

СООБЩЕНИЯ
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ИНСТИТУТА
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Дубна

E13-95-522

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INVESTIGATION OF THE READOUT ELECTRONICS
OF DELPHI SURROUND MUON CHAMBER

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1995

1 Introduction

According to the proposal [1] the DELPHI Surround Muon Chambers (SMC) are at present under construction. For this chambers plastic streamer tubes (PST) with the anode and strip readout are used. In this paper the detailed proposal of the design of the readout electronics is presented along with the results of prototype studies which justify our choice.

The following sections contain: recall of the construction of the SMC module, general overview and principal design of the proposed electronics, results of the prototype tests which were done and finally time scale and cost estimates for the mass production.

2 Construction of the module

SMC detector consists of 8 parts mounted at the sides, top and bottom of both Endcaps. Each part consists of two modules, and each module of two planes.

Planes have a honeycomb material as a supporting structure, on which cathode strips, tubes and ground plane are glued.

Sensitive detectors are Plastic Streamers Tubes of similar construction as those of DELPHI hadron calorimeter [2] with a few modifications:

- Low resistive graphite coating of the cathode was used.
- Open profile geometry of tubes was chosen.

There are 16 tubes in plane with lengths up to 4m. Geometrical efficiency of each plane of tubes is about 90% due to the 1mm profile walls and space between tubes in plane. Tubes in two planes are staggered. Total number of tubes is 540.

Strips have a 4cm pitch (with 1mm gap between strips) and a length of up to 1.5m. They are made of copper laminated on the kapton (connector part) and polyester (strip prolongation). Total number of strips is 2600.

The SMC detector provides space resolution of about 1 cm and single hit efficiency close to 100% both for anodes and strips.

3 Readout Electronics

The proposed readout electronics is based on the AMPLEX chip which was originally designed for multielement silicon detectors (AMPLEX16 [3]) and than modified for use with silicon calorimeters (AMPLEX-SICAL [4]).

3.1 Basic parameters of AMPLEX

Both AMPLEXes are low noise, low power consuming analog signal processors which are produced using commercial $3\mu\text{m}$ CMOS technology. Each chip contains 16 channels with charge amplifier, shaper amplifier and track-and-hold stage. The channel outputs in chip are connected to an analog multiplexer which is controlled by digital circuit.

AMPLEX16 has an adjustable 600 to 800ns peaking time, gain about $5\text{mv}/\text{fC}$ and maximal output signal of about 1.5v. The power consumption of AMPLEX16 chip is about 15mW.

In AMPLEX-SICAL peaking time is about 250ns and the output voltage swing was increased to more than 5.5v for large dynamic range of input charges up to about 4pC. In addition it has fast analog sum output and a calibration system. The power consumption of AMPLEX-SICAL chip is 100mW.

Both AMPLEX16 and AMPLEX-SICAL are well suited for their original applications in silicon detectors providing very good signal to noise processing. They also fit very well modern readout architectures which could work with high ¹ input rates. However, for the use with wire chambers operating in streamer or proportional mode the input charge range of AMPLEX should be adapted.

When operating in streamer mode with $\text{Ar} : i\text{C}_4\text{H}_{10} : \text{CO}_2(1 : 3 : 6)$ gas mixture the SMC detector provides an average charge on anode wire of about 40pC and of about 10pC on strips. At lower voltage in proportional mode these numbers are roughly an order of magnitude less. Operation in proportional mode increases the signal to noise ratio but certainly has an advantage of more quit running of the detector, increasing detector life time etc.

¹For example, system with AMPLEX16 could be sensitive to a new event within $1\mu\text{s}$ after a negative trigger decision. This feature is important taking into account plans to run LEP with larger number of bunches.

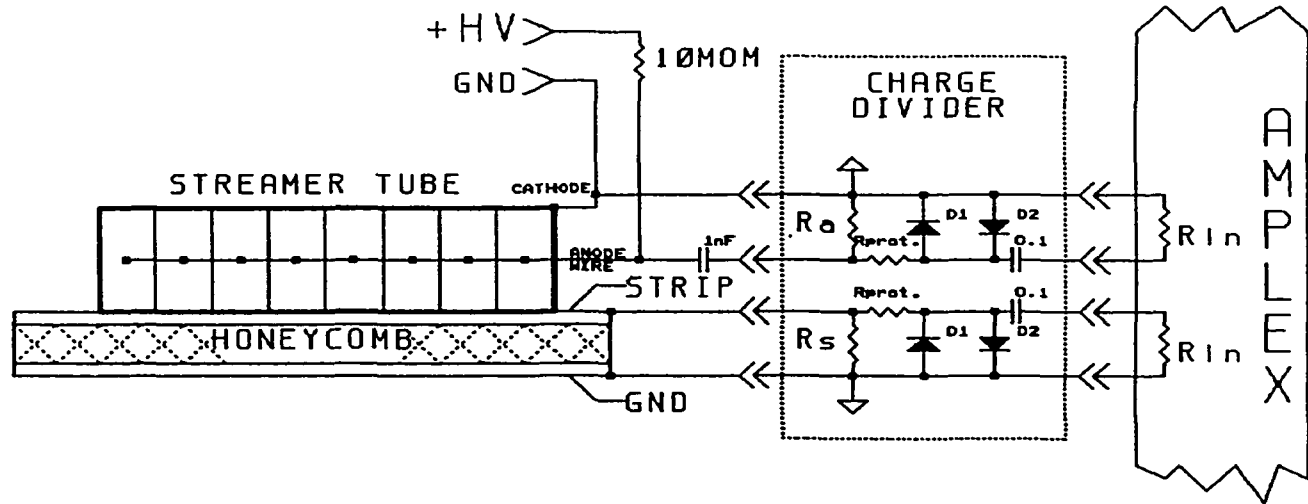


Fig.1. Scheme of Input Card connection to the detector.

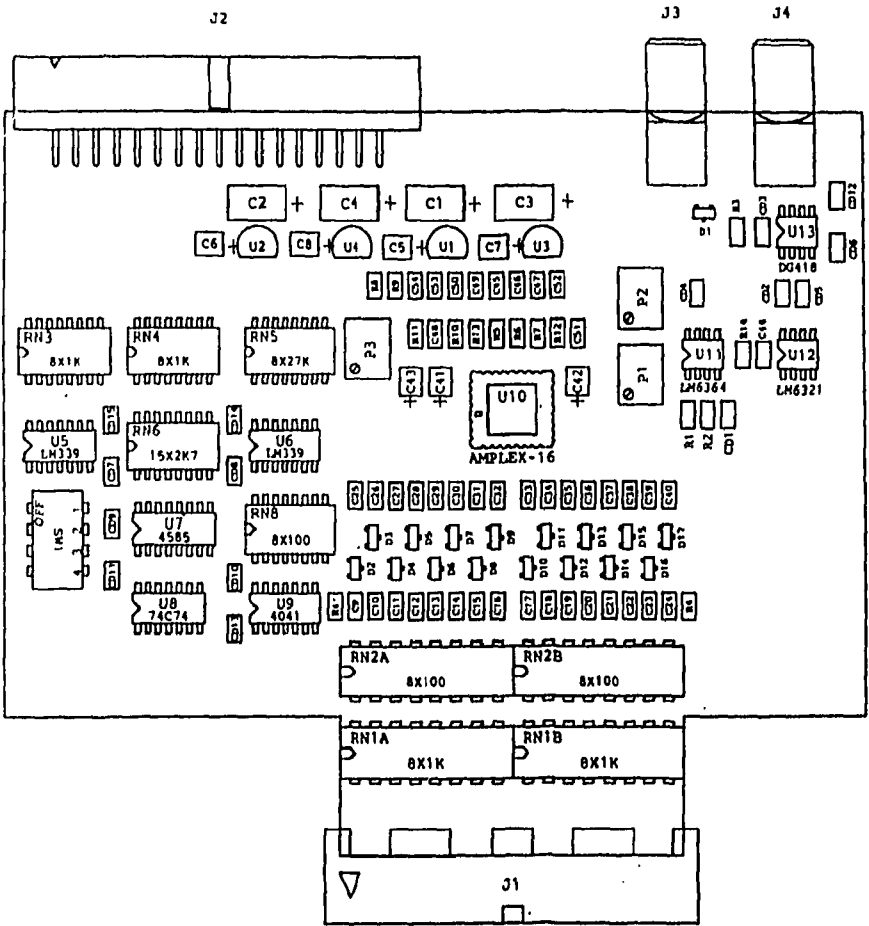


Fig.2. Input Card component side.

3.2 Input card and readout scheme

Input card ² containing 16 channels (1 AMPLEX chip) is placed on the detector and is directly, without cables, connected to the strips (or wires). This is schematically shown on fig.1. The size of Input Card is about $90 * 110mm^2$. Layout of components is shown on fig.2.

Input Card contains charge dividers R_s/R_{in} (or R_a/R_{in}) which translate signals from detector strips (or anodes) to the input charge range of AMPLEX. The range could be tuned by changing these resistors which are installed on the card in sockets. Input Card contains also diode protection and AC coupling input to AMPLEX. The block-scheme of the Input Card is shown on fig.3. Fragments of the principal scheme are shown on fig.4a-c.

Input Cards are connected in series by coaxial output line and by 17 twisted pairs flat cable bus containing power and control lines. Internal regulators on the card provide stable voltage from power lines. Control signals are:

- Trigger to initiate charge holding
- Start Readout
- Address to select Input Card
- Clock to control multiplexing
- Clear to reset analog multiplexor

Output analog signals of AMPLEX are transmitted via coaxial output line to digitizer situated in the readout crate. Power consumption of one Input Card is 420mW.

General block-scheme of SMC readout is presented on fig.5. There are 2 readout crates (1 per Endcap) in the system. The units in the crate perform also functions of control, zero suppression and interface to the memory in FASTBUS. For operation of the control units WNG_{BCO} , $T2_{YES}$ and $T1_{NO}$ timing signals from PANDORA are used.

²The name Current to Voltage Converter (CVC) is also used for Input Card in the following text and figures

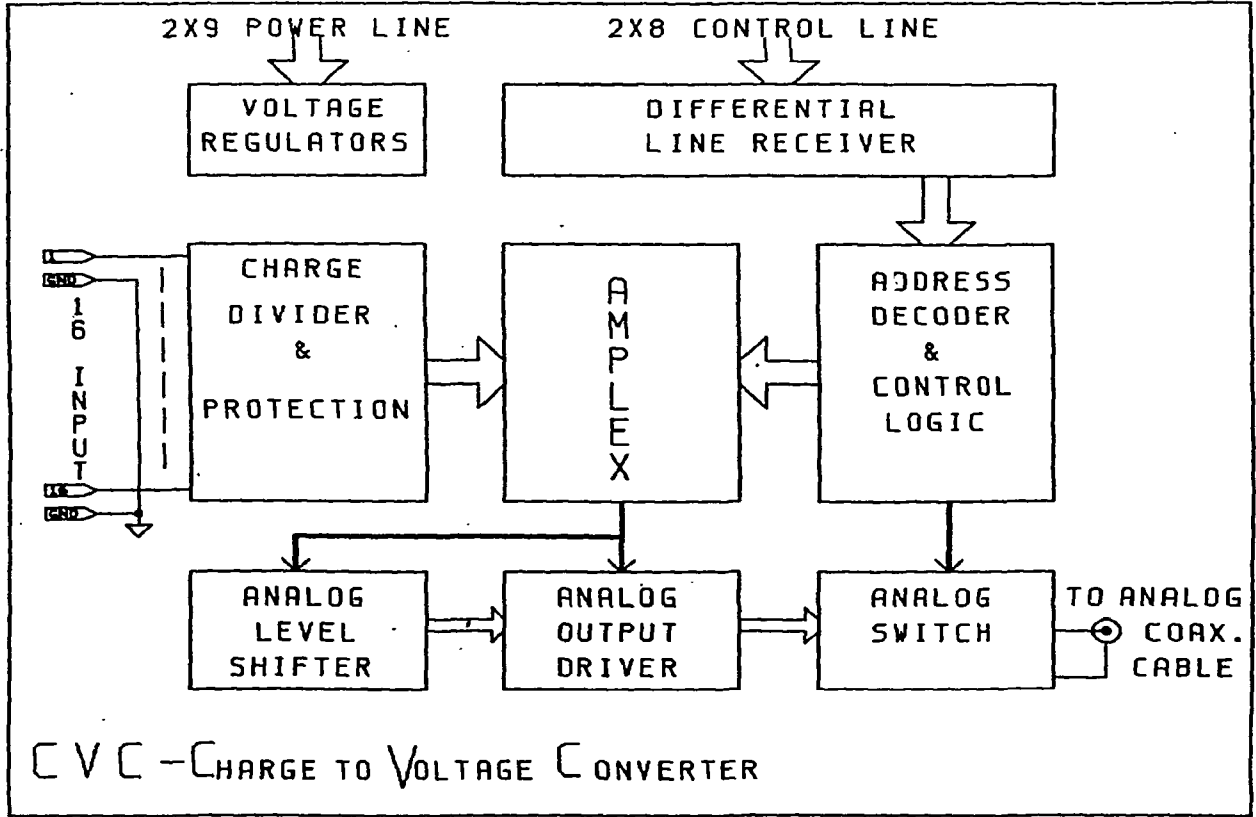


Table.1. Cost estimate

Item	Price (SFr)
PCB film design	3000.
PCB pilot	1000.
Total	4000.
Input Card	
PCB manufacturing	20.
Montage	25.
Components:	
AMPLEX	100.0
LM339	3x 0.50
74HCT74	1.25
Diode BAV99	21x 0.10
Diode BAV23	3x 0.10
CD4041	0.55
CD4585	0.50
Resistors	100x 0.015
Capacitors	60x 0.07
Capacitors	6x 0.50
LM6364	4.18
LM6321	4.02
DG418	2.75
LM607(OP7)	1.95
Connector LEMO	2x 3.37
Flat cable connector	2x 2.50
	184.59
Total for 250 Cards	46.2 KSF
Cables and Connectors	3000.
Controllers	2x 1000.
Crates	2x 1500.
Total	8 KSF
Grand total	58.2 KSF

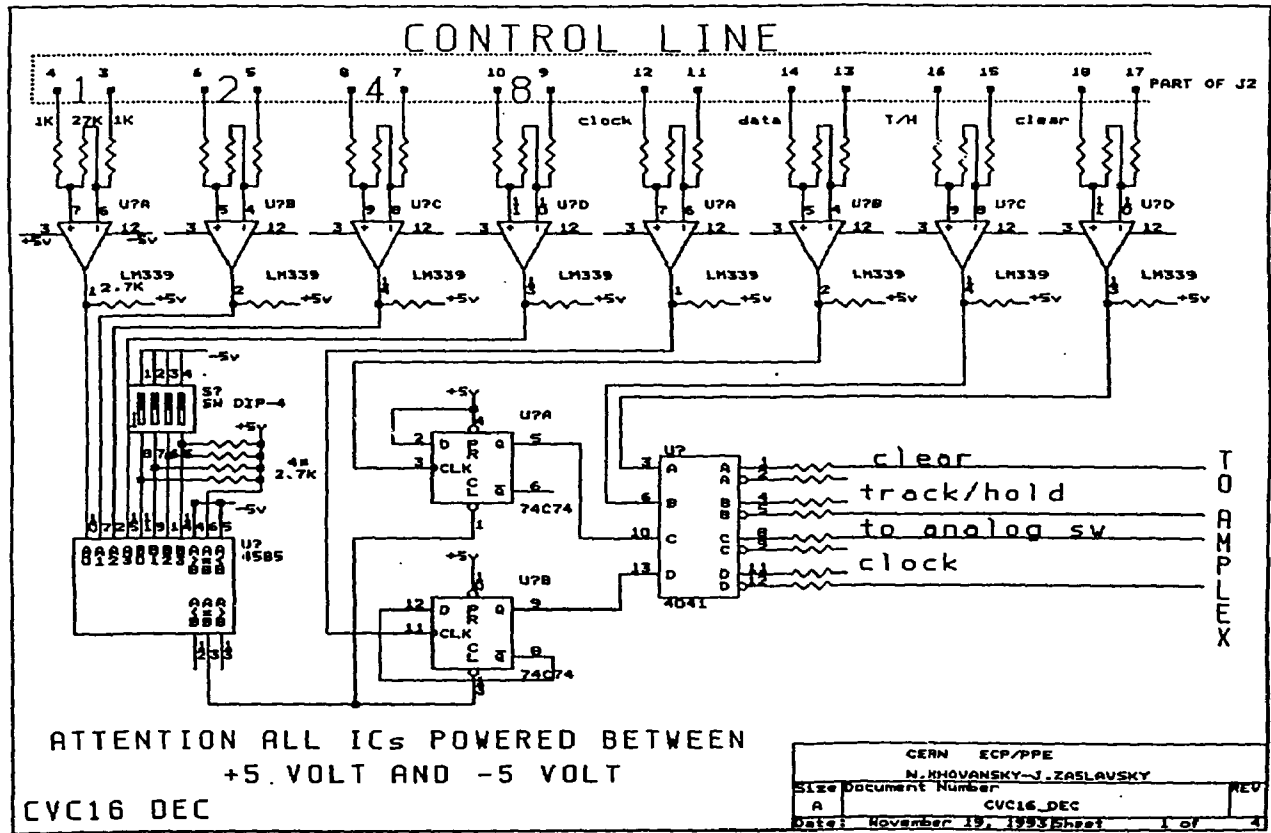


Fig.4. a)

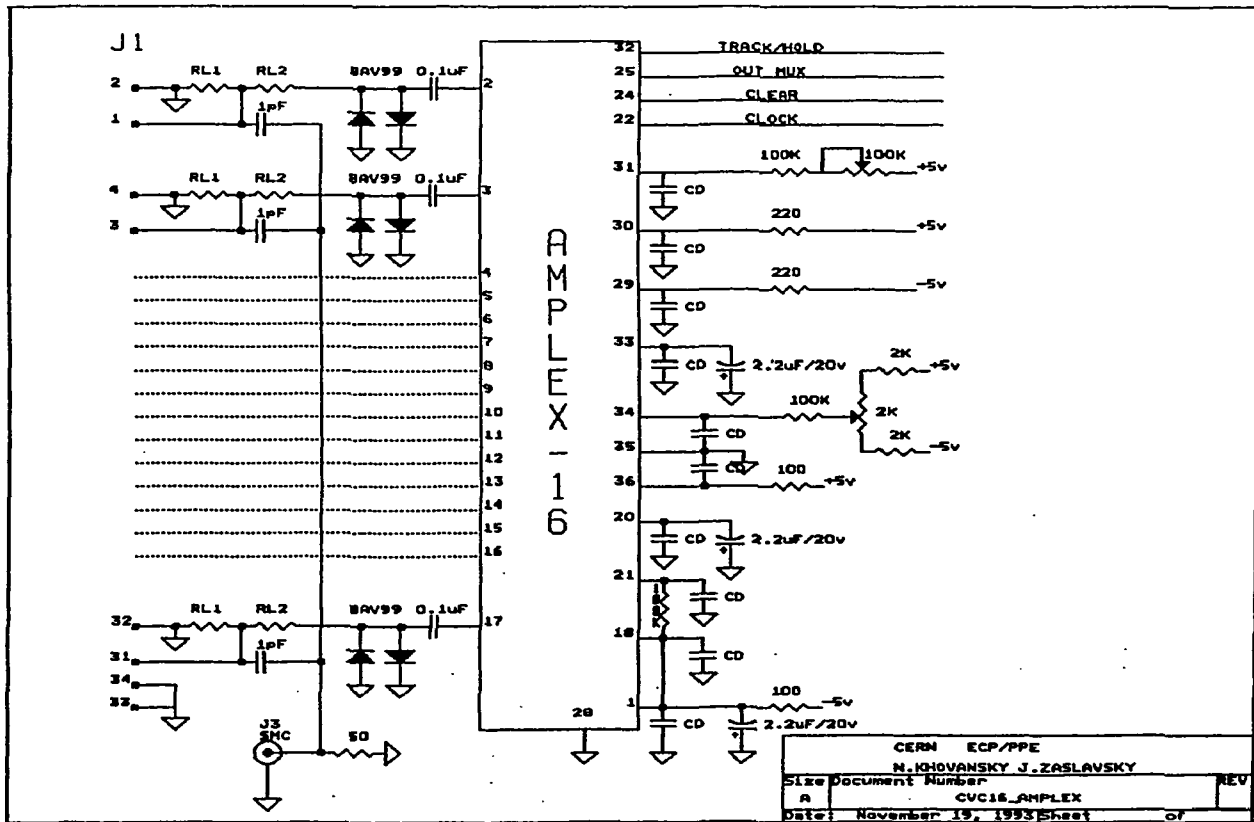
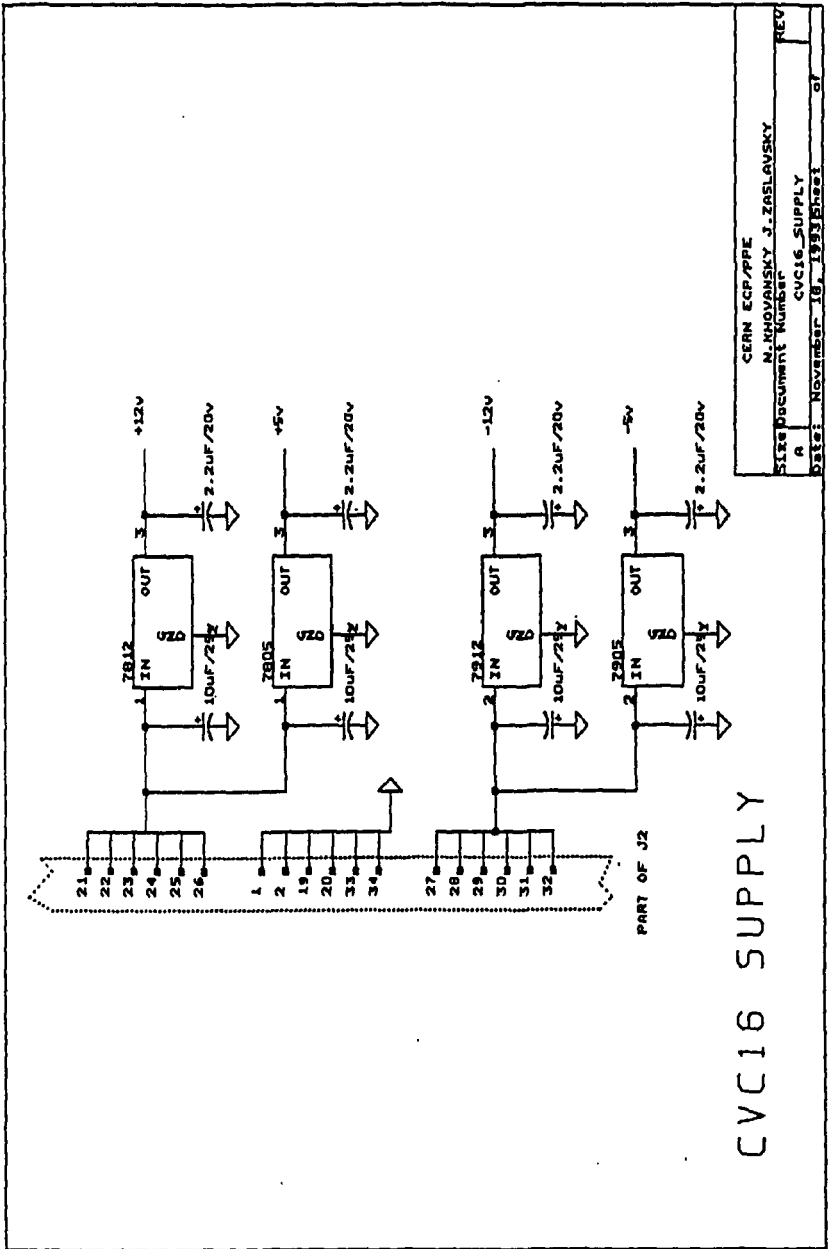


Fig.4. b)



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Fig.4.c)

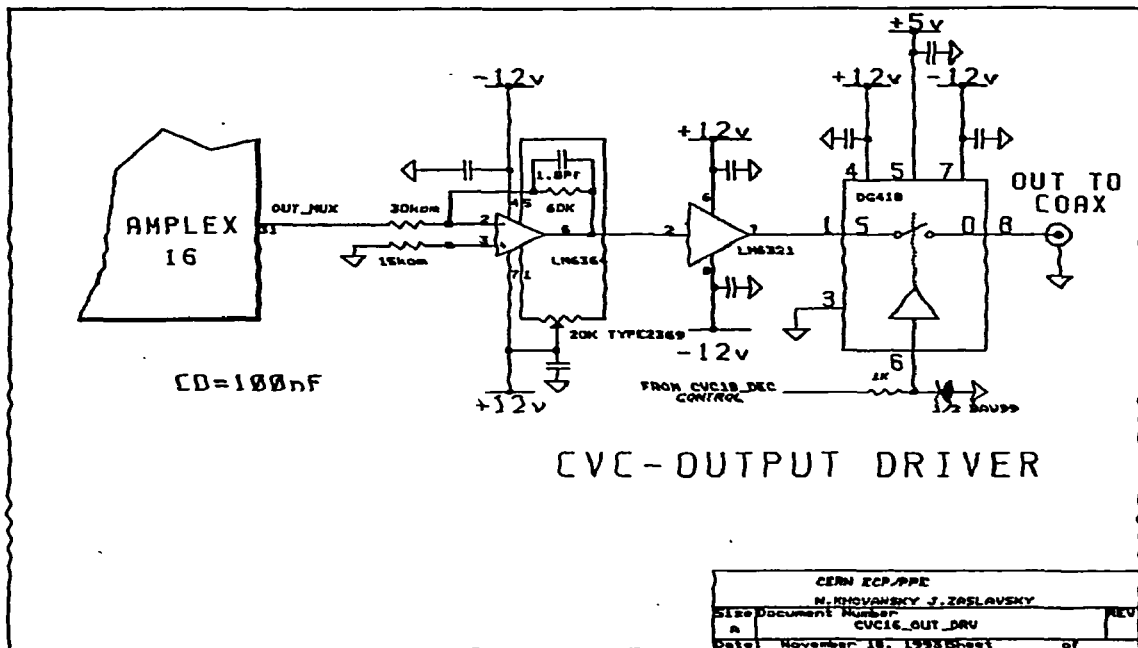


Fig.4.d)

Fig.4. Fragments of principal scheme:

- a) Line receiver, address decoder and control logic
- b) AMPLIX part
- c) Voltage regulators
- d) Output driver

4 Prototype tests

Performance of the proposed electronics was studied in cosmic rays tests of SMC modules which were prepared for installation in the DELPHI pit.

Tests were performed with the real gas mixture to be used in the pit $Ar : iC_4H_{10} : CO_2(1 : 3 : 6)$.

Coincidence of signals from two scintillating counters triggers holding of the amplitudes and multiplexing readout via one output line to the 10 bit ADC in CAMAC.

Two prototype cards one with AMPLEX16 and another with AMPLEX-SICAL were in the readout chain. They were connected to the strips of inner and outer plane of the detector.

To study the noise conditions a run from random trigger was done showing that the r.m.s. of pedestals is about 1-2 ADC channels. The noise situation in the DELPHI pit on the SMC module installed on side A was found to be similar to the one in the test area.

Data were recorded with the detector operating at 4200V (streamer mode) and at 3700V (proportional mode). Finally, the detector was purged with CO_2 and the data were taken at 4100V (again in proportional mode).

Simple procedure to analyze the recorded data was used. Namely, search for maximal amplitude was performed in each plane. The spectra of maximal amplitudes obtained for AMPLEX16 and AMPLEX-SICAL in a different conditions are presented on fig.6. To estimate efficiency a cut of 20 ADC channels (well above pedestal variation) was applied. It resulted in the efficiency $> 92\%$ for each plane which corresponds to the geometrical efficiency of the detectors. Since tubes in two planes are staggered the single hit efficiency of the whole module is high. Indeed, it was found to be $> 99\%$.

Obtained results of the prototype test proved that the proposed electronics could be used for the SMC detector. Since both of AMPLEX modifications give similar results the choice of AMPLEX16 was done on the basis of availability in time.

5 Time scale and Cost

Cost estimates are presented in Table.1. They include PCB layout and pilot production, the cost of components, cables, crates and manufacturing of the electronics.

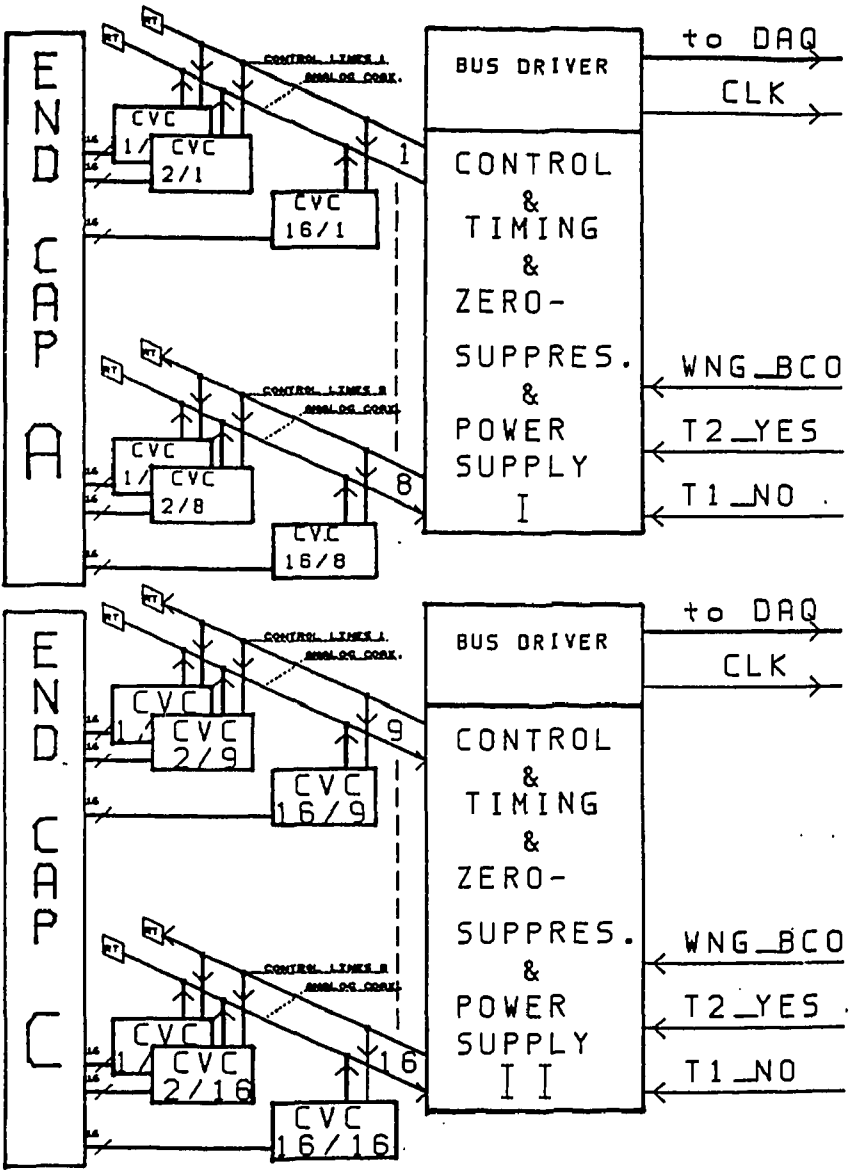


Fig.5. General block-scheme of SMC readout.

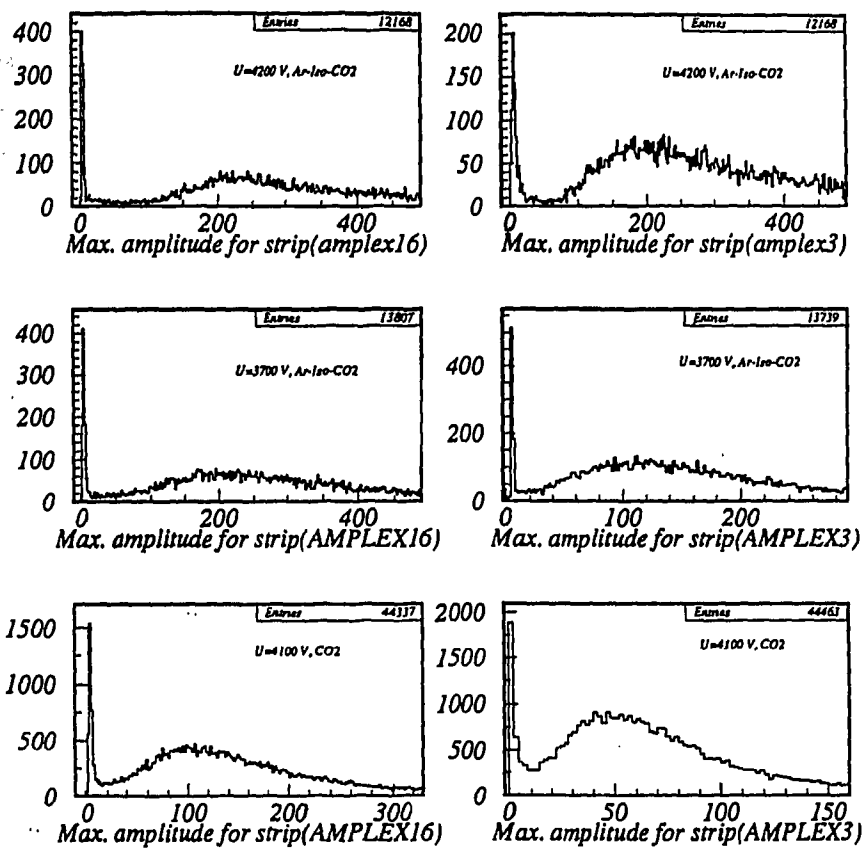


Fig.6. Spectra of maximal amplitude in event.

We have studied manufacturing possibilities and delivery time for different components (including AMPLEX). This study shows that proposed electronics could be produced in 6 months.

6 Acknowledgements

The authors wish to acknowledge E.H.M.Hejne and P.Jarron for their valuable consultations and R.Grabit for his constant assistance. We are grateful to H.Herr, J.M.Maugain and A.M.Wetherell for their interest and support and to all colleagues who participated in discussions of the design and tests at different stages.

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- [1] DELPHI Collaboration, DELPHI 92-139 Track 71
- [2] P.Aarino et. al., NIM A303(1991)233.
- [3] E.Beuville et al., NIM A288(1990)157.
- [4] E.Beuville et al., IEEE Trans. Nuclear Science, v.39(1992)766

Received by Publishing Department
on December 21, 1995.

Принимается подписка на препринты, сообщения Объединенного института ядерных исследований и «Краткие сообщения ОИЯИ».

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E13-95-522

Исследование считывающей электроники для дополнительных мюонных камер установки ДЕЛФИ

В работе представлены характеристики считывающей электроники дополнительных мюонных камер установки ДЕЛФИ с различными микросхемами типа АМПЛЕКС (АМПЛЕКС16 и АМПЛЕКС-СИКАЛ). Исследования проводились на реальном модуле дополнительных мюонных камер с использованием космических мюонов.

Работа выполнена в Лаборатории высоких энергий и Лаборатории ядерных проблем ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1995

Khovansky N. et al.

E13-95-522

Investigation of the Readout Electronics of DELPHI Surround Muon Chamber

The characteristics of the readout electronics of the DELPHI surround muon chambers with various AMPLEX chips (AMPLEX16 and AMPLEX-SICAL) are presented. This electronics is studied in a cosmic rays test of the real surround muon chamber module.

The investigation has been performed at the Laboratory of High Energies and Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1995

Макет Т.Е.Попеко

Подписано в печать 22.02.96

Формат 60 × 90/16. Офсетная печать. Уч.-изд.листов 1,71

Тираж 370. Заказ 48898. Цена 1026 р.

Издательский отдел Объединенного института ядерных исследований
Дубна Московской области