Fermilab

THE BELLCORD - A MULTILEVEL FAST PREPROCESSOR FOR 1024 ECL CHANNELS

TM-819
2510.000

Cordon R. Kerns
Fermi National Accelerator Laboratory*
Batavia, Illinois 60510

October 1978

Abstract

To provide a fast decision trigger on multiple tracks passing through multiwire proportional chambers, a high speed (arriving at an answer in 60 nsec) track counting system was developed at Fermilab. The circuit is capable of selecting the track multiplicities utilizing a coaxial cable "Bus" (the Bellcord) on which fast pulses are summed. Up to 16 Bellcord coax cables, each having 64 inputs, are fanned into a central "Hub" processor where the trigger level decision is made.

Introduction

The track counting system described here (see Fig. 1) was designed and built for Fermilab Experiment E272. Apparatus for charged particle detection consisted of several planes of drift chambers and multiwire proportional chambers (MWPC's) which were placed upstream and downstream of a large aperture analyzing magnet. The problem at hand, was to selectively trigger the readout system on final states which contained a specified number of charged particles. The track counting system had to arrive at an answer within 60 nsec.

Actually, two separate Bellcord systems were built to permit track counting to be done separately for the MWPC stations upstream and downstream of the analyzing magnet. This allowed for different selection criteria to be applied which took into account the deflection of the particle tracks caused by the magnet as well as the presence of additional tracks due to knock-on-electrons.

Bellcord Etymology

The electronic problem to be solved was one of detecting and enumerating a few coincident hits (1, 2, 3, 4, 5 or more) from about 1000 possible sense wire sources and arriving at the level decision within 60 nsec or less. The fast pulses necessarily involved, dictated wide bandwidth pulse techniques be used with little time for signal propagation delays, cable lengths, etc.

Why call the present solution a Bellcord? You, the reader, doubtless recall another situation where distributed signal sources (say, 64 passengers on a city bus) are all capable of making their requests for attention known to a single detector (the driver) via the bus bellcord. If the bellcord had bandwidth (a coax cable) and the requests were fast pulses introduced at many points along its length, summing could occur on the bellcord together with propagation along the cord toward the level detector. Because we wish to know just how many requests are being made simultaneously, each "request" is a standardized pulse. The pulses are added linearly to produce quantized multilevel pulses which are finally evaluated at the level detector.

Thus conceived in concept and title, the Bellcord is herein described!

System Description

Block Diagram

A simplified block diagram of the Bellcord/Hub interconnection is shown in Fig. 2. A brief overview shows the central Hub module which can have up to 16 each of the Bellcord modules radially driving it via equal delay coaxial cables. Signals from the Bellcord module are standardized in amplitude. They go to the Hub where they are summed at a single junction. Sums thus appear as pulses of discrete amplitudes of 1, 2, 3, 4, etc. depending on the number of sense wire areas involved in coincidence. It is possible that very many wires might register simultaneous hits. In this case† the Hub output decision is 5 or more.

Bellcord Module

The Bellcord electronics centers around the use of a well-matched 50 Ω coax line. In Fig. 3 the shield cover has been removed to facilitate an internal view of the mechanical construction details of the line proper. For space reasons, it is two separate coax lines constructed side by side resulting in a U shape when the ends of the individual lines are coupled with a short length of RG-58U. In normal use, a center partition shield is between the two coax center conductors. The shield is part of the cover and was removed with it.

Electrically the 50 Ω impedance of the line is maintained not only by its physical dimensions, but by allowing for the capacitance of the diodes that are tapped along the line. They become an integral part of the total capacitance ($Z_0 = \sqrt{L/C}$). A fine trimming of the L of the line was accomplished as seen in Fig. 3 by the addition of a second thin wire twisted about the center wire. Trimming was done via time domain reflectometry. The final Bellcord lines showed less than 5% impedance mismatch.

*Work supported by the U. S. Department of Energy.

†Separate output decisions of up to 5 is all the E272 experimenters asked for. Bench experiments showed that up to 20 were feasible.

Figure 4 is the schematic of the Bellcord module. Note that there are two diodes at each tap along the line. The diode with its anode grounded is normally biased on by its associated transistor collector current and thus causes the companion diode tapped on the line to be biased off. When chamber hits occur, pulses from chamber sense wire/amp combinations result in momentarily turning off the transistor collector current and permitting the tap diode to conduct. The current path of all tap diodes includes the two 50Ω terminating resistors, one at each end of the Bellcord line. In our case, we chose to set the individual diode current pulses to be 1 mA thus providing by Ohm's Law 25 mV standardized pulse heights at the terminated ends of the line.

Each of the chamber sense wires had an amplifier and discriminator; the output signals were ECL levels of 40 to 60 nsec duration. These signals were taken alternately from two staggered planes and passed pairwise through twofold AND gates as shown in the schematic. This resulted in a single input signal to the Bellcord even though two or more adjacent sense wires had collected sufficient signal from the passage of a single particle to exceed threshold. Note that the electrical length of the trimmed coax summing lines is only about 2 nsec, thus the sense wire pulses of 40 to 60 nsec duration will always overlap. Exact overlap is not required for level quantization.

The Hub

The Hub is a 16 fold, fast linear fan-in with flash encoder readout. As well as providing a common summing junction, it must provide an adequate 50Ω termination to each input line. This is accomplished as shown in Fig. 5 by making use of standard feedback techniques applied to the summing junction at the amplifier input.

In addition to terminating, summing and inverting the Bellcord pulses, a gain of two is provided by the amplifier to create a larger increment between pulse heights to be coded by the subsequent flash encoder. Tests made on the quantizing accuracy of the Hub are shown in Fig. 6. We found that the only fine adjustments necessary to trim threshold levels between our two Hub units could be provided by the current source resistors R_1 and R_2 of Fig. 5.

One concern on our part was the susceptibility of Bellcord output pulse heights to variations in the +6 volt source, q. v., Fig. 4. In order to provide automatic tracking of comparator threshold levels to just such drifts of the +6 volts, a gain of one inverting amplifier was used to make a tracking -6 volts supply to drive the comparator threshold level inputs.

Additional compensation protection against changes in the Bellcord output pulse heights due to thermal effects of the tap diodes was provided by using a similar diode at the output of the gain one inverting amplifier.

The Hub was constructed in a NIM package as shown in Fig. 7.

Performance in E272

Evaluation of the Bellcord track counting system was done on several levels. At all levels the system worked well. When triggering the experimental apparatus on mostly single tracks, a comparison was made of the number of tracks counted by the Bellcord with the number recorded by the MWPC readout system (a much slower system, naturally). A greater than 98% agreement was found. With the added requirement of a low multiplicity interaction in the target the agreement was still greater than 97%. In both cases, those events which disagreed were evenly split between the track counter being lower and higher than the readout system.

When trigger requirements were added to raise the average number of tracks to three the agreements dropped to ~90%. For most of the disagreeing events, the Bellcord counted low by one count (7% of total). Thus the Bellcord agreed well with off-line "hit" counts.

The next level of evaluation was to determine how well the number of "hits" counted agreed with the number of reconstructed tracks. With reconstructed events, one also finds good agreement. For those events with three reconstructed tracks, the upstream Bellcord counted those tracks for ~80% of the events, less than three ~10%, and more than three ~10%. These fractions are consistent with normal MWPC resolution. The finite resolution of the MWPC's tends to cause missed "hits" and production of low energy knock-on-electrons in upstream interactions produces spurious hits.

Future Work

It is planned to build at least one additional system of this design again for use in E272. Meanwhile our experience with fast multilevel systems having been quite positive, we agree with the remarks of Dao, "I've always felt that binary logic was a very inefficient way to utilize an integrated circuit... It makes much more sense to use the same pathways to send three, four or ten levels of information, rather than just two."[1,2]

With the future of multilevel logic in view, one challenge to the industry would be the construction of a well-matched, broad bandwidth, diode loaded, strip line in integrated circuit form. Such a chip, cascaded as required, could take the place of the discrete coax lines presently used in the Bellcord, doubtless with advantages in greater bandwidth and reduced size and cost. I would certainly welcome a laser-trimming approach to impedance matching, speaking from experience in trimming the discrete lines used herein.

Acknowledgments

Appreciation is due Fermilab physicists Peter Koehler and Alan Jonckheere for their encouragement. Special thanks to Bob Jones and Richard Newman who constructed the modules.

References

[1] Electronics, February 17, 1977, page 14.

[2] Electronics, October 28, 1976, page 31.

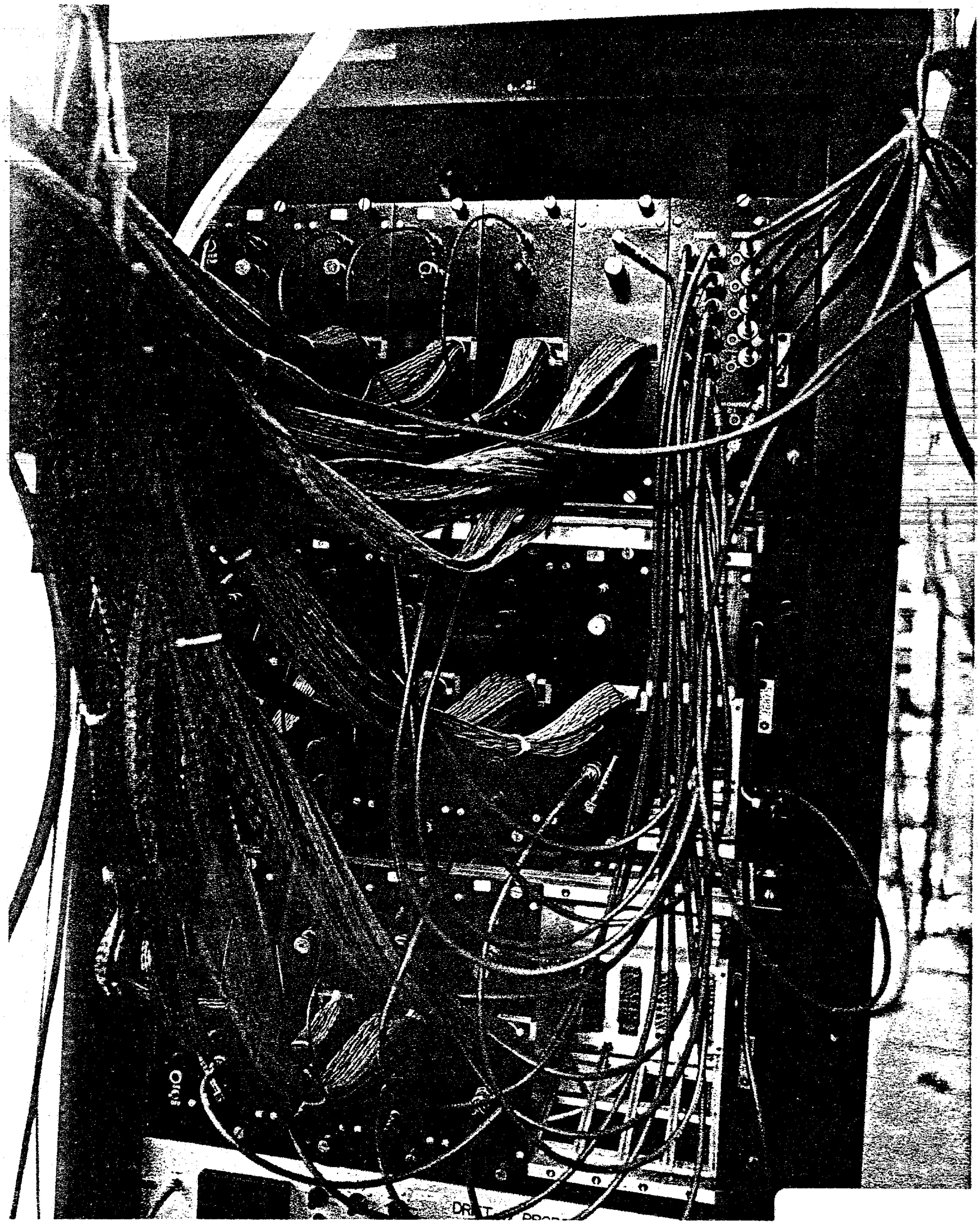


Fig. 1. Bellcord track counting system.

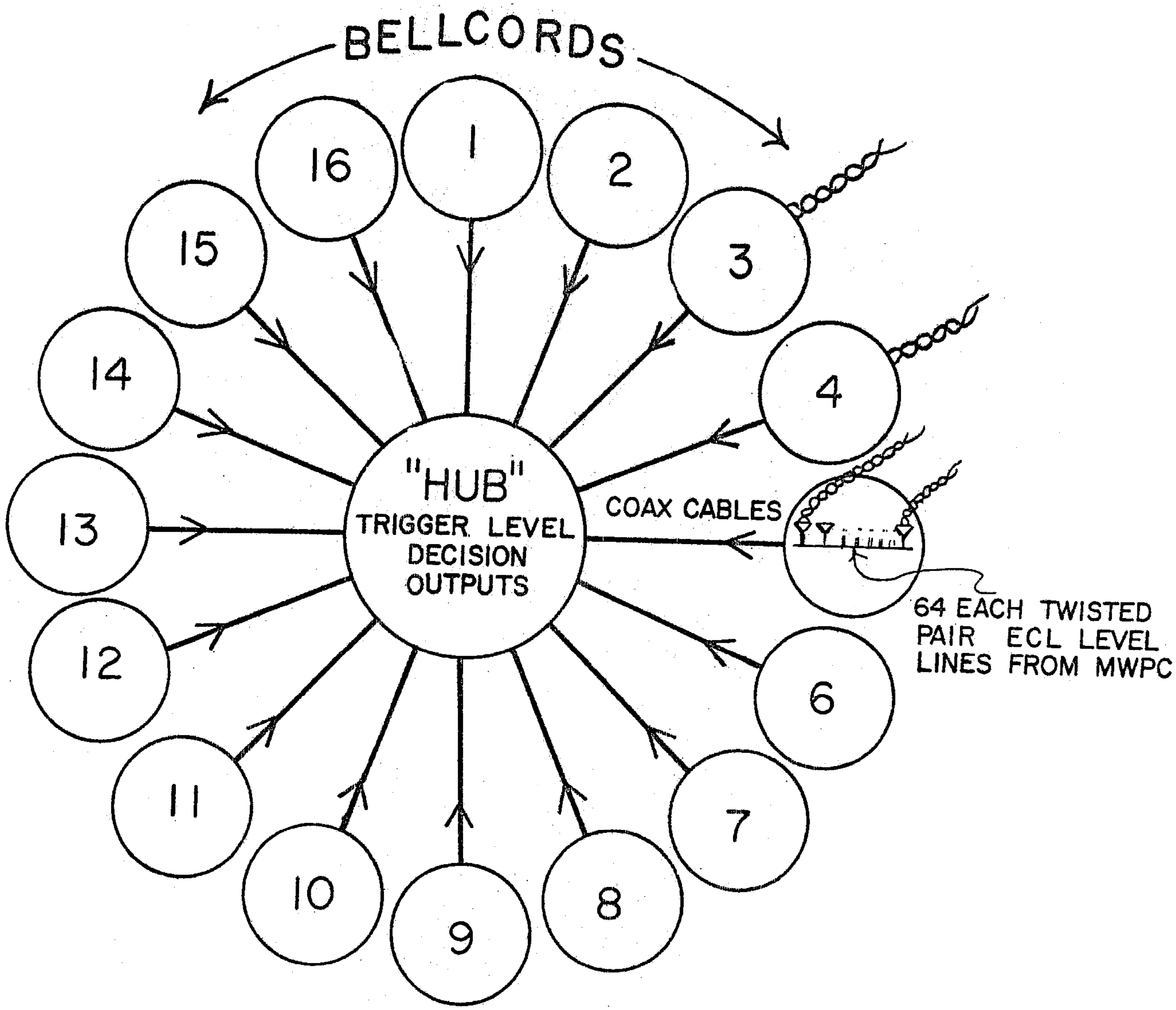


Fig. 2. Bellcord/Hub interconnections.

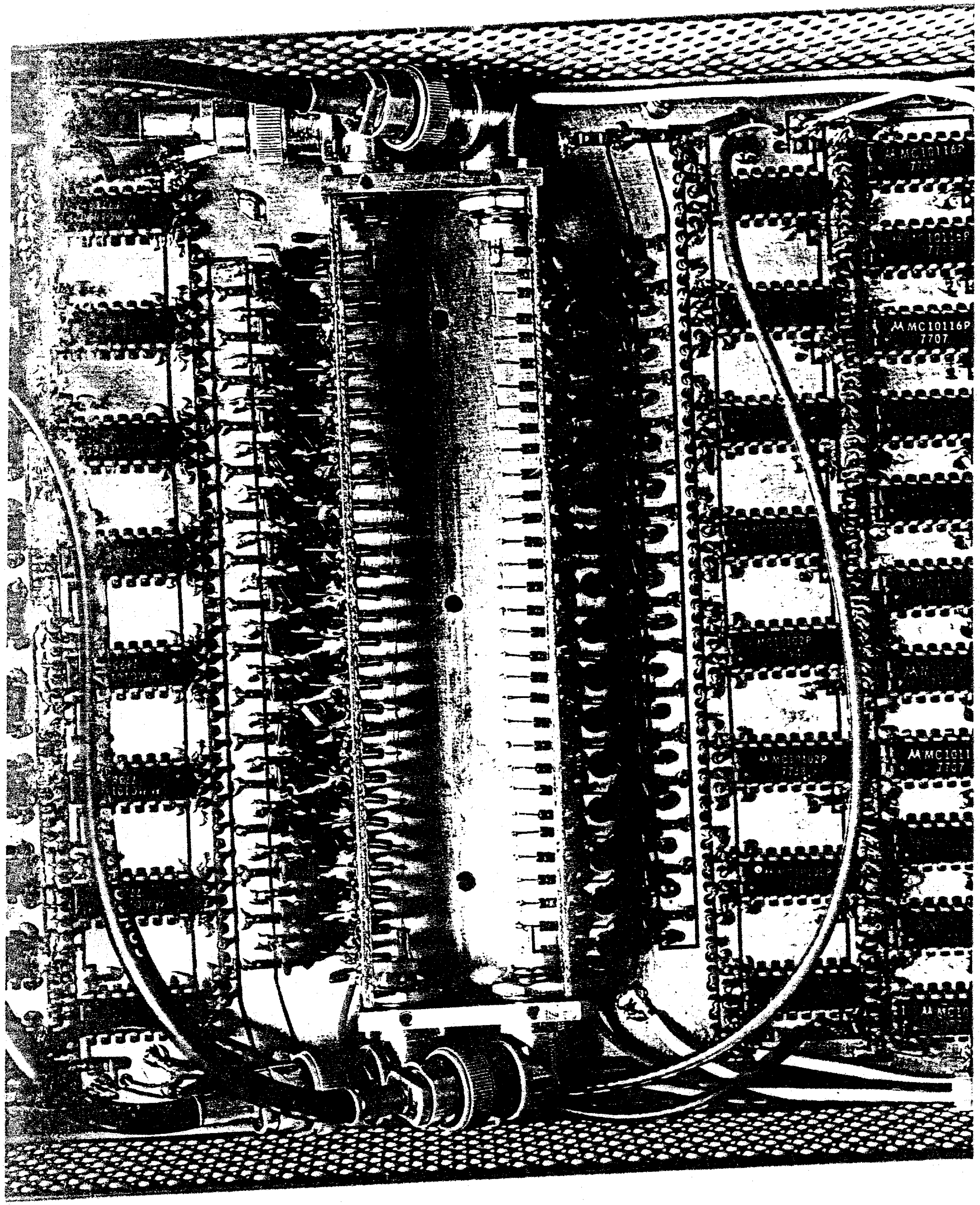


Fig. 3. Bellcord close-up view.

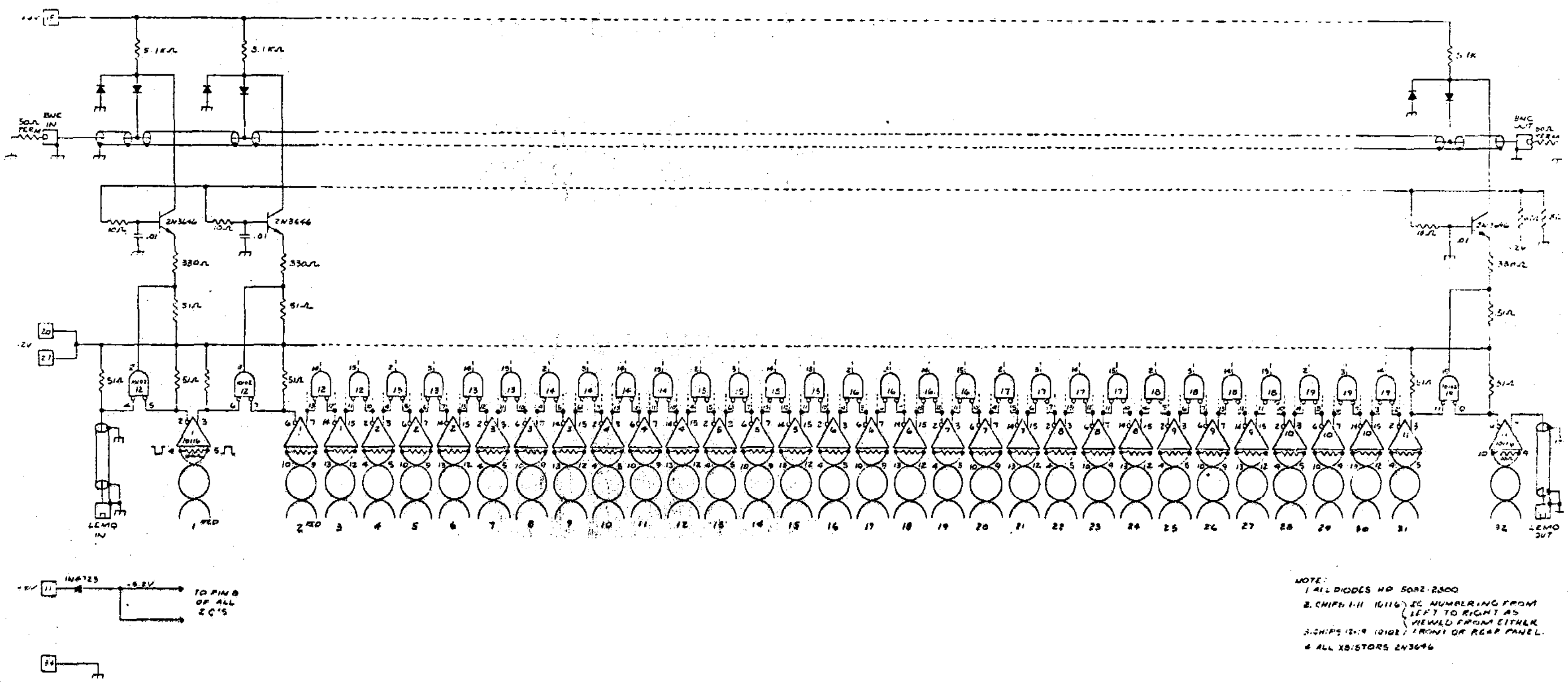


Fig. 4. Bellcord schematic.

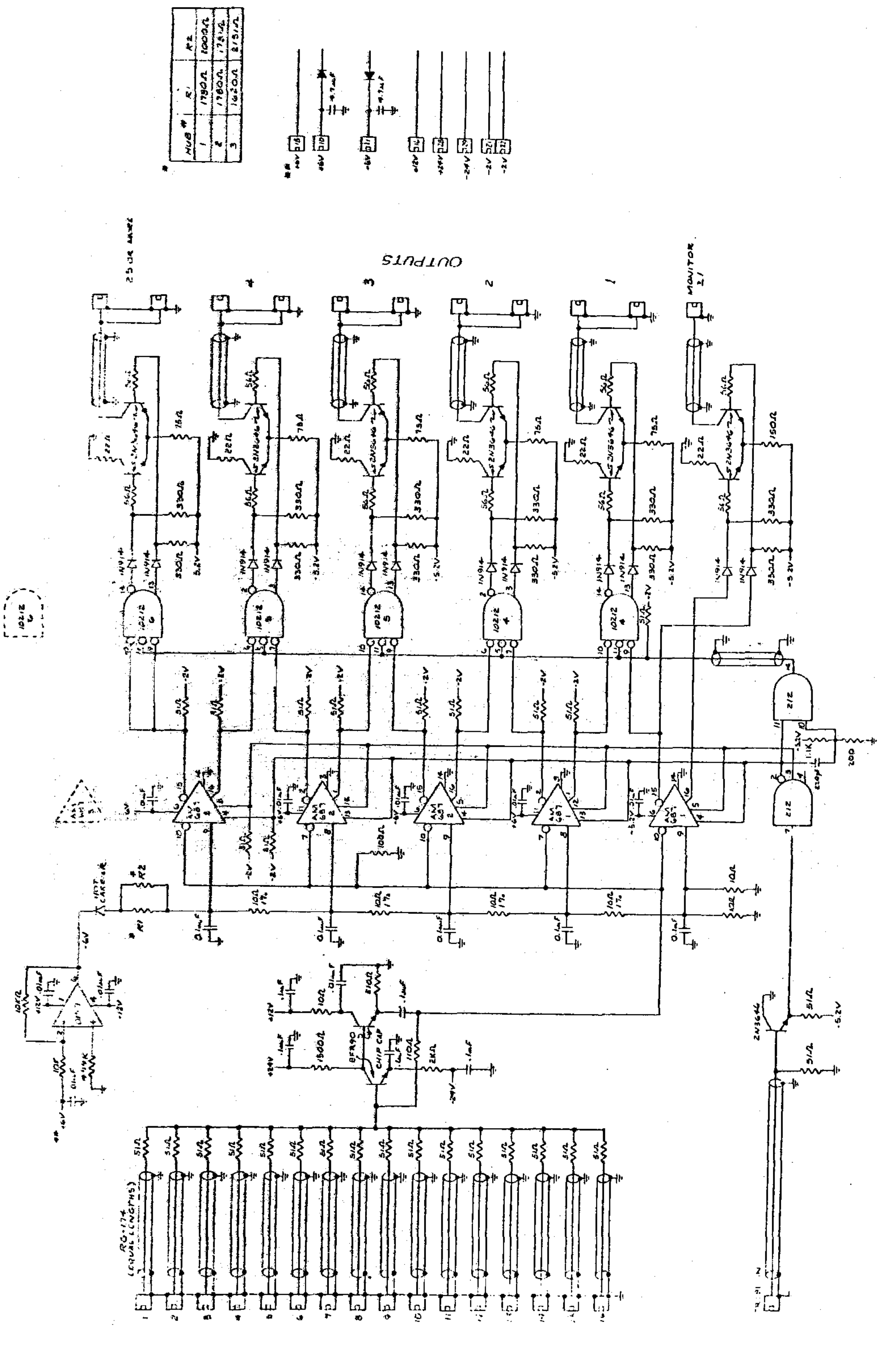


Fig. 5. Hub schematic.

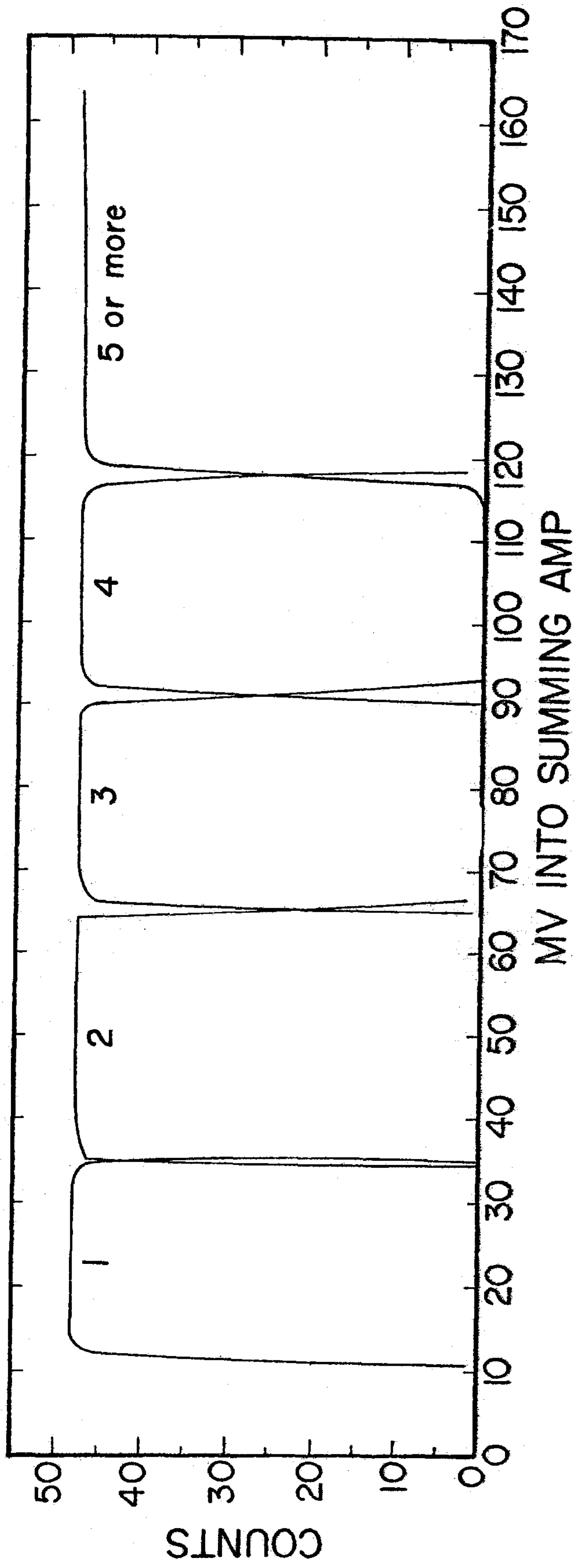
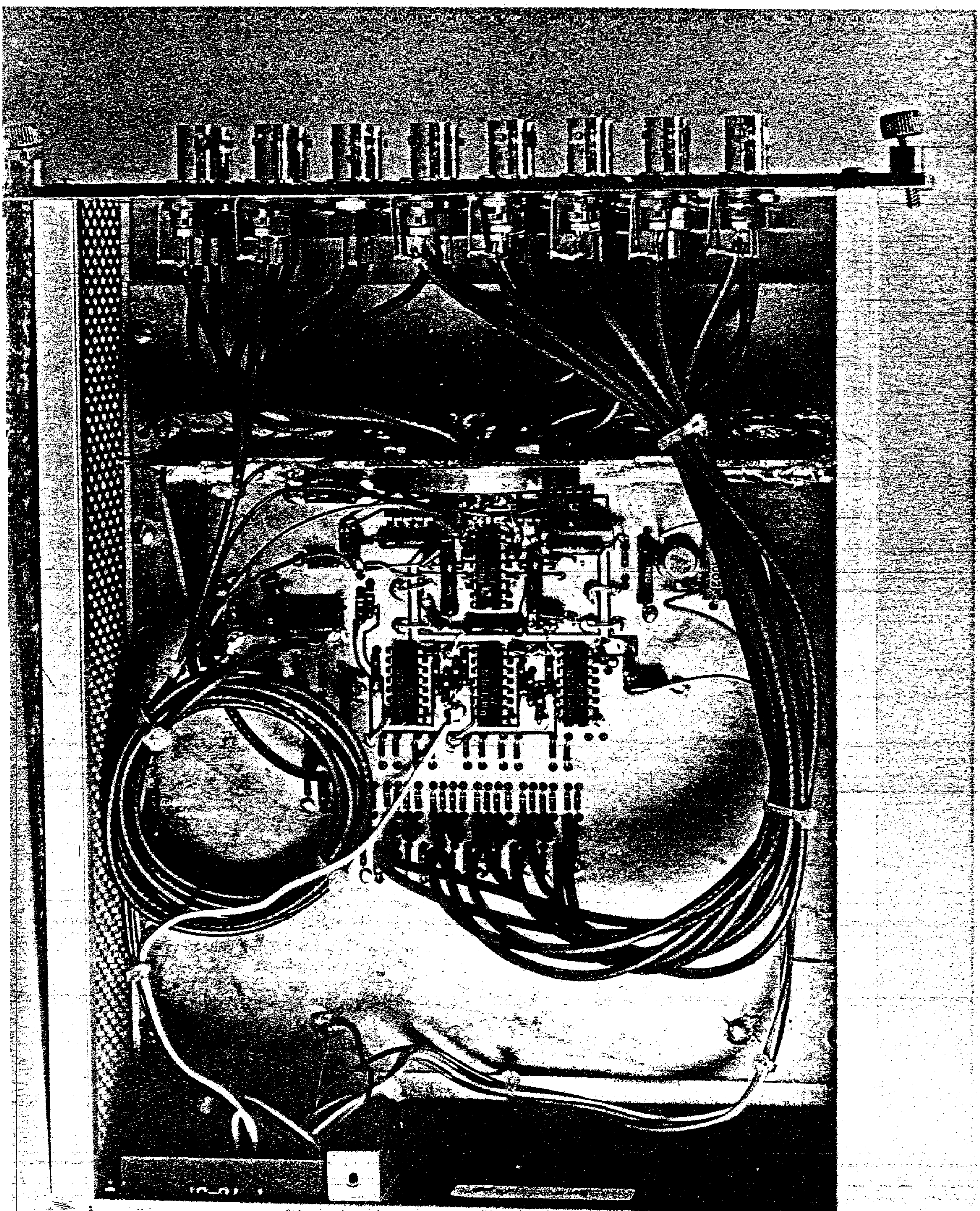


Fig. 6. Hub quantizing accuracy.



A-MP 202394-2
76-43

Fig. 7. The NIM packaged Hub.