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ABSTRACT

We describe a remotely controlled power supply multichannel system delivering a current of 200 μA per channel up to 5.5 KV, and allowing voltage setting as well as current monitoring. The system is presently used in the charmed meson photoproduction experiment (NA1) at SPS, CERN.

The novel characteristics of the system are : 16 independent channels, under remote control of a standard CAMAC - minicomputer interface, and a console that allows the manual control and read-out of a maximum of 16 systems. This system can usefully replace the conventional power supplies, eliminating high voltage distribution encumbrance and often several kilometers of high voltage cables.

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1. - INTRODUCTION

In recent years high energy experimental apparata have dramatically grown, requesting hundreds of devices like plastic scintillators, drift and proportional chambers, strewed in a large area, to be controlled periodically at great distances. As size of experiments enlarges, it becomes increasingly important to check the detector status, frequently with an automatic computer control during data taking. The first stage of this on-line check is to supply and control automatically and remotely the high voltage of the detectors and to monitor the instantaneous current. During the preparation of the apparatus for NA1 experiment running at 400 GeV SPS accelerator at CERN to study charmed meson photoproduction(1), a new approach has been adopted to provide and control all voltages requested by the detectors. Our apparatus consists of a forward spectrometer for momentum measurement of charged particles emitted in a narrow cone ($\theta \leq 7°$) and of a Vertex Detector for energy and direction measurement of charged and neutral particles emitted at larger angle. The Vertex Detector comprises four cylindrical MWPCs(2) sorrounding the target, a set of fourteen drift chambers, two plane MWPCs and a hodoscope shower detector consisting of 1500 sensitive elements seen by 500 photomultipliers. The system used to supply all detectors has the following innovative approach: high voltage generators are located as near as possible to the experimental set-up in slave stations which can be remotely controlled by a suitable interface via CAMAC. Data transmission is performed in serial format, allowing a small number of low voltage cables to provide the link between CAMAC and H.V. generators. This solution ensures a permanent control reducing also the number of high voltage cables.

In the following we describe the "FRAM 76 System" we designed and built in the Laboratori Nazionali di Frascati, INFN, to provide the negative high voltage at low current needed to supply the multiwire and drift chamber of the Vertex Detector. FRAM 76 consists mainly of 16-independently-controlled H.V. generators adjustable from -0.5 to -5.5 KV and capable of supplying up to 200 μA to the chambers with adjustable current limitation. The device operates in two modes: by on line computer control (via CAMAC) or by means of a manual console handling up to 16 system (a total of 256 channels). The system is organized to guard the detectors against power failure and computer errors.

2. - OVERALL DESCRIPTION

The functional elements of the system, whose logical diagram is shown in Fig. 1, are four negative Quad High Voltage Modules (QHVM), a Multichannel Conversion System (MCS), a Remote Control Unit (RCU), a Master Control Unit (MCU) and a Manual Console (MC).

High Voltage Modules, MCU and RCU modules are linked and powered together in a crate (Fig. 2) conforming to mechanical standard of CAMAC, where the dataway has been replaced by a suitably designed bus. This crate is located near the apparatus in the experimental room. Four low voltage coaxial cables link the RCU to the MCU which is a CAMAC conforming device plugged in a standard CAMAC branch in the control room. The QHVM's are slave both of RCU and the MCS; the former receives commands from MCU to control QHVM; the latter provides a suitably multiplexed Digital to Analog and Analog to Digital interface via CAMAC. It also links the Manual Console which permits to use the system without computer. All the programmable MCU functions (and other in addition) can be performed with the Manual Console which can be daisy-chained to a maximum of 16 MCU units by means of two rotary switches. Transmission from MCU to RCU is accomplished in an asynchronous mode at a maximum rate of 40 Kbytes/second. The byte has a constant lenght of 15 bits with a main clock frequency of 1 MHz. Transmission from RCU to MCU is accomplished in a synchronous mode with a constant rate of 3.3 Kbytes/second, a constant lenght of 25 bits and a main frequency of 1 MHz.

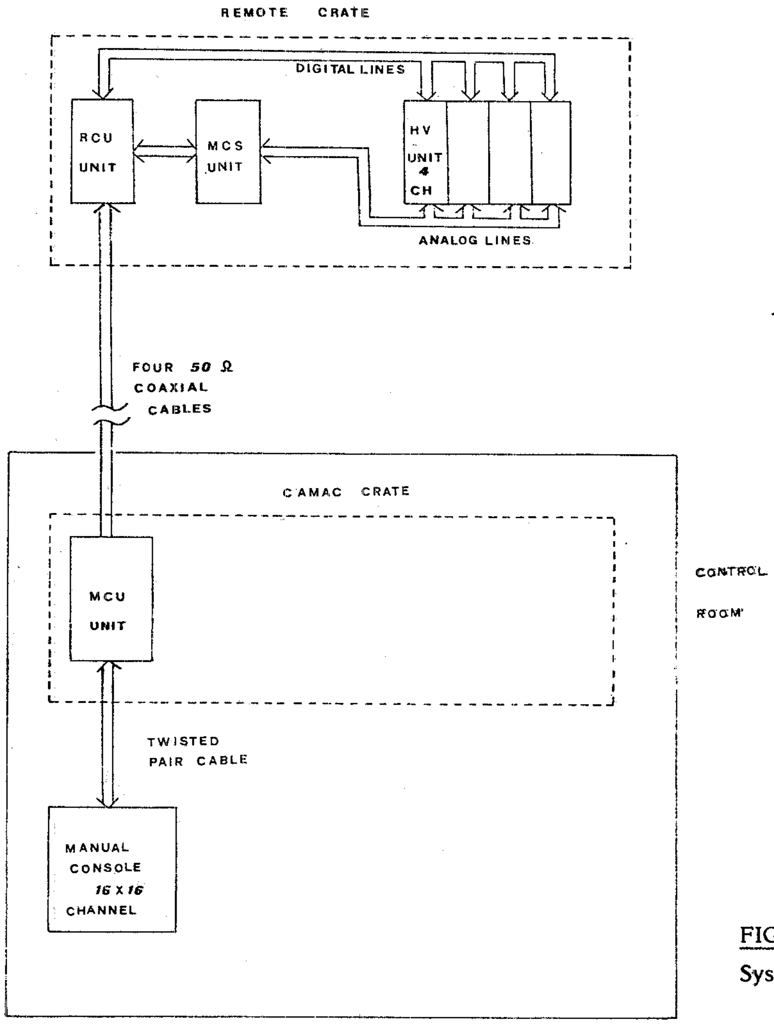

FIG. - 1 Block diagram of the FRAM 76 System.

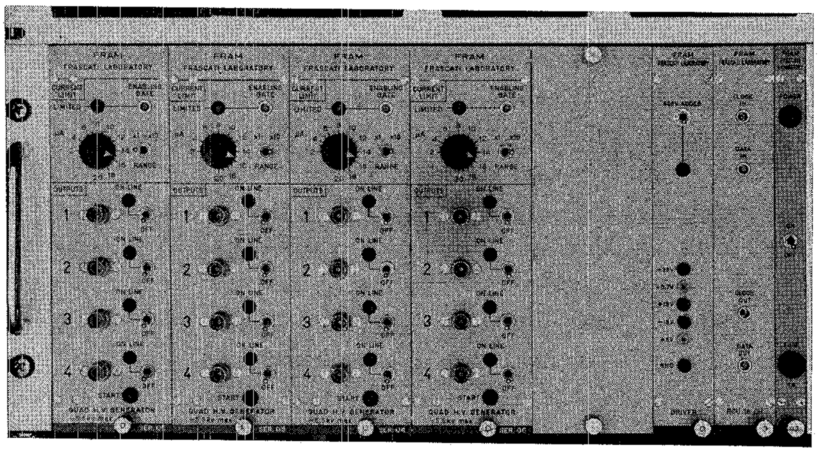

FIG. - 2 Front view of the remote crate. From left are visible the four quad H.V. generators, the MCU (driver), and the RCU.

2.1. - Master Control Unit (MCU)

Located in the control room, up to a hundred meters away from the apparatus, MCU (Fig. 3) interfaces the system to the Computer and Manual Console. The device has the width of one standard CAMAC module. It is linked to the Manual Console by a twisted pair cable.

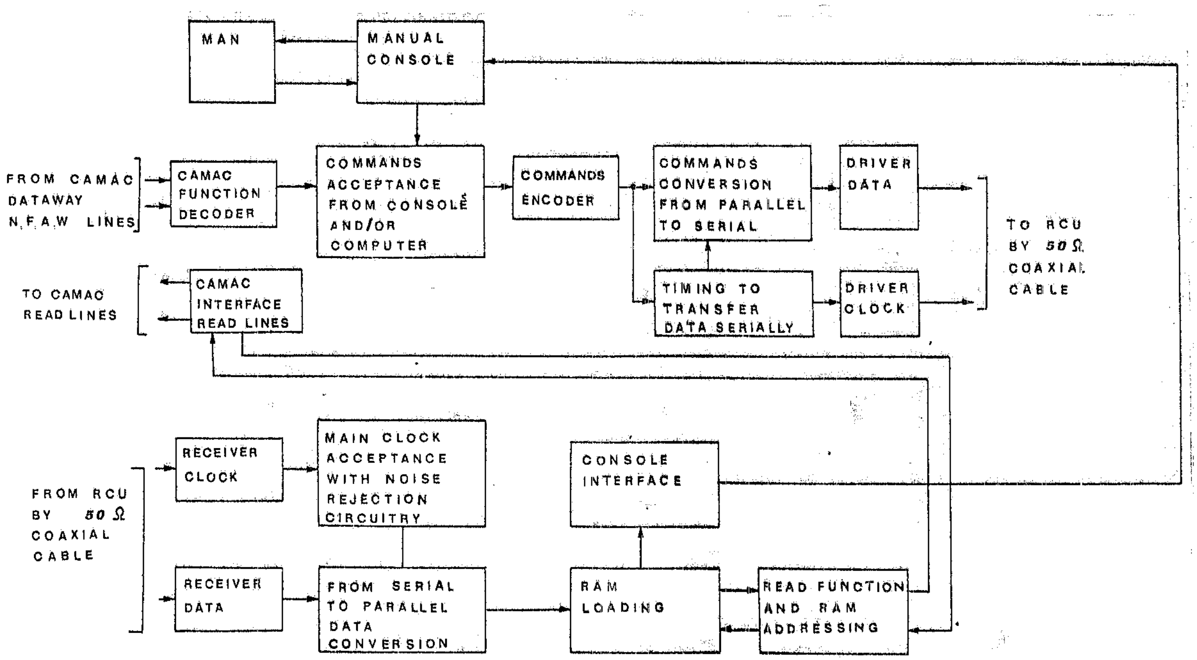

FIG. - 3 Block diagram of MCU

The MCU can be logically divided in two blocks, the transmitting section, whose diagram is shown in Fig. 4, and a receiving section, shown in Fig. 5.

Commands coming from CAMAC dataway (N,F,A,W lines) are first decoded and then encoded, in accord to a constant lenght byte, and sent to RCU. Commands from Manual Console, transmitted in parallel format, can be sent directly to RCU. Ambiguities which originate when two commands from console and computer, are simultaneously present in the MCU input are processed by using the "first-in first-out method". The commands are parallelly loaded on shift registers and serially sent to RCU. A main clock signal is also transmitted for the information recognition. Any information has a constant word lenght (15 bits) to facilitate the reconstruction of the message. Both data string and clock signal make use of discrete components power drivers to drive the two 50Ω coaxial cables which link the RCU. Data transmission from MCU to RCU is active only when a new command is available from Computer or Manual Console. Messages from RCU are serially received from MCU and organized in "clock" and "data" as made in MCU transmitting section. A constant word lenght of 25 bits from RCU to MCU is used. The received data are submitted to two different controls before being accepted. The first refers to the single bit of the main clock which must have standard values: width of 200 ns and TTL standard level; the second refers to the total time necessary to send completely any information which must not exceed the maximum width of 35 μs. A data string, after being checked and reconstructed from serial into parallel format, is loaded in a suitable location (one per channel) in the system image memory using RAM. Every memory location stores information about status control bytes, voltage setting and current sink values of each H.V.

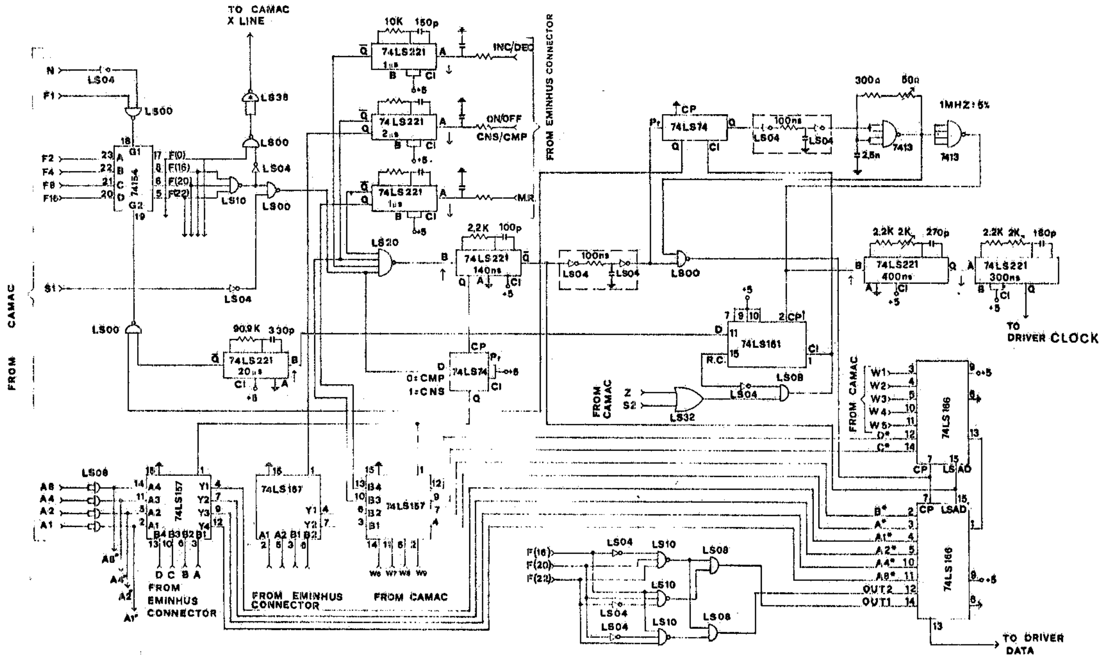

FIG. - 4 Diagram of the transmitting section of MCU. The link with console is performed by an Eminhus connector. The functions of console (increment-decrement, on-off, console-computer enable, master reset) are activated by the corresponding three independent triggers.

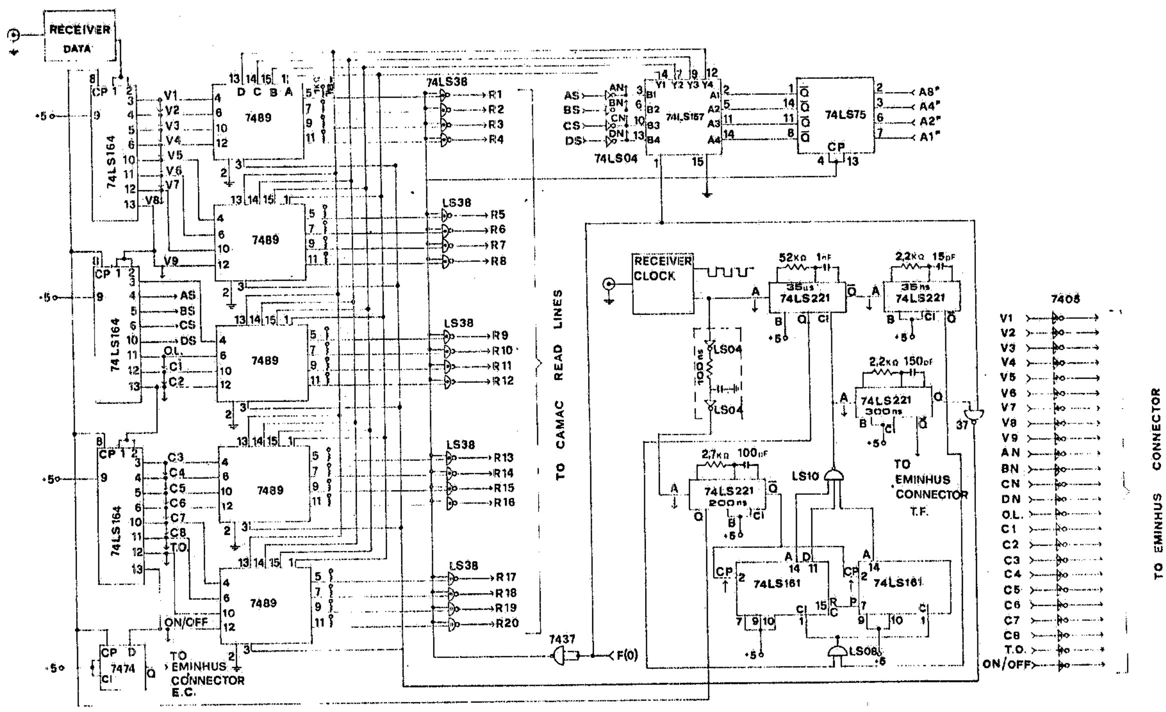

FIG. - 5 Scheme of receiving section of MCU. As for the transmitting section, the link with the console is performed via an Eminhus connector.

channel. Such informations are made available to the computer through CAMAC Read Lines. Adresses are fully decoded. The information of all the 16 channels are transmitted continuously and automatically to the Manual Console exibiting a display to the users. Data transmission from RCU to MCU is automatic and continuous allowing a permanent updating of the H.V. generator status. Such a facility permits to know the load current of the chambers during beam spill-out.

2.2. - Remote Control Unit (RCU)

The RCU, powered in the crate near the experimental apparatus, is linked by a special bus to the multichannel ADC and DAC device (MCS) and to the four QHVM's. (Fig. 6).

The functional organization of the RCU is similar to that of MCU only for the I/0 circuit (Fig. 7) and transmission section. The detailed scheme of reciving section of RCU is shown in Fig. 8a, 8b, while the transmitting block scheme is shown in Fig. 9. Control informations and H.V. setting, after acquisition and checking, are distributed on static RAM. RCU operates in two modes: processing commands or cycling stored data. When it is storing data a clock-counter system, at constant frequency, causes a continuous cycling of the RAM addresses which select the content sent to MCS. The DAC-Analog Multiplexer circuitry of MCS set continuously the proper positive voltage level to the analog momories (capacitors) of the high voltage generators. When RCU receives new commands the address counter is loaded with the selected channel address and a read-modify-write memory operation is generally performed in accord to the following:

a) Read on the selected RAM the old voltage value;
b) Modify (two modes are allowed):
   - the new values set by a WRITE command in the CAMAC logic (F(16));
   - the previous stored value by increasing or decreasing 1 bit or 10 bits.

The byte length transmitted from RCU to MCU consists of 25 bits composed as follows:

a) 4 bits for channel selection;
b) 9 bits for the setting voltage value;
c) 8 bits for the current drawn by chambers;
d) 1 bit for the status of ON/OFF of H.V. generators;
e) 1 bit for the overload condition of H.V. generator;
f) 1 bit for the ENABLE/DISABLE COMPUTER condition;
g) 1 bit for the possible conversion error of the ADC used to digitize the value of the sink current.

2.3. - Multichannel Conversion System (MCS)

MCS Unit is a double-width module plugged in a crate in the experimental area, which contains also RCU and the QHVM's.

MCS basic function is to interface the digital RCU with the analog H.V. generators. Obvious advantages exist in having a single MCS instead of a conversion device dedicated to each channel. This unit is contained in a card housing three 16-channels analog multiplexers driven by a common set of address lines coming from RCU. In normal operation these lines are constantly cycling at about 3KHz, selecting each time one of the sixteen H.V. channels over which the following operations are accomplished:

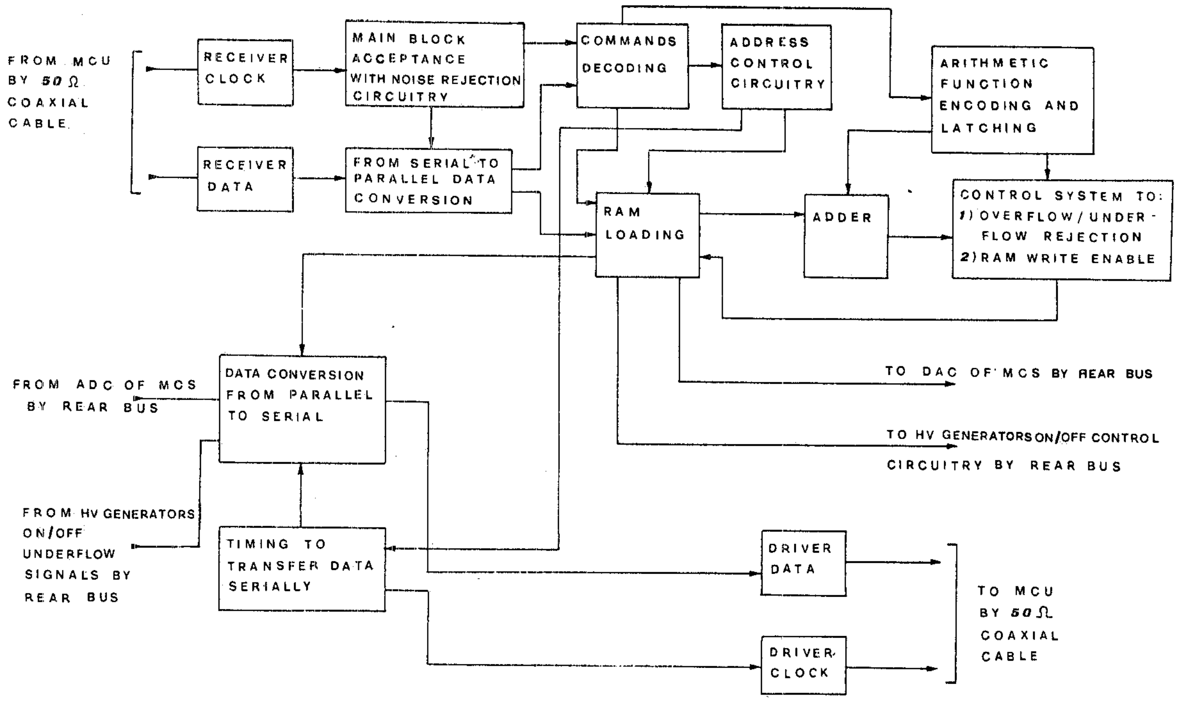

FIG. - 6 Block diagram of RCU.

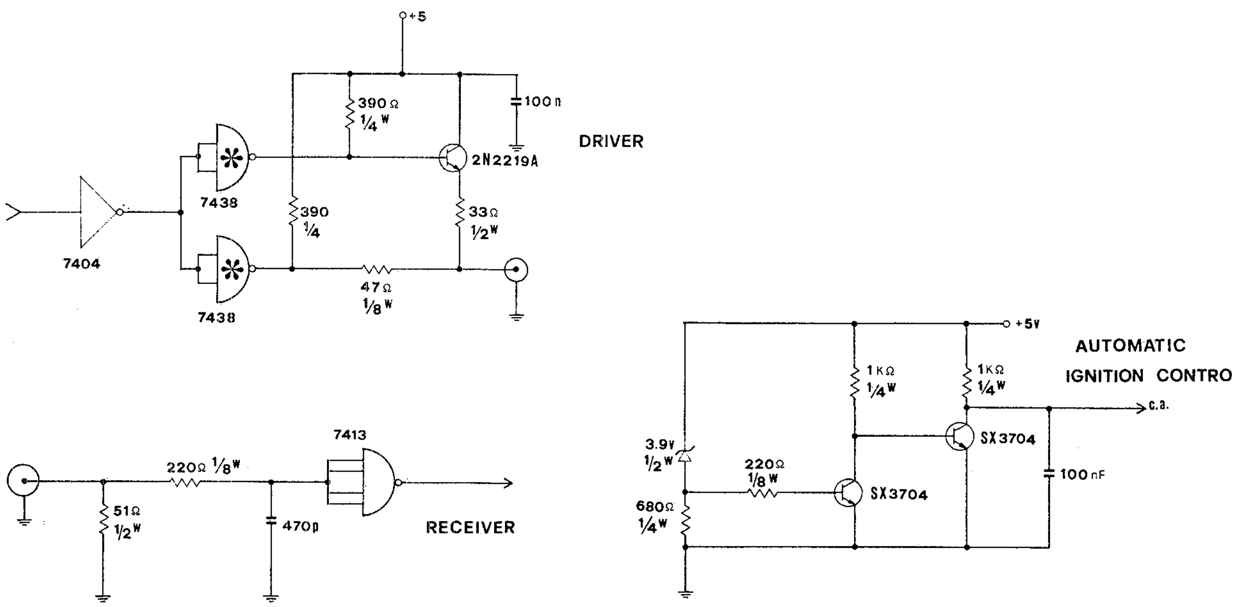

FIG. - 7 Circuitry of driver, receiver and automatic ignition control. The first and second are the input and output sections of RCU and MCU. The third one performs a function equivalent to the CAMAC Z for the remote crate. The automatic ignition control (c.a.) simulates a "master reset" signal when the crate is powered.

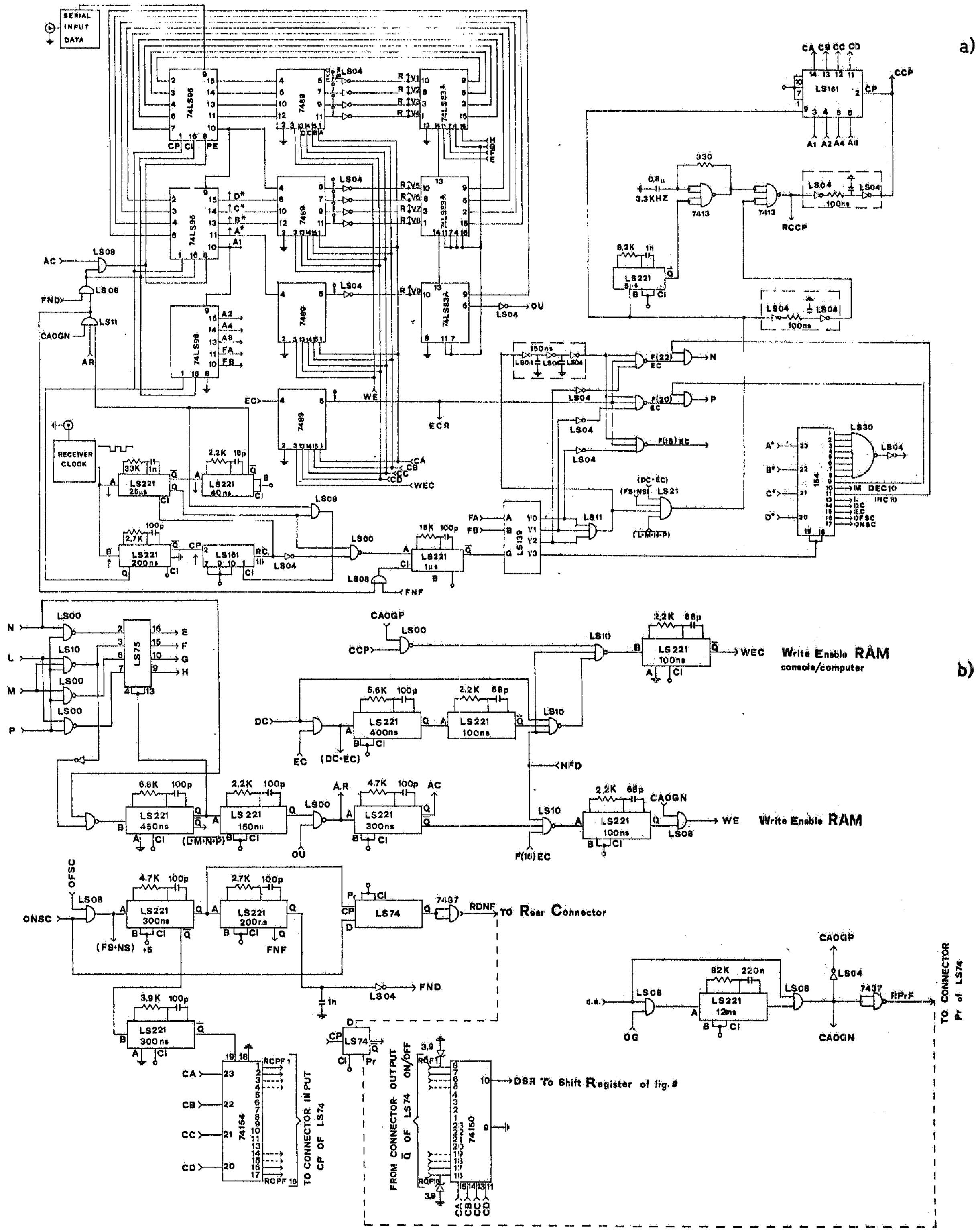

FIG. - 8 Diagram of RCU. Commands received from RCU are decoded by the circuitry of section a), and actuated by the circuitry of section b). Connections between them are indicated by reference arrows. External links performed through the rear connector are labeled by "R". Clock signals, which gives the main syncronization are labeled by "C".

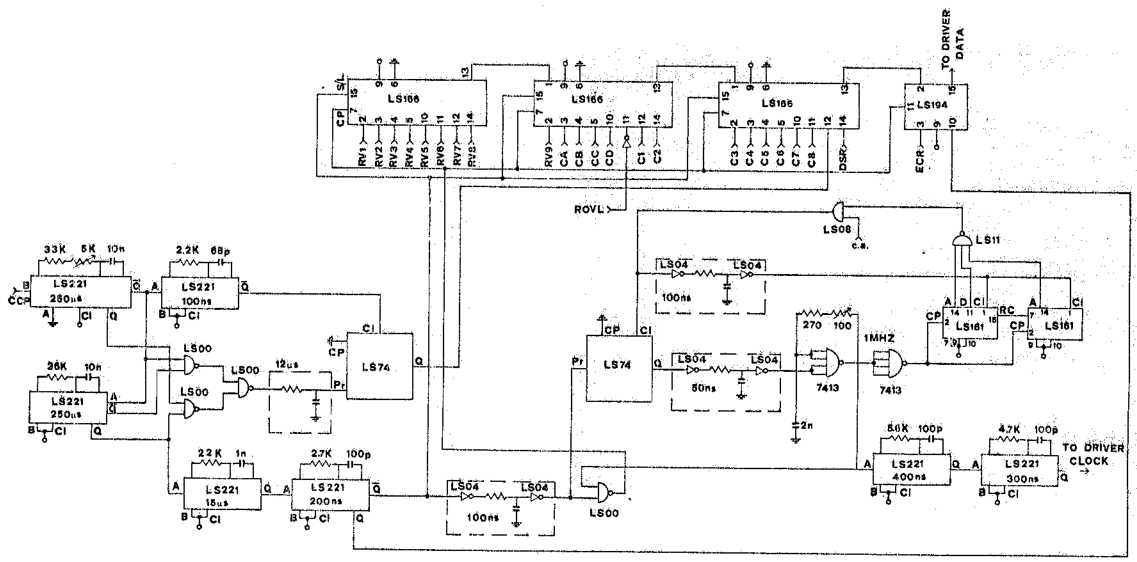

FIG. - 9 Diagram of RCU. Transmitting section. A signal for ADC time-out during current reading conversion is provided by the exclusive OR between the two one-shot 74LS221 set to 250 μs. The first one is driven directly by the clock pulse CCP, and the second one is set in a non-retriggerable configuration.

a) Digital to Analog conversion. The voltage value present in memory location addressed by RCU is sent to a 9 bits DAC.
The programmed voltage appears at the selected output of the multiplexers only for a short time every 5 msec, but a capacitor located on the H.V. generator card is enough to store the analogic value.

b) Output current readout and conversion. A double-ramp ADC performs the conversion into 8-bit digital format.

2.4. - Quad High Voltage Module (QHVM)

Each unit contains four independent H.V. generators assembled in a single card (Fig. 10). The high voltage generator is a switching-mode flyback DC-DC converter using primary supply voltage modulation (within a local feedback loop) to get a large output voltage range.

A high voltage generator channel consists of an oscillating converter externally drived. The converter is built around the step-up transformer T1 (Fig. 11a). It was decided to use a commercial television transformer for its easy availability and for its highly insulating properties. A realatively low efficiency and the rather large size are the main drawbacks of this transformer. The DC supply voltage (10 ÷ 35 volt) is chopped on the primary winding T1 from transistor Q6 driven by an external oscillator, in common to all channels. The negative peaks which appear on the T1 secondary are rectified by the high voltage diode D10 together with the capacitors C9 and C10. After crossing a filter cell (Q7, Q8, C11), the H.V. signal goes to the connector J1 through protection resistors R21 and R22. In order to control and change output voltage the following circuitry is used:

a) A circuit which senses output voltage by a separate coil on transformer T1 followed by a diode and a capacitor. Such a method of inductive partition was chosen in order to avoid the non-linearity effects

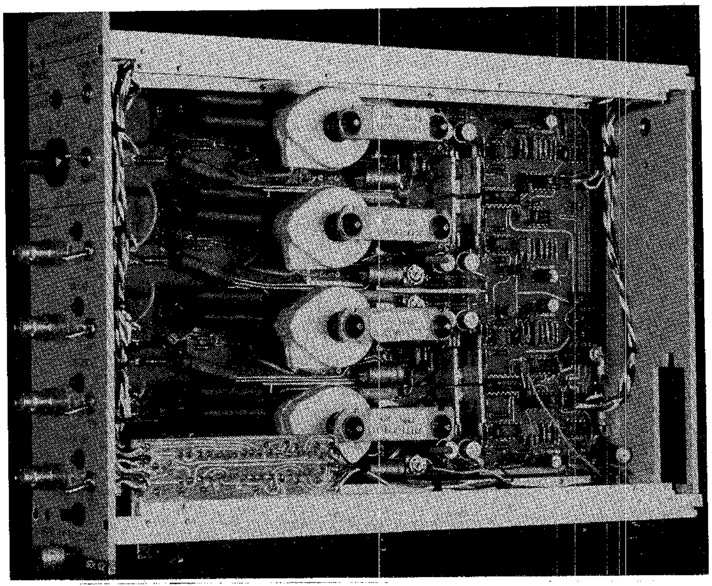

FIG. - 10 Internal view of quad high voltage module. The high voltage transformers as are low cost standard television components.

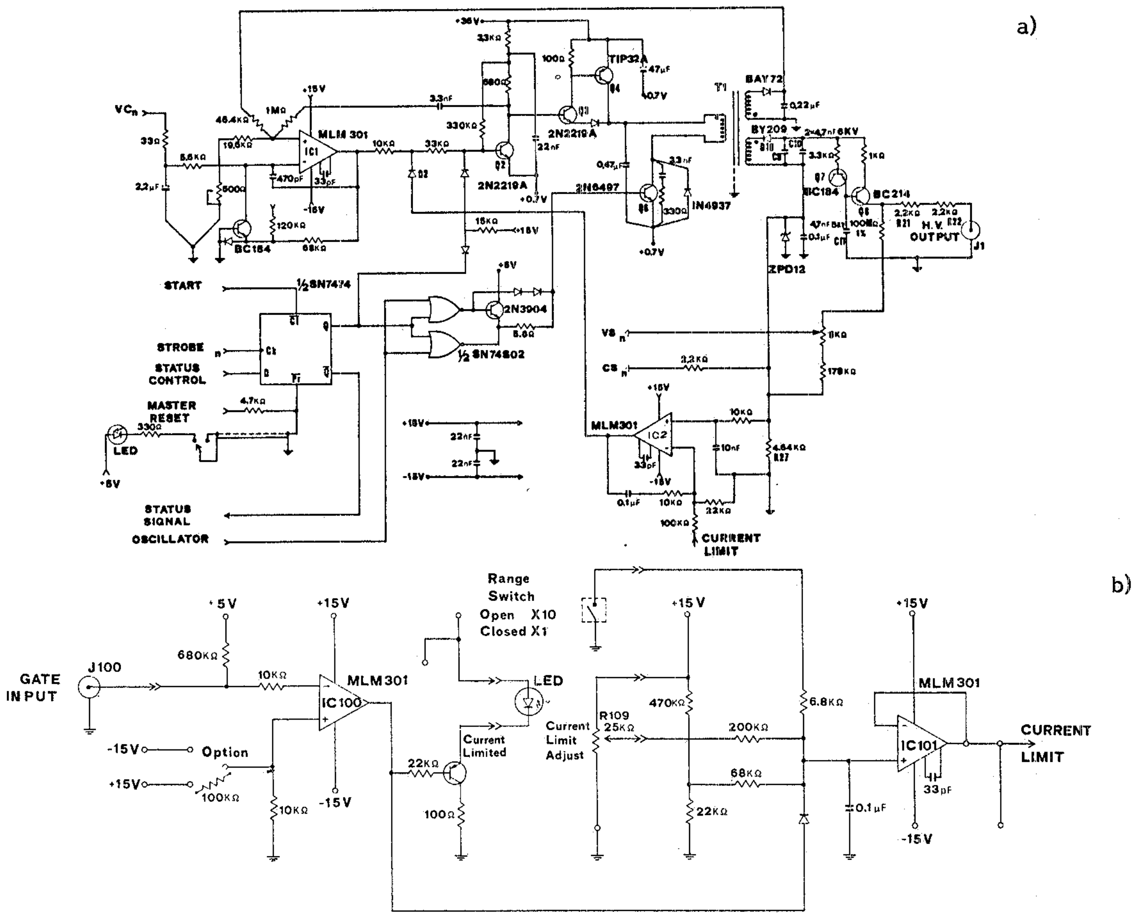

FIG. - 11 Diagram of QHVM. In section a) the high voltage generator is shown. Section b) shows the circuitry for current limit. Connection to front panel are indicated by double arrows.

and noise problems which arise with resistive partition when high resistor values are used. In this way an improvement in the characteristics of the dialogue between the control signal sent by DAC in RCU and the H.V. is achieved.

b) A differential amplifier (IC1), with the sensing voltage applied to one input and a signal (Vcn) proportional to the desired output voltage at the other one.

c) A modulator of the transformer primary voltage (Q2, Q3, Q4) controlled by IC1. When this voltage is varied the power level and the output voltage of the DC-DC converter varies over a wide range (about 0.5:5.5 Kv); in contrast the operating frequency, 4 KHz, is held constant.

In addition to the above voltage controlled mode of operation, a current-controlled mode is also available. A resistor R27, inserted in the earth return of the transformer develops a voltage proportional to the H.V. output current. An amplifier IC2 compares this value with the present one and lowers through the diode D2 the power level if it is exceeded. Here, however, the preset current limit value is common to all four channels in the unit, and can be changed only locally by variable resitor R109 connected to the amplifier IC101 (Fig. 11b).

It is also possible to raise the current limit, independently of the R109 resistor setting, to about 400 μA by applying a TTL low signal to the GATE INPUT J100.

2.5. - Manual Console (MC)

The Manual Console, whose functional diagram is shown in Fig. 12, is a special device which allows to control and monitor all H.V. generators by-passing the ON LINE computer. In the I/0 organization, similar to MCU, the setting operations performed directly by an operator replace the CAMAC Write Functions and "Free Functions" (used to accomplish INCREMENT/DECREMENT operations). Reading is performed by decimal display and LED's instead of CAMAC Read Lines. The initialization and main control on H.V. generators are

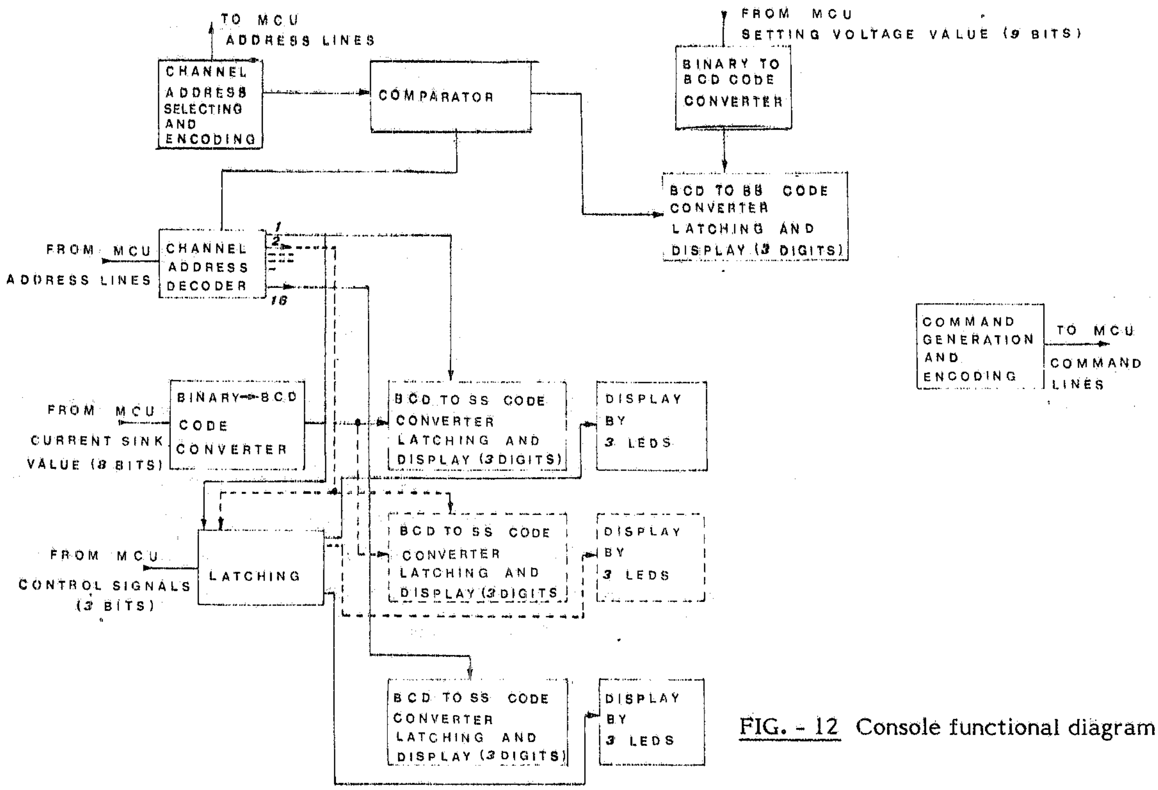

FIG. - 12 Console functional diagram.

accomplished only by Console (items a, b, c below).

Commands generated by the Manual Console and transmitted in parallel format along short distance to MCU are listed below:

a) Master Reset (common to all 16 channels);
b) ON/OFF for each channel;
c) Enable/Disable computer (EC/DC): this command selects the source of the SET Voltage command;
d) Increase/Decrease (INC/DEC), Slow, Fast (S/F) for setting voltage.

The use of redundant strobe lines has been used to resolve or minimize any problem arising from cable bad connections. We used three completely independent strobe lines, devoted to the following commands:

a) Master Reset;
b) ON/OFF, EC/DC;
c) INC/DEC, S/F.

Four encoded lines to identify the 16 channels of H.V. generators are also sent to MCU.

The console acquisition part receives in parallel format from MCU the reconstructed information coming from RCU. These informations, sent together with the encoded channel and the main reading strobe, are listed below:

a) setting voltage (9 bits);
b) chamber load current value (8 bits);
c) status identification to transmit setting commands by Console or Computer (1 bit);
d) OVERLOAD condition identification for the H.V. generators (1 bit);
e) ON/OFF status of DC/DC converter for H.V. generators (1 bit).

The voltage information is automatically displayed when 1 of the 16 channels is selected while the remainder information display (items b....e) refers to all 16 channels since they concern the operation of MWPCs. Information updating is performed at a frequency of 3.3 KHz, as generated by RCU. Time required for a complete updating of one channel is about 5 msec (330 μs x 16 channels).

3. - FINAL REMARKS

A long term stability test under work conditions has been made reaching 0.2% level. Setting reproducibility of output voltage value is better than 0.2%.

The system is presently operative in NA1 experiment providing the output H.V. supply to the multiwire and drift chambers of the Vertex Detector.

The planned improvements of design look for increasing compactness up to 64 channels in a CAMAC mechanical conforming crate instead of 16 now available.

We stress that the basic design of FRAM 76 system can be used in a general way, to set, display and control any kind of devices to be handled remotely in large number. Finally we anticipate that a photomultiplier H.V. supplying system is being developed(3) in Laboratori Nazionali di Frascati following the general design reported in this paper ensuring management, control and remote monitoring of hundreds of independent high voltage generators (3KV, 2 mA) powering photomultipliers in the same experiment.

APPENDIX I - MAIN SYSTEM FEATURES

HV outputs	: 16 per crate, SHV connectors on front panel.
Output Voltage	: 0.5 to 5.5 KV, negative, adjustable in 10 V steps.
Output current	: 0 to 200 µA.
Current limit	: adjustable from 2 to 200 µA (common to 4 channels) by a single-turn front-panel potentiometer scaled 2 to 20 µA in two switch-selectable ranges (x1,x10). Accuracy ± 10%.
Line regulation	: ± 5V output change for ± 10% line variations.
Load regulation	: 1% drop from no load to 200 µA load.
Stability	: Temperature coefficient 0.02%/°C (10° to 40° room temperature).
Ripple	: 0.5 V_{pp} .
Under/Over shoot	: ± 10 V for 100 µA step load change, at 5 KV output. Recovery to within 10 V of final value in 100 ms or less (resistive load).
Gate input	: LEMO 00 connector, common to 4 channels. A TTL "low" level on this high impedence input causes the inhibition of the current limit feature (actually, the limit point is raised to about 400 µA). Normal operation is assured leaving the gate input open, or by TTL "high" level. A green LED lights in this current-limited condition.
Short circuit	: continuously allowable. Output current: as set by current limit, after discharge of 15 nF capacitor on the 2 KΩ serial resitor.
Switch off time	: 10 sec, at no load.
Voltage programming	: by 9 bits straight binary word. Ratio 10 Volt/step (5110 Volt full scale) adjustable within ± 0.1%. Linearity: ± 10 V, from 1 to 5.5 KV output. A pedestal value, common to 16 channel adjustable by a 10-turn front panel potentiometer from about 0 to 500 V is added linearly to the digital setting, and allows reaching the maximum operating voltage (5.5 KV) of the generators.
Current monitoring	: by 8 bits straight binary word. Ratio: 1.0 µA/bit nominal, 255 µA full scale. Accuracy: ± 2% of reading.
Status control	: for each channel one "OVERLOAD" LED lights when the output current reaches the limit-point value.
Digital transmission	: the information is transmitted in serial format by two 50Ω coaxial cables (RG 174/U) with TTL levels for both lines. The MCU can transmit to RCU up to 50,000 commands per second. The MCU receives about 190 updating status words per channel per second.

APPENDIX II - CAMAC FUNCTIONS

Read out control : the status of each channel is stored in RAM in the CAMAC interface and is continuously updated by the remote unit. The information is at any time ready for CAMAC readout.

CAMAC command : X = 1 (command accepted), is generated when a valid N, F and A command is generated.

Status readout format : R1 + R9 : H.V. setting (R1 = LSB; R9 = MSB);

R10 : overload (current);

R11 + R18 : actual current value (R11 = LSB; R18 = MSB);

R19 : TIME OUT ADC of current;

R20 : SWITCH ON/SWITCH OFF HV.

APPENDIX III - MANUAL CONSOLE FACILITIES

The console is a special purpose device which provides the following readout and setting facilities:

Read out operation : the readout operation allows:

- to select, with two rotary switches, the address: the first selects the channel (one of 16) within the group selected by the second one (one of 16);
- to monitor, by 3-digit LED display, the voltage setting of the selected channel;
- to monitor, by sixteen 3-digit LED display, the actual output current of the 16 channels of the selected group;
- to monitor, by three LED's, the status of the 16 channels of the selected group about the ON/OFF H.V. status, OVERLOAD of H.V. output and Console/Computer settability.

Setting operation : the setting operation performs the following functions:

- a MASTER RESET signal can be generated in order to:
  1) Turn off the H.V. generators;
  2) Write the word zero (=0 volt) in the memory system of RCU;
  3) Switch the 16 channels to manual control
- the following commands can be manually implemented on the selected channels:
  1) Switch OFF: like MASTER RESET, but only for the selected channel;
  2) Switch ON: like Switch OFF but Switch ON the H.V. generators;
  3) Computer Disable: cause the selected channel to be manually controlled;
  4) Computer Enable: opposite of Computer Disable;
  5) Increase 1: increase of 1 step the chosen high-voltage digital value;
  6) Decrease 1: opposite of Increase 1;
  7) Increase 10: increase of 10 steps the chosen high-voltage digital value;
  8) Decrease 10: opposite of Increase 10.

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