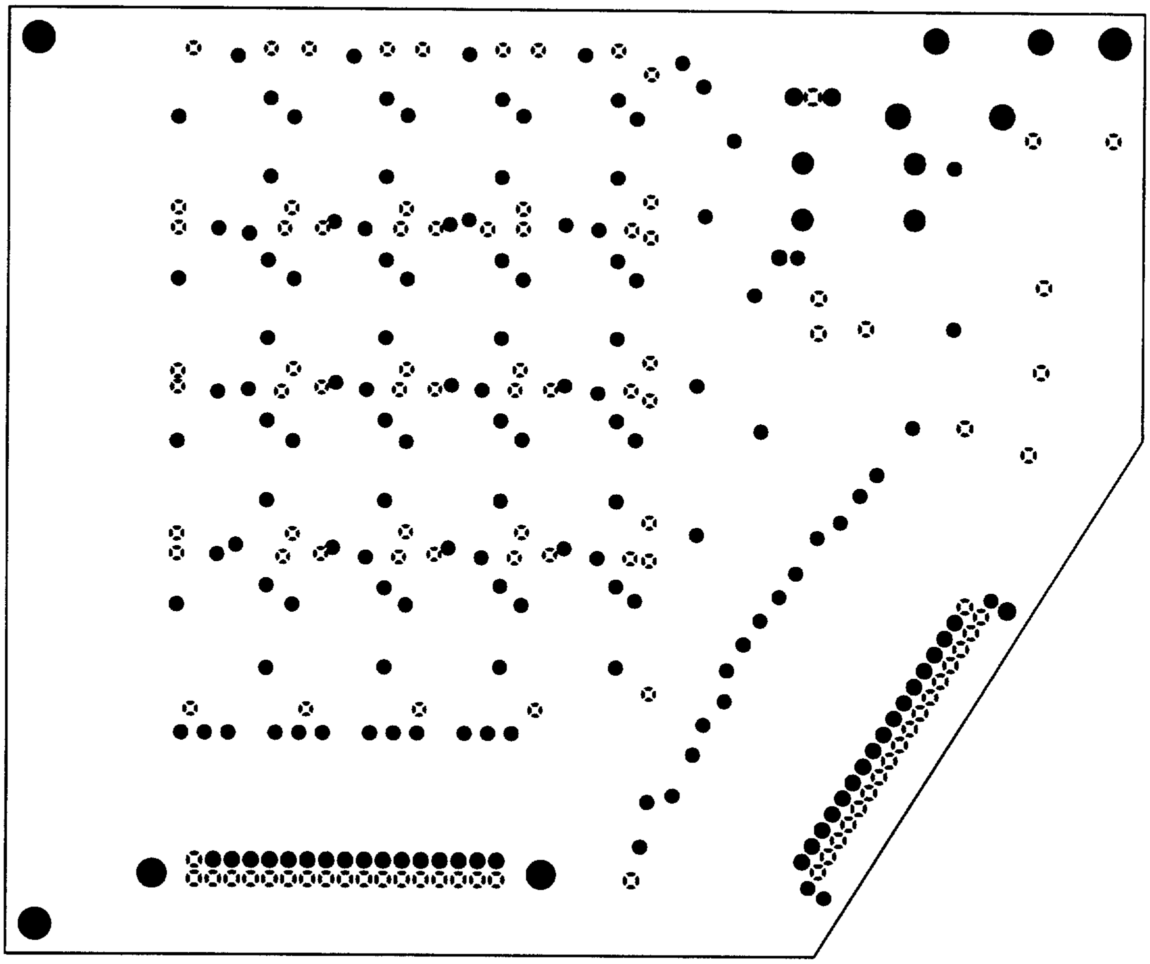


Fig. .4. Layer 3 for GND.

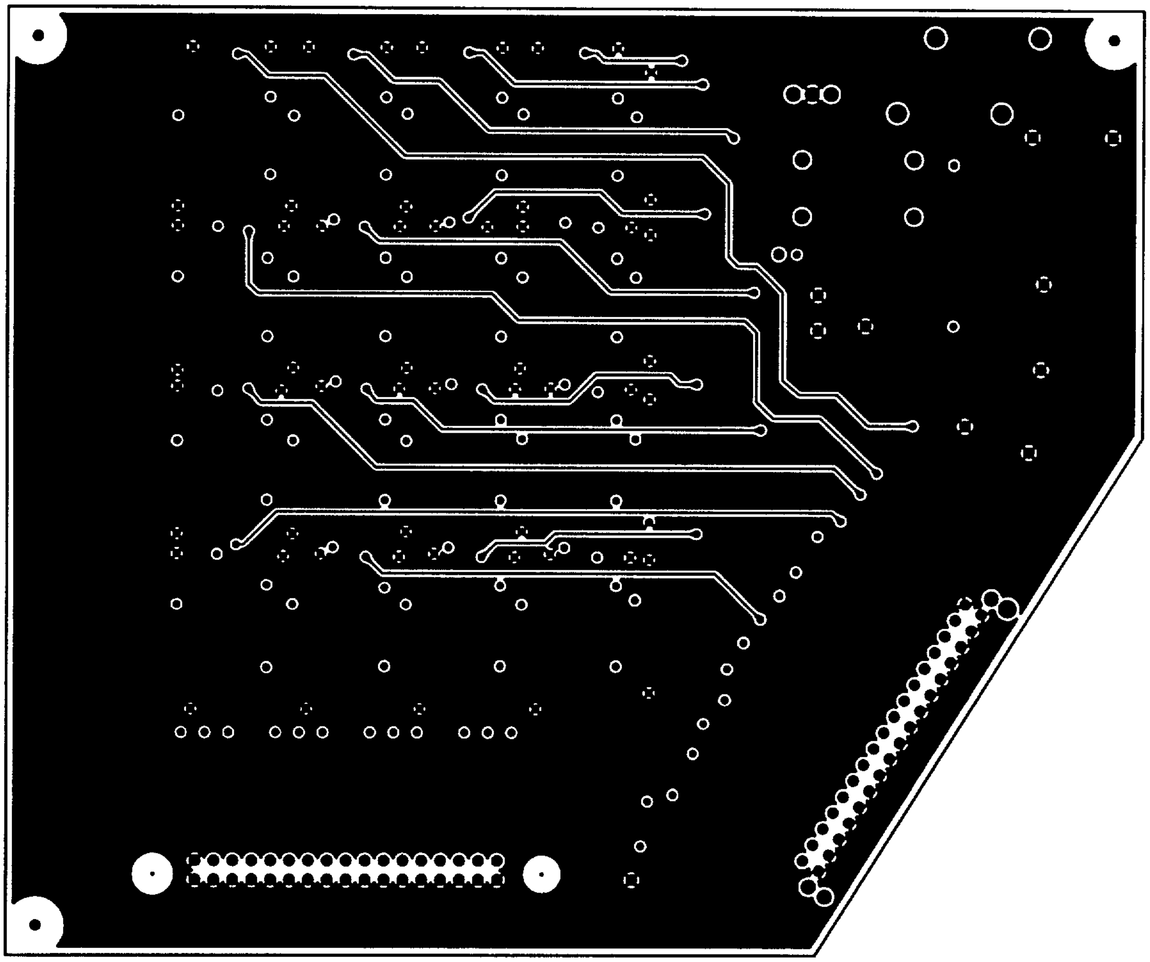


Fig. .5. Layer 4 for signals (output).

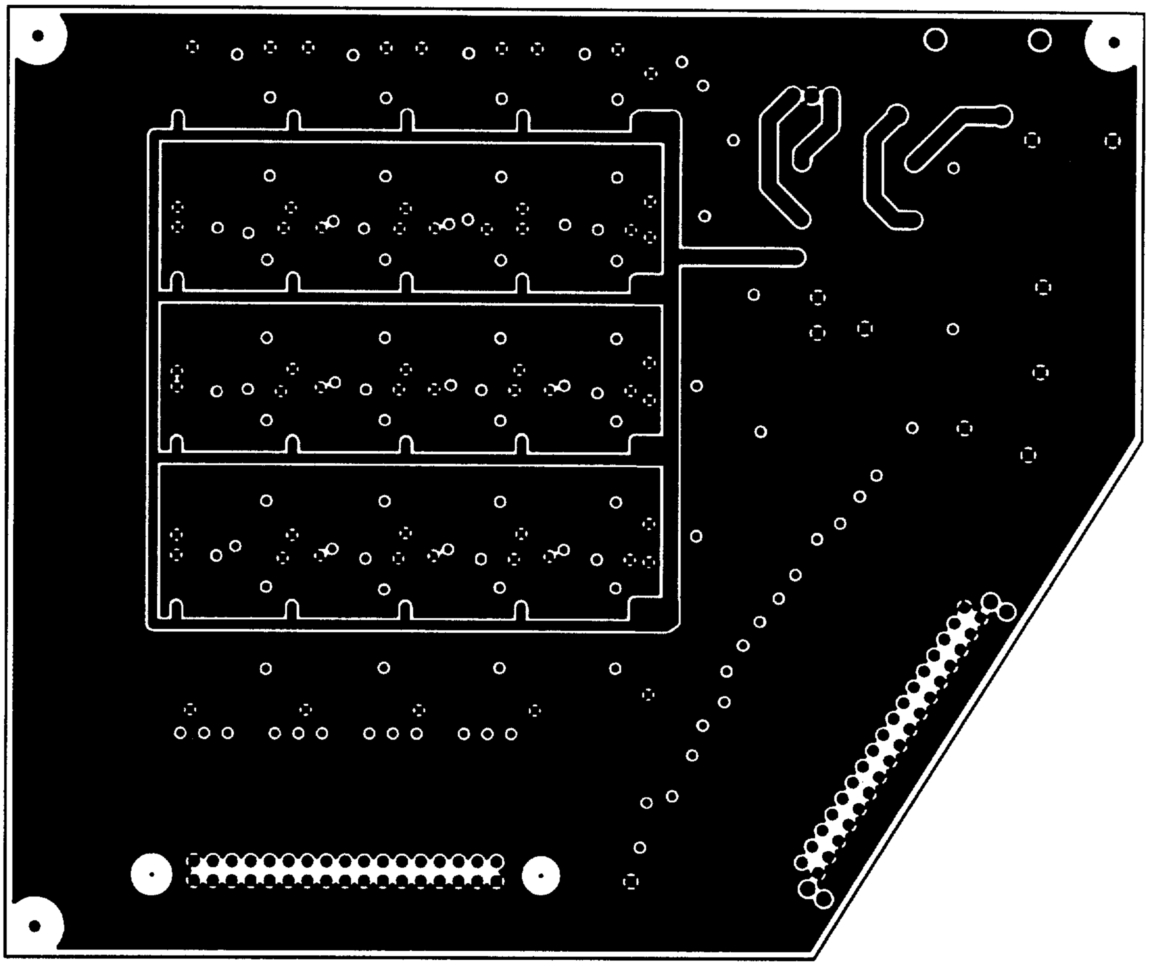


Fig. .6. Layer 5 for GND and -5V.