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CLEARING ELECTRODE CONTROL SYSTEM

by

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Abstract

Due to the introduction of new high voltage power supplies in the clearing electrode system, a control system was built with improved remote controlled capability. This system is essentially a serial transmission network, allowing the control of 128 independent locations, 3 separate commands being possible in each station. Speed is rather low (about 100 commands per second) but noise immunity is high.

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INTRODUCTION

This paper gives a description of the electronics needed for the clearing electrode control system. To outline this system, a short description of the whole clearing electrode system is required.

The vacuum pipes of the two ISR rings are provided with a large number of electrode pairs which have the major task of removing the electrons which are created by the proton beam. Quality and stability of the beam are strongly affected by the efficiency of this clearing system. Thus, a very high degree of reliability is required.

The electrode network is supplied with + 6 kV on one electrode of each pair, + 0.2 to + 3 kV being applied to the second electrode. In this way, we have both the electrical potential and gradient needed to trap the electrons. Thus, two sets of high-voltage supplies are necessary in each ring. Physically, each octant is provided with four high-voltage supplies that are located in the auxiliary buildings. These supplies have an output voltage that can vary from 0 to + 20 kV, with an adjustable maximum output current of 0 to 5 mA. The electrodes are fed via a distribution network, consisting in each octant of 5 main cable-pairs for each ring, feeding high voltage distribution boxes in the ISR tunnel. Each distribution box can insure the high voltage connections to 8 electrode pairs.

The control system of the clearing electrodes had to be modified considerably due to the introduction of more sophisticated power supplies. Those supplies can be completely remote-controlled including the switching of the polarity of the output voltage and the high voltage setting. The previously used control system (Carryplex) was saturated and it did not allow the remote control of the polarity, a feature which appeared to be very desirable during development runs. So, we decided to build up a completely new control system. However, we tried to minimise the cabling work. So, we kept the status indication and the remote high voltage setting cabled as it had been at the design period of the machine. Only the Carryplex system was replaced with the system later described. But it should be mentioned that all the status indications could be transmitted via this control system, needing only the addition of one or two plug-in circuit cards in each auxiliary building and an appropriate receiver-station in the control room.

The control system is essentially a serial transmission network. A single multicore cable is linked to form a loop from the control room to the auxiliary buildings. Although only two wires are needed for transmission, we use a

double-screen 3 + 6 pole cable. Wire 1 and 2 are used for transmission, wire 3 and the first screen for an emergency power supply which feeds the critical circuits of the system. The six remaining wires are intended to be used for transmission of analog signals such as the high voltage power supplies output currents to the control room.

This report gives only a general description of the system with figures showing the block-schemes. Detailed drawings are available under the following ISR documentation : ISR-4116, ISR-4126, ISR-4129.

1. PRINCIPLE

The control system described below performs the following tasks :

- switching ON and OFF the clearing electrodes power supplies
- switching the polarity of each individual power supply.

The whole system is completely sequential. All the information is multiplexed on to a two-wire link around the ISR ring.

Each command is done by means of a one-word instruction, 12 bits long. The bits have the following code :

bit 1	defines even parity within the first 8 bits
bits 2, 3, 4	define 1 of 8 selected octants
bits 5, 6, 7, 8	define 1 of 16 addresses within each octant
bits 9, 10, 11	define 1 of 8 possible commands
bit 12	is a synchronisation bit

Distinction between "0" and "1" is done by comparing their respective lengths. The synchronisation bit is longer than any other bit, so it can be decoded independently (see figure 1).

It is relevant to note that the system speed is quite low, so the various pulse lengths are not at all critical and the margin between these lengths is very large.

The emitter station, located in the ISR control room, is divided into two main parts :

- a control unit which generates the timing for the whole system
- four coding units which generate the appropriate bit pattern under timing of the control unit.

Each auxiliary building is equipped with a control station which amplifies the received word and transmits it to the next building, picking up only the information destined for this particular location.

Each receiver station (within the control station) shifts the bit train into a register transforming the serial data into a parallel word. The address is then decoded, the parity checked and the command is routed to the device to be controlled.

2. EMITTER STATION

2.1 Main control logic (ISR 4126/2)

This unit generates the timing for the complete system starting from a 1 μ s pulse with about 2.85 kHz repetition rate. This clock is alternately routed to two counters referred to as delay counter and address counter (see figure 2). The address counter generates a 12 count sequence which is sent out to up to four remote coding units. The delay counter enables each coding unit to transmit a message and send it out to the buildings. This is done by acknowledging a send-request and enabling the unit concerned between two address counter sequences. The addresses sent out to the coding units are used to multiplex the word to be sent. When a "1" is detected, it triggers a long pulse, otherwise a short pulse is sent. When the address counter has fulfilled its sequence, it triggers the synchronisation pulse and increments the position counter which selects the next coding unit.

Nevertheless, between selection of two successive coding units, a complete sequence of the address counter is left free. This allows the system to receive a message which would be sent from any building to the SRC (see timing diagram, figure 3).

The output to the buildings may be disconnected for testing purposes (SW1). This switch is also controlled by the delay counter in order to avoid sending only parts of a word.

This control unit is mounted on a "3H" standard plug-in card with double-width front panel. Each coding station may be disabled by means of switches mounted on this panel.

2.2 Coding unit (ISR 4126/1)

This unit is implemented in the same crate as the main control unit is. It permits generating any message by selecting the building, address and word on thumb-wheel switches. A decoding circuit disables the output of the unit

if the settings of the switches are not compatible with the word format.

The following combinations are allowed :

Building : 1 to 8

Address : 0 to 15

Commands : 1 to 8

Any other setting will light a lamp on the front panel and disable the output. Once a word has been generated, a send-request is transmitted to the main control unit which in turn enables the data to be sent out.

The 10 bits selected from the thumb-wheel switches are presented to the input of a multiplexer. A parity bit is generated from the first 7 bits (building and address code). When the send-request is acknowledged by the control unit, it enables the multiplexer and gets the data in the sequence given by the address counter (see figure 4). The double-width front panel holds the thumb-wheel switches and the lamps used for the indication of wrong codes.

2.3 Line Interface (ISR 4126/3)

To allow the use of longer cables between the main control unit and the 3 coding units which are not located in the same crate (ON/OFF and POLARITY-control), line drivers and line receivers are used. The same plug-ins also contain one line driver each that can be used for driving the line to the buildings. Although only one of them is needed, this set-up allows interchanging the plug-ins.

2.4 Complete emitter crate

This crate holds one main control logic, one coding unit and three line drivers which are used to interface the other coding units (described later on). It needs a 5 volt supply with about 1 amp. Each plug-in card is provided with a L-C type decoupling circuit to avoid interferences between them. A block diagram of the crate is given in figure 5.

3. ON/OFF REMOTE CODING UNIT (ISR 4129)

The purpose of this unit is to generate the proper bit code for the ON/OFF control. A diode matrix has been used to improve flexibility as compared to a hardwired logic. The address and the commands were defined as follows :

Buildings :	1 to 8	
Address	01	Command 4 = R1, ON
		3 = R1, OFF
	02	Command 4 = R2, ON
		3 = R2, OFF

Both HV supplies of one ring, within one octant, are switched ON and OFF together. So we need 32 columns in our matrix. These 32 columns are sequentially scanned at about 5 kHz rate. When an input line is activated, the corresponding column is set at the time defined by the scanning system. In return, a request signal is generated, stopping the clock of the scanning system and waiting for the word to be transmitted to the main control unit. This is done in exactly the same manner as for the coding unit described earlier. Once the word has been transmitted, the clock runs again until the next activated line is met.

The block diagram is given in figure 6. The control switches are arranged in a way that allows either individual control of each building or general (ring-wise) control. The unit fits in a "2H" high crate which also holds the status lamps. These lamps are hardwired to the status relays of the supplies since the cabling already existed when we started with this control system. Nevertheless, the ON-OFF status indications could have been retransmitted through the multiplexed control system. Both status lamps and general ON and OFF, are provided on a remote control panel which is located at the high voltage reference control panel (ISR-1406).

4. POLARITY CONTROL (ISR 4129-A)

The basic configuration is the same as for the ON/OFF control. However, since each individual HV power supply has to be commuted, we need 64 columns. In order to use the same circuitry and hence to facilitate maintenance, we use two crates (one for each ring).

The main difference is the cabling of the control switches. We use a single address to define the four possibilities of polarities, using four out of eight possible commands.

Buildings :	1 to 8	
Addresses :	03	Command 7 $U_1(+)$ $U_2(+)$
		2 $U_1(-)$ $U_2(+)$
		1 $U_1(+)$ $U_2(-)$
		8 $U_1(-)$ $U_2(-)$

RING 1

Addresses :	04	Command	7	$U_1(+)$	$U_2(+)$	
			2	$U_1(-)$	$U_2(+)$	
			1	$U_1(+)$	$U_2(-)$	RING 2
			8	$U_1(-)$	$U_2(-)$	

So we have to activate only one out of four columns at a time. This is done by an appropriate cabling of the front panel switches (see figure 7).

5. REMOTE RECEIVER AND CONTROL STATION

Each building is provided with a control and receiver crate. These crates are linked serially to the control room, via a 3 + 6 pole multicore cable. The first two wires are used for transmission of the multiplex signal; the third one is used as a common "emergency" supply line.

5.1 Relays (4116/1)

This first plug-in contains the line receiver and line driver connected in differential mode, allowing the use of a twisted pair line from one building to the other without ground-loop or common-mode voltage problems. A buffered output feeding the receivers located in the same building is also provided. This output may be "wire-ored" with some other line drivers, allowing a message to be sent from one building to another or to the control room. This plug-in is also provided with a 5 volt regulator which is fed with 24 V from three different lines :

- an autonomous 24 V power supply
- a link to the 24 V used in the valve system
- the "emergency" supply line of the multiplex cable.

In this way, it is possible to ensure correct supply in various fault cases. This 5 volt line is used for some critical latch and interlock circuits and is referred to as "+ 5 V secours".

A further feature of this plug-in is the detection of a power supply failure. This circuitry generates a fault signal when either the 5 V or the 24 V supply drops out. This signal is used to strobe the ON/OFF and POLARITY controls, avoiding erroneous interpretations of the commands. The front panel holds four lamps indicating the status of the various power supplies. A "BNC" socket is also provided, allowing reception testing.

5.2 Dual receiver (4116/2)

The serial multiplexed signal has to be converted into a parallel form. This is done by feeding this signal into a 12 bit shift register, with parallel outputs. The clock of the shift register is derived from the positive edge of the input signal and delayed by about 50 μ s. In this way, a "one" is only shifted into the register when the input pulse is longer than 50 μ s (see figure 8).

The first 8 bits are checked for parity. Each "address" and "building" bit (that is bit 2 to 8) may be defined as true or inverted, allowing each receiver to recognise a specific bit pattern. This selection is done by means of miniature dual-in-line switches.

Each input pulse is compared with a 150 μ s pulse. If the input pulse is longer, it is detected as the synchronisation pulse and it is used as a validation pulse for the command.

The state of the last-entered bit of the shift register is given by a lamp on the front panel. Since the last bit must always be recognised as a "1" (synchronisation bit), this indicator is normally lit.

Each plug-in holds two complete receivers, allowing the use of one plug-in for the control of both ISR rings.

5.3 On/Off Control (4116/3)

The data word is decoded on this board in the following way :

command 4 = ON
command 3 = OFF

Nevertheless, due to incomplete decoding of the "ON" command, words 5, 6 and 7 are also interpreted as "ON". An R-S flip-flop latches the command. The entry of this flip-flop is disabled via the "fault" signal in case of power failure.

The output stage of the ON/OFF control unit consists of two transistors, serially linked. One of them is driven by the R-S flip-flop, the other by the interlock network. Any of the 3 interlocks (opened covers, removed connectors and high pressure) generates an output signal from the interlock network. Pressure and connector interlocks may be overridden by means of a key switch on the front panel. For security respect, the "opened covers" interlock, which indicates that a high voltage distribution box has been opened, cannot be overridden.

The interlock status is indicated for both rings on the front panel. Manual ON/OFF control of the high voltage supplies is also provided.

5.4 Polarity control (4116/4)

On this board the information is first latched and then decoded in the following way :

word 2 and 8 = R1 negative
word 1 and 8 = R2 negative

Any other combination forces both R1 and R2 to positive polarity. The latches are disabled by the "fault" signal in the same manner as for the ON/OFF control. The output stages are driven via opto-couplers. This is done to avoid ground-loops, since the high voltage supplies have a common ground for ON/OFF and POLARITY control signals.

The status of each supply is indicated by a bi-colour led lamp. Green indicates normal operating polarity positive and red indicates negative polarity.

5.5. General layout (figure 9)

Each receiver crate contains, at the moment, the following plug-in :

1 relay 4116/1
2 dual receivers 4116/2
1 ON/OFF control 4116/3
1 polarity control 4116/4

Up to seven plug-ins may be added to extend the controls.

Each of the four high voltage power supplies in each building is linked via two 8 pole cables to the receiver crate. One cable is used for the ON/OFF and POLARITY controls, the other for transmission of voltage and current monitor signals. The status of each power supply is individually fed to a junction rack through a third 8 pole cable.

A 19 pole cable between the junction rack and the receiver crate carries the reference voltage for the high voltage setting and the pressure interlocks.

In octants 1 and 8 two auxiliary power supplies are added. They are controlled with R1 in octant 1 and R2 in octant 8. Only ON/OFF control and output voltage monitoring are provided.

Direct current monitoring of the most positive high voltage supplies is done via a 28 pole link to a 48 pole loop cable. At this time, only 4 poles are used in each building.

6. POWER SUPPLY (4117)

Each building and the control room are provided with a dual power supply, delivering 5 V at 5 A and 24 V at 1.5 A. The 24 V supplies of all buildings are linked together via diodes allowing the critical circuitry to be fed quasi-permanently.

These power supplies have all remote sensing, allowing the use of any length of cable between supply and user's crate.

CONCLUSIONS

This system has been use for two years without any difficulties. The various interlocks and fault detection circuits have worked satisfactorily and the interpretation errors occurred extremely rarely. Even in cases of power failure, the memorisation of the commands was correct. Mostly due to its relatively slow speed, it is quite insentitive to parasitical effects like noise or common mode voltages between buildings. It uses at the time only 32 of 128 possible receiver stations, allowing its extension very easily.

The system has been built with simple and inexpensive components, most of them being integrated circuits and CERN stock items. Due to the rapid development of LSI circuits, such as micro-processors, it would probably now be possible to reduce dramatically the number of components and at the same time to increase the flexibility. Nevertheless, it should be pointed out that the principle could be kept exactly the same and that only a little design effort would have to be paid for a more "up-dated" design.

- Fig 1.

- Fig 2 -

- Fig 3 -

-Fig 4-

-Fig 5-

- Fig 6 -

- Fig 7 -

-Fig8-

On design no part shall be used in the
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Proportion européenne
 First angle projection

- Fig 9 -

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