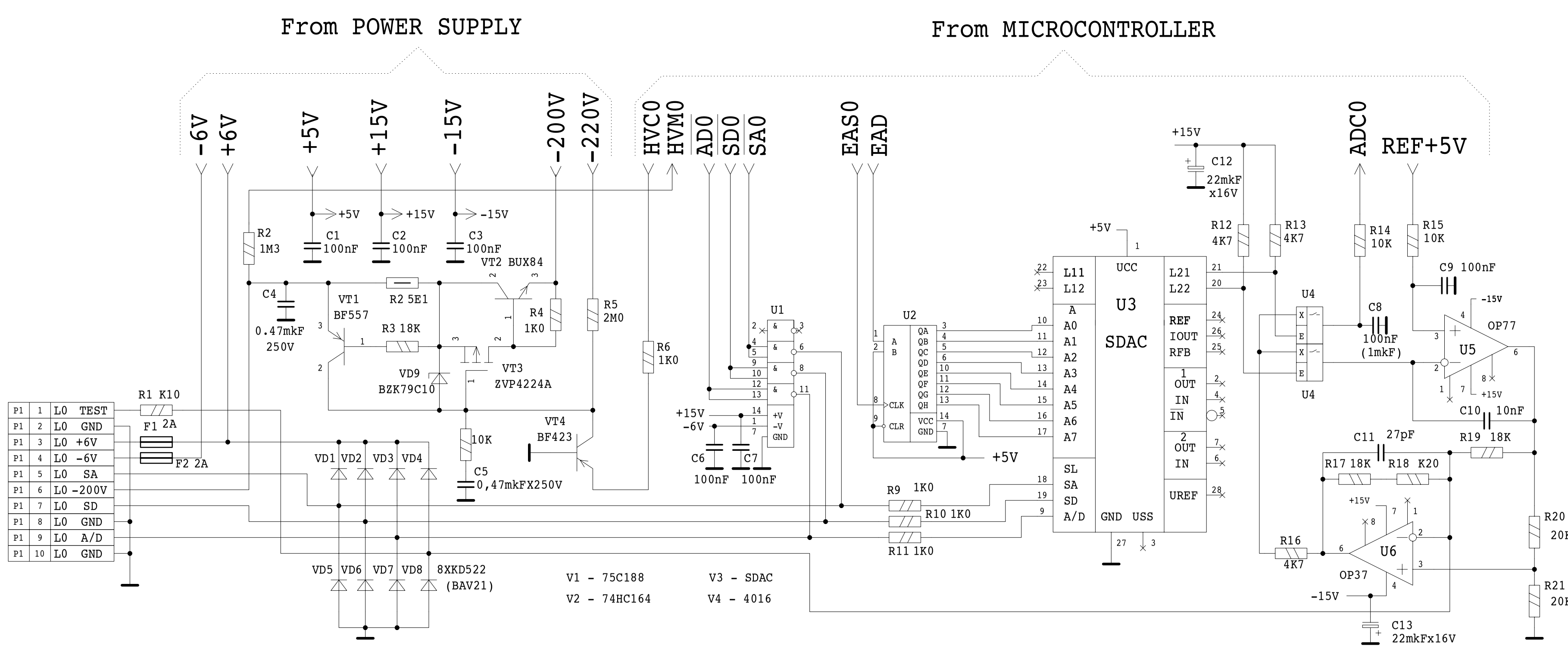
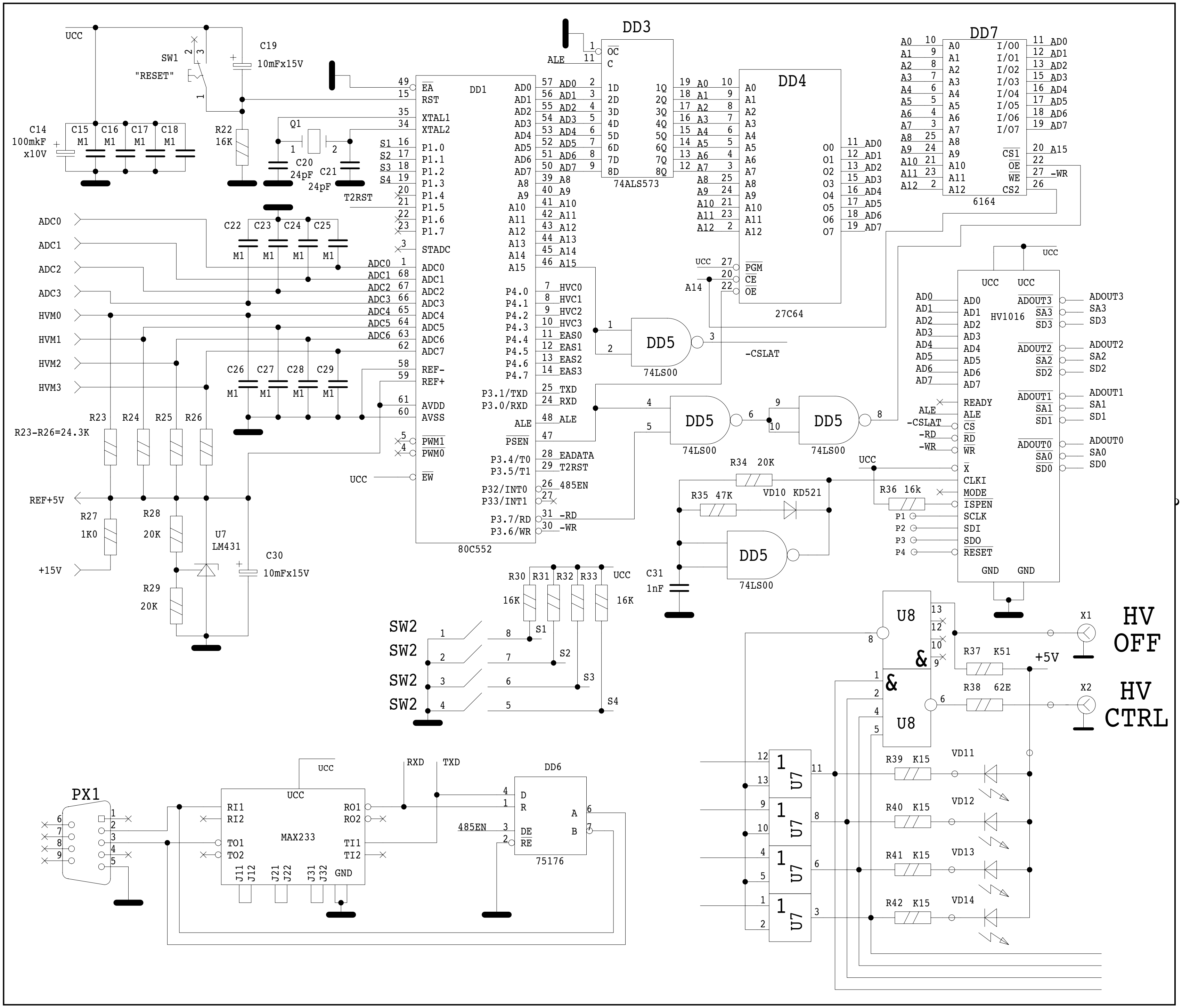
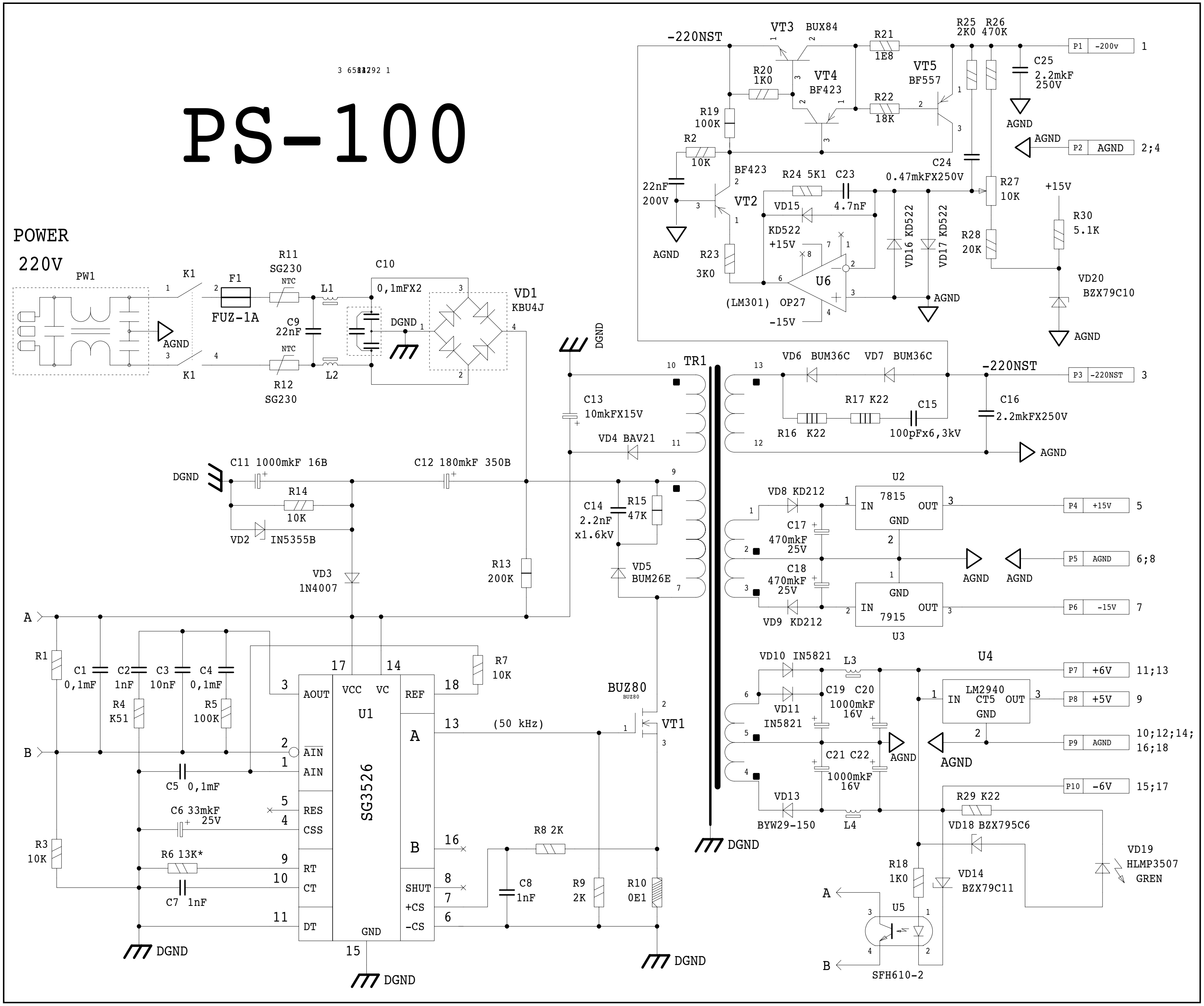
SM255-A



From POWER SUPPLY
From MICROCONTROLLER
-6V
+6V
+5V
+15V
-15V
-200V
-220V
HVC0
HVM0
AD0
SD0
SA0
EAS0
EAD
ADC0
REF+5V
R1 K10
F1 2A
F2 2A
R2 1M3
C1 100nF
C2 100nF
C3 100nF
C4 0.47mkF 250V
VT1 BF557
R2 5E1
R3 18K
VT2 BUX84
R4 1K0
R5 2M0
R6 1K0
VD9 BZK79C10
VT3 ZVP4224A
10K
C5 0,47mkFX250V
VT4 BF423
VD1 VD2 VD3 VD4
VD5 VD6 VD7 VD8 8XKD522 (BAV21)
U1
U2
U3
SDAC
U4
U5 OP77
U6 OP37
C6 100nF
C7 100nF
C8 100nF (1mkF)
C9 100nF
C10 10nF
C11 27pF
C12 22mkF x16V
C13 22mkFx16V
R9 1K0
R10 1K0
R11 1K0
R12 4K7
R13 4K7
R14 10K
R15 10K
R16 4K7
R17 18K
R18 K20
R19 18K
R20 20K
R21 20K
V1 - 75C188
V2 - 74HC164
V3 - SDAC
V4 - 4016
P1 1 L0 TEST
P1 2 L0 GND
P1 3 L0 +6V
P1 4 L0 -6V
P1 5 L0 SA
P1 6 L0 -200V
P1 7 L0 SD
P1 8 L0 GND
P1 9 L0 A/D
P1 10 L0 GND



UCC
SW1
"RESET"
C19
10mFx15V
C14
100mkF
x10V
C15 C16 C17 C18
M1
R22
16K
Q1
C20
24pF
C21
24pF
T2RST
DD1
80C552
EA
RST
XTAL1
XTAL2
P1.0 P1.1 P1.2 P1.3 P1.4 P1.5 P1.6 P1.7
STADC
ADC0 ADC1 ADC2 ADC3 ADC4 ADC5 ADC6 ADC7
REF-
REF+
AVDD
AVSS
PWM1
PWM0
EW
AD0 AD1 AD2 AD3 AD4 AD5 AD6 AD7
A8 A9 A10 A11 A12 A13 A14 A15
P4.0 P4.1 P4.2 P4.3 P4.4 P4.5 P4.6 P4.7
HVC0 HVC1 HVC2 HVC3 EAS0 EAS1 EAS2 EAS3
P3.1/TXD
P3.0/RXD
TXD RXD
ALE
PSEN
P3.4/T0
P3.5/T1
EADATA
T2RST
P32/INT0
P33/INT1
485EN
P3.7/RD
P3.6/WR
-RD
-WR
C22 C23 C24 C25
C26 C27 C28 C29
ADC0 ADC1 ADC2 ADC3
HVM0 HVM1 HVM2 HVM3
R23 R24 R25 R26
R23-R26=24.3K
REF+5V
R27
1K0
+15V
R28
20K
R29
20K
U7
LM431
C30
10mFx15V
DD3
74ALS573
OC
C
1D 2D 3D 4D 5D 6D 7D 8D
1Q 2Q 3Q 4Q 5Q 6Q 7Q 8Q
DD4
27C64
A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12
O0 O1 O2 O3 O4 O5 O6 O7
PGM
CE
OE
A14
DD7
6164
I/O0 I/O1 I/O2 I/O3 I/O4 I/O5 I/O6 I/O7
CS1
OE
WE
CS2
DD5
74LS00
-CSLAT
HV1016
UCC
ADOUT3 SA3 SD3
ADOUT2 SA2 SD2
ADOUT1 SA1 SD1
ADOUT0 SA0 SD0
READY
CS
RD
WR
X
CLKI
MODE
ISPEN
SCLK
SDI
SDO
RESET
GND
P1 P2 P3 P4
R34 20K
R35 47K
VD10 KD521
R36 16k
C31
1nF
R30 R31 R32 R33
16K
S1 S2 S3 S4
SW2
U8
&
X1
HV
OFF
R37 K51
+5V
R38 62E
X2
HV
CTRL
U7
R39 K15
R40 K15
R41 K15
R42 K15
VD11 VD12 VD13 VD14
PX1
MAX233
RI1 RI2
TO1 TO2
RO1 RO2
TI1 TI2
J11 J12 J21 J22 J31 J32
GND
DD6
75176
D
R
DE
RE
A
B
485EN


PS-100
POWER
220V
PW1
K1
F1
FUZ-1A
R11
SG230
NTC
L1
L2
R12
SG230
C10
0,1mFX2
C9
22nF
DGND
VD1
KBU4J
AGND
C11 1000mkF 16B
C12 180mkF 350B
R14
10K
VD2
IN5355B
VD3
1N4007
R13
200K
C13
10mkFX15V
VD4 BAV21
C14
2.2nF
x1.6kV
R15
47K
VD5
BUM26E
TR1
-220NST
VT3
BUX84
R20
1K0
VT4
BF423
R21
1E8
R22
18K
VT5
BF557
R19
100K
R2
10K
22nF
200V
BF423
VT2
R23
3K0
R24 5K1
C23
4.7nF
VD15
KD522
+15V
U6
(LM301)
OP27
-15V
VD16 KD522
VD17 KD522
C24
0.47mkFX250V
R25 2K0
R26 470K
C25
2.2mkF
250V
R27
10K
R28
20K
R30
5.1K
VD20
BZX79C10
P1 -200v
P2 AGND
P3 -220NST
VD6 BUM36C
VD7 BUM36C
R17 K22
R16 K22
C15
100pFx6,3kV
C16
2.2mkFX250V
U2
7815
IN
OUT
GND
VD8 KD212
C17
470mkF
25V
C18
470mkF
25V
VD9 KD212
7915
U3
P4 +15V
P5 AGND
P6 -15V
U4
LM2940
CT5
VD10 IN5821
VD11
IN5821
L3
C19 C20
1000mkF
16V
C21 C22
1000mkF
16V
VD13
BYW29-150
L4
P7 +6V
P8 +5V
P9 AGND
P10 -6V
R29 K22
VD18 BZX795C6
VD19
HLMP3507
GREN
R18
1K0
VD14
BZX79C11
U5
SFH610-2
A
B
R1
R3
10K
C1
0,1mF
C2
1nF
C3
10nF
C4
0,1mF
R4
K51
R5
100K
C5 0,1mF
C6 33mkF
25V
R6 13K*
C7 1nF
R7
10K
U1
SG3526
AOUT
AIN
RES
CSS
RT
CT
DT
VCC
VC
REF
SHUT
+CS
-CS
GND
(50 kHz)
BUZ80
VT1
R8 2K
C8
1nF
R9
2K
R10
0E1

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MULTICHANNEL HIGH VOLTAGE SYSTEM FOR PHOTOMULTIPLIER TUBE ARRAYS

(option for WASA experiment)

The High Voltage System (HVS) provides the powering of large arrays of PMT's ($10^2 - 10^4$) in large-scale physical experiments.

The main features of the system:

- **HIGH DENSITY, UP TO 1020 CHANNELS PER SYSTEM MODULE;**
- **HIGH STABILITY OF PMT VOLTAGES - 0.05%;**
- **THE OWN DISSIPATED POWER LESS THEN 0.15 W/channel;**
- **ABSENCE OF HV CABLES AND CONNECTORS;**
- **THE CONTROL VIA COMPUTER THROUGH SERIAL LINE RS-232-C;**
- **ON-LINE CONTROL OF ALL HV CHANNELS;**
- **ONBOARD CURRENT LIMITATION.**

FUNCTIONAL DESCRIPTION

The High-Voltage System (HVS) (Fig. 1) consists of:

1. System modules, servicing 256 PMT's each. (64 HV cells in four branches).
2. System bus, connecting system modules with high-voltage cells.
3. High-voltage cells to provide generation of high voltage for PMT powering.

The System Modules (SM) are designed as cells of the EUROMEKHANICS-6 U standard 40 mm wide.

The system bus is made from a flat cable containing 10 lines with step of 1.27 mm.

The High-Voltage Cells (HVC's) are designed as cylinders 38 mm in diameter and 35 mm long. HVC's contain a socket to connect PMT, and structurally form with the latter a functional unit.

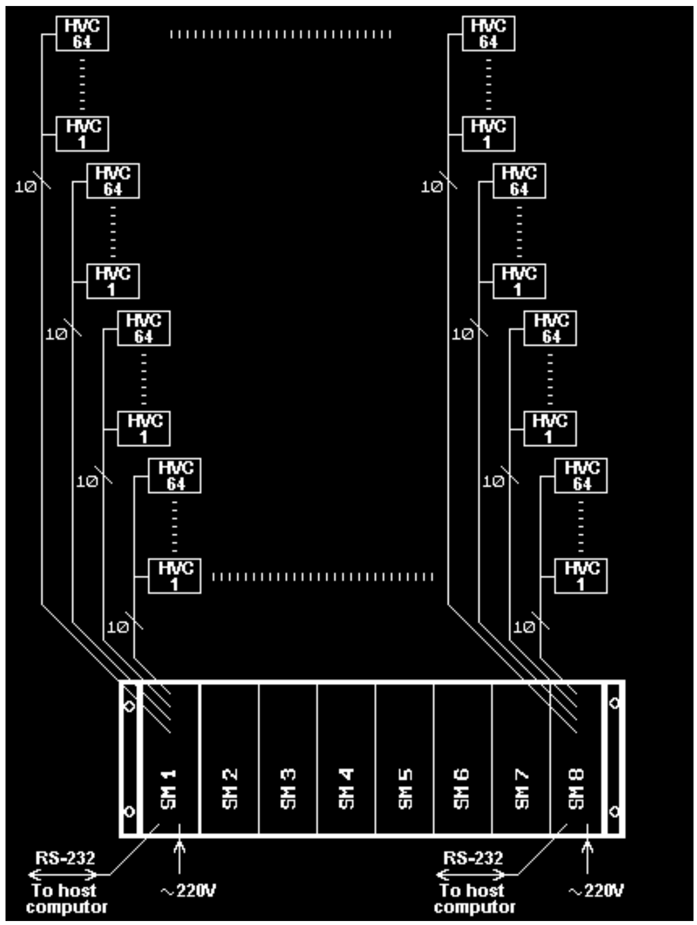

Fig.1 Functional circuit of HVS.

One SM (Fig.2) serves up to 256 HVC's. Its main units: system power supply; system microcontroller; electronic switch (ESW); readout receiver. SM is developed as a 4-channel circuit and serves independently four branches of a system bus, thus increasing flexibility of system and permitting to handle by a single SM up to 1020 HVC's.

The power supply operates in a switch mode. It provides all supply voltages for HVS. These include: ±6V for powering the low-voltage HVC part , and -200V for powering their high-voltage part. In addition, some auxiliary power supply voltages used only inside of SM, i.e. ±15V, +5V, are produced.

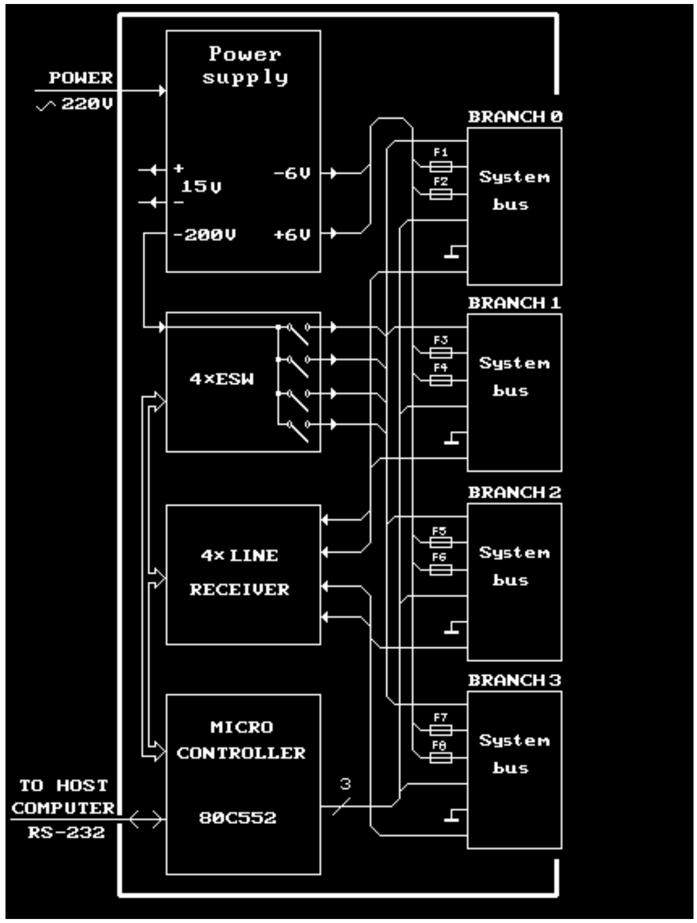

Fig.2 Functional circuit of System Module.

The microcontroller, being a part of SM structure, is constructed on the base of single chip 8-bit microcontroller PHILIPS 80C552 and microcircuit of programmed logic LATTICE 1016. The microcontroller has the builtin MONITOR operational program. It supports the communication of SM with a host computer through the serial communication RS-232 or RS-485 line. A microcontroller transforms the received information into a format necessary for the HVC operation. The microcontroller provides also both control and diagnostics of system's workability.

The readout receiver provides control of HVC operation by means of the multiplexed reading of their output voltage through a special analog line of the system bus. The receiver has four independent channels, each to serve one branch of the system bus.

The Electronic SWitches (ESW) enable and disable the -200V voltage lines. From this power line a high voltage of HVC is formed, i.e. each ESW switches on and off the HVC high voltage. The high voltage of each branch of the system bus can be switched independently. The ESW circuit implements the mode of a high voltage smooth rise and the mode of its fast switch-off. Moreover, ESW's provide an independent protection of the -200V lines from short-circuiting. This protection is a two step one. On exceeding the rated current in the -200V line an ESW goes into a current limitation mode. The microcontroller periodically (each 4 s) checks up the ESW output voltage for nominal's conformity. On detecting a voltage discrepancy of the -200V line against the nominal value, the microcontroller disconnects the ESW of the faulty line.

To protect against short-circuit the ±6V power lines, each of the system bus branches is provided with fuses (F1 - F8).

The system bus connects all HVC's of a given branch to an appropriate SM channel . All HVC's of one branch are connected in parallel. For connecting four branches of the system bus, on the SM front panel is placed a 40- pin connector.

The functional assignment of bus lines :

- ±6V - powering of the low voltage HVC part;
- −200V - powering of the high-voltage HVC part. It is used for generating all the PMT power voltages;
- HVC analog readout line;
- The 3-wire serial communication line involves:
  - SA - Synchronisation of Address recording;
  - SD - Synchronisation of Data recording;
  - A/D - Address and Data.

The HVC (Fig. 3) accepts data from the system bus and transforms these to high voltage. Each HVC has a 8-bit address switch to allocate a unique address (1-255) within a particular section of the HVS. The HVC receives a current address via system bus and compares it with its own one. If these coincide, then the HVC records the necessary data in the register of a given cell. These data will be transformed into a high voltage via a digital-to-analog converter, a voltage multiplier driver circuit and the voltage multiplier itself.

The HVC is functionally divided into two units: a driver and a voltage multiplier, each located on their own printed-circuit-board.

The driver is designed on the basis of specially developed large digital-analog integrated CMOS microcircuit (ASIC). The microcircuit integrates a large part of driver units. In Fig.3 these units are enclosed by dotted line:

- DAC - 8-bit Digital-to-Analog Converter with independent addressing and serial interface. Its address space is 8-bits;
- RVS - 2,5V Reference Voltage Supply;
- CDS - clock driver of signal, to perform frequency and phase synchronisation of signals of the driver control unit;
- BUFF - BUFFer of the driver control;
- OA - Operational Amplifiers.
- SW1 - analog SWitch of the HVC readout.

The DAC output current controls the driver circuit of voltage multiplier. The driver generates a variable voltage of rectangular shape with amplitude 0 - 200V and frequency about 10kHz. This signal is pumped up of the high-voltage multiplier.

The HVC output voltage is stabilised by a feedback loop composed of divider Rfb/Ro, follower OA1 and error signal amplifier OA2. Therefore, and also due to the availability of the built-in RVS, the HVC output voltage is stable. It does not depend on the HVC powering voltages even if these change within a rather wide range.

For zero data values Ds = 0, the HVC output voltage amounts to:

$$U_{out} = U_{ref} \times R_{fb} / R_o;$$

and for maximum data values equal to Ds = 255:

$$U_{out} = 2 \times U_{ref} \times R_{fb} / R_o.$$

The circuit of the voltage multiplier driver provides a limitation of its output current. This measure permits to keep within given limits the maximum average current from PMT anode.

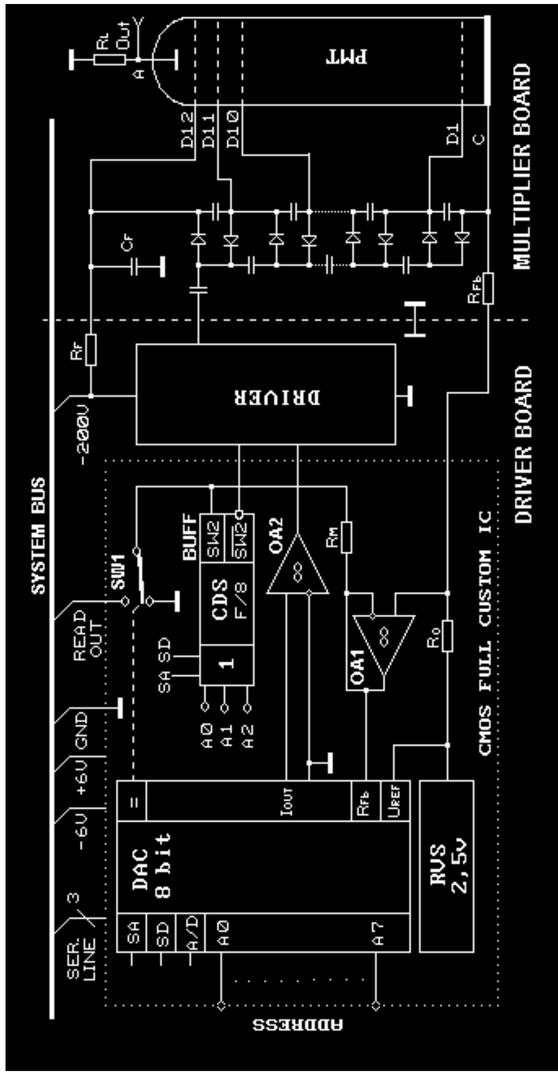

Fig.3 Functional circuit of HVC.

The clock frequency of all voltage multiplier drivers is synchronised by the CDS unit. The output part of this unit is composed of a pair of opposite high current MOS switches (BUFF) intended for controlling the driver operation and the modulation of HVC readout signal. The frequency of the CDS output signal results from division by 8 of the frequency of clock signals, SA and SD, of a serial communication line of system bus. Thereby the phase of the CDS output signals depends on a condition of three low-order bits of HVC address. This permits to distribute homogeneously in time the current pulses consumed by the HVC from the -200V power line.

The control of HVC output voltage is executed via one of the lines of system bus in an analog form. To do this, the HVC structure includes the analog switch SW1. When addressing a given cell this SW1 connects the measuring circuit to the control line of system bus.

To reduce the HVC analog readout channel error, this channel operates according to the principle of modulator-demodulator. The HVC output voltage is controlled by a signal from the divider Rfb/Ro output. On passing after voltage follower OA1 and resistor Rm this signal is modulated by switch SW2, and through multiplexed switch SW1 arrives into the analog readout line. The switch SW1 is connected to the readout line during addressing only the given HVC, and there it remains to be connected all the time up to the moment of addressing another cell.

The demodulation of readout signals is executed by readout receivers, located in SM.

The high voltage multiplier (Fig.3) operates according to the principle of a charge pump (Greinacher or Cockroft - Walton voltage multiplier). Each PMT dynode is powered from one step of the voltage multiplier. The powering of the PMT-84 last dynode is executed from the same line (-200V), which powers the driver of a voltage multiplier. Last dynode is powered via the filter RfCf.

Both schematic and topology of the multiplier printed-circuit-board depend on the intended PMT type.

OPERATIONAL DESCRIPTION.

SYSTEM MODULE (SM). On its front panel are located (from above downwards):

- switch of the 220V power line and enable indicator of the module (green);
- 40-pin connector of the system bus;
- opposite to the appropriate branch of a system bus, the enable indicators of branch high voltage (red) are located;
- above, under switch indicators of the branch, a connector "LEMO" for the remote control of a high voltage enable is located. The indication circuit is shown in Fig.4;

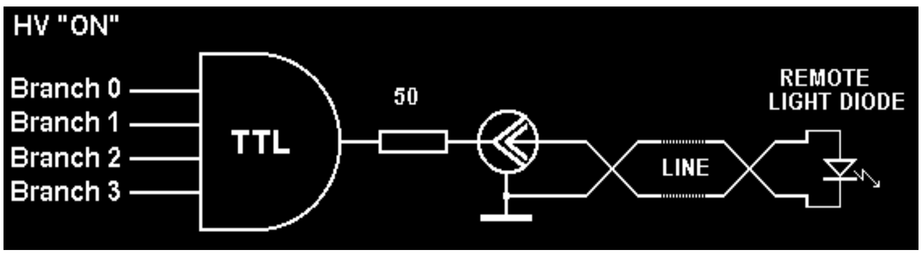

Fig.4 HV remote control circuit.

- below, over the enable indicators of branch, the connector "LEMO", marked "HV OFF" is located. It serves for simultaneous remote hardware disabling of high voltage of all the branches of the given SM module;
- under the system bus connector the "RESET" microcontroller button is located;
- below is placed the 9-pin connector of the RS-232-C communication line.

At the component side of the SM255 module printed-circuit-board, nearby the system bus connector, the power line ±6V fuses (F1-F8) are located. The even numbers correspond to the -6V line (Fuse TR5-F-1), and the odd ones, to the +6V line (Fuse TR5-F-1).

At the solder side of the SM255 module printed-circuit-board, in its top part, there is a protection fuse of 220V mains (FuseTR5-T-0,63).

At the back plane of the SM255 module supply unit is located a plug for connection to the 220V AC mains.

Even at the maximum load of 256 HVC's the SM can work in a continuous mode round the clock. In this case the SM's have to be operated with the crate ventilation switch-on.

SYSTEM BUS. The numbers of system bus lines and their assignments are given in Table 1:

Table 1

LINE	TEST	GND	+ 6V	- 6V	SA	- 200V	SD	GND	A/D	GND
Branch 0	1	2	3	4	5	6	7	8	9	10
Branch 1	11	12	13	14	15	16	17	18	19	20
Branch 2	21	22	23	24	25	26	27	28	29	30
Branch 3	31	32	33	34	35	36	37	38	39	40

The HVC's are out-of-service, except of their address switch in the system. This switch is located at the same HVC side, where the system bus connector is positioned, under the pocket in a plastic case. All the cells are manufactured being programmed for a definite address. This address is marked on cell's connector. However, if need be, this address can be changed. Thereby it is important that there would be no HVC's with identical addresses in the same HVS branch.

For changing the HVC address it is necessary to remove a pocket cover of the address switch. The appearance of the HVC address switch is shown in Fig.5. There is also given an example of its programming. Unnecessary jumpers have to be removed, while necessary ones are soldered by thin wires. The central pins of the address switch cannot be left in a non-connected state, as well as to short-circuit "ON" and "OFF" conductors. After an address change it is necessary to glue up the address pocket by black Scotch tape for the best PMT light protection.

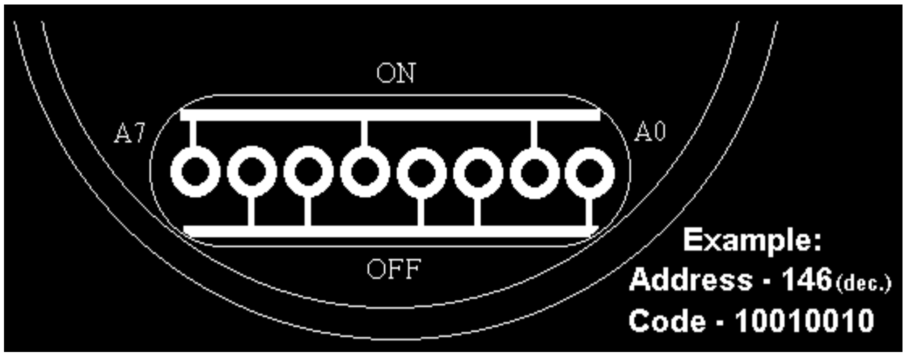

Fig.5 HVC address programming.

Mechanical fastening of the HVC cells in physical installation, and also the PMT's fastening to ensure their optical contact can be executed only by means of the external rim of the HVC case. The fastening effort directed along the axis of the cell should be applied to the rim of the case and should not exceed 10 kg.

Voltage distributions for PMT-84, PMT-115 and Hamamatsu R1924 are:

Table 2

	K G Dy1 Dy2 Dy3 Dy4 Dy5 Dy6 Dy7 Dy8 Dy9 Dy10 Dy11 Dy12 P
PMT84	0,5 1,5 1 1 1 1 1 1 1 1 1 1 1 200V
R1924	2 - 1 1 1 1 1 1 1 1 1 1 1 1
PMT115	3 2 1 1 1 1 1 1 1 1 1 1 1 200V

PROGRAMMING THE HVS

The HVS is controlled by means of MONITOR commands via the serial communication line RS-232-C. The MONITOR is a dedicated program for information interchange between HVS and host computer. This program is stored in ROM of the SM microcontroller. The MONITOR can interact with any terminal or computer possessing both RS-232-C port and program of terminal emulation .

SPECIFICATION OF RS-232 COMMUNICATION LINE.

The HVS microcontroller supports the following parameters of the RS-232 communication port:

Baudrate - 9600;
Databits - 8-bits;
Stopbits - 1-bit;
Parity - None;
Flowcontrol - None.

MONITOR OF MICROCONTROLLER.

All commands of MONITOR are divided into two groups.

The first group of commands is represented by capital letters and is intended for the HVS operation under a user program. The commands of this group do not generate any answer marks such as "ok" or "err" etc. and usually require a small time for their execution. This time is usually less than 100 mks (without the result transfer time).

H<branch> - high voltage (HV) switch-on at the corresponding branch. **Branch**=0,1,2,3. (Attention - the branch value accepts 0x0, 0x1, 0x2 and 0x3 instead of "0" or 0x30, "1" or 0x31 etc.)

G<branch> - high voltage (HV) switch-off at the corresponding branch. **Branch**=0,1,2,3. (Attention - the branch value accepts 0x0, 0x1, 0x2 and 0x3 instead of "0" or 0x30, "1" or 0x31 etc.)

I -check of the state of the high voltage switch of the SM, which is located on the front panel. "0" corresponds to the switched-off state.

T - check of the state of the automatic short circuit protection at the -200V power supply lines of the system bus. Four digits, reflecting the states of protection along each branch, are displayed on the screen. Digit "0" corresponds to a case of protection coming into action . Thereby the HV of this branch is switched-off.

W<branch cell value> - data record of **value** (0x0.. 0xff) into the cell with the address: with the number of branch, **branch** (0x0.. 0x3), and the number of cell, **cell** (0x1.. 0xff).

R<branch cell> - calling a cell. This command rewrites the value from the controller internal buffer into a cell with number **cell** (0x1.. 0xff) at a **branch** (0x0.. 0x3). It is a necessary condition for reading out the indicated cell by the readout receiver. The measured analog value is fed into an ADC input. The "R" command is used together with commands "0";..; "3" (see below). The process of measurement in line receivers of reading out lasts ~200 ms, therefore in the operational program, using the "R" commands and "0";..; "3", a delay of not less than 200 ms between the "R" command and the commands "0" ;..; "3" should be supplied.

Note: 1. As against interactive commands "c and "a" the "R" command has no internal delay of 200 ms.

2. "R" Commands and "0";..; "3" are subdivided (not unified into the one command) for the reasons of efficiency of the use of the host computer CPU.

0;1;2;3 - reading the indicated ADC channel of the microcontroller. The number of the ADC channel corresponds to the number of HVS branch . These commands are used after the "R" command for data digitisation. ADC produces the result as a 10-bit digit appropriate to the voltage at the cell addressed by the "R" command. The result is produced as two bytes, the high byte of the result being transferred first. The second transferred byte contains two low bits of the result. The measured value should be calculated as: upperbyte × 4 + lowerbyte.

4;5;6;7 - reading the ADC channels of the microcontroller which control the -200V power supply line of the system bus (the analog of the "p" command - see below). The fourth ADC channel corresponds to a zero branch of system bus etc. The format of data output corresponds to the previous case.

X - reset command of the initial phase of frequency dividers of the CDS unit of the chip (see Fig.3). The command operates at once at all the four SM branches. This command provides a correct operation phase of the time alignment circuit of the consumption current pulses of HVC's (the -200V power supply line). The same CDS unit controls the modulation phase of HVC readout signals. Therefore, the correct decoding of these signals by the line receiver (located in SM) needs the correct initial phase of the CDS frequency dividers. To do this, the "X" command is used before the data readout from HVC.

The second group of commands is presented by small letters and is intended for operation in an interactive mode with terminal emulation program. Some commands require the time slice about 0.2 s.

Format of representation of data and address:

Data - are presented by an 8-bit word. At enter they are presented by decimal numbers from 0 up to 255.

Address - is presented by a 10-bit word. Two bits - number of the SM branch, i.e. decimal numbers within 0 - 3. The cell number is presented by decimal numbers within 1 - 255. The zero cell address is not used, since it is associated with special hardware functions.

The full list and brief descriptions of monitor commands from the second group are indicated below. The commands are presented by the way of their appearance in the MONITOR help.

"h" - MONITOR help. The contents of the help are indicated below;

==

High voltage monitor help

a<adr0>,<adr1>,<adr2>,<adr3> - readout one cell of each branch
b<bran> - get Buffer and write to the branch
c<bran>,<cell> - readout of the specified cell
d<bran>,<cell> - set Default address
e<bran> - switch on high voltage at specified branch
f<bran>,<val> - Fill all addresses of the branch by the value
g<bran> - show all buffer values of the branch
i - readout state of the HV switch
m - readout of the default cell
o<bran> - switch Off high voltage at specified branch
p - power check (all - 200V line)
s<bran>,<cell>,<val> - set voltage at the specified address
t - Test status of HV short circuit protection (br0-first bit)
v<val> - set voltage at the default address
u - increase voltage at the default address by 1
l - decrease voltage at the default address by 1
x - send reset to all cells

==

a<adr0>,<adr1>,<adr2>,<adr3> - HVC readout and dumping on screen from 4 cells simultaneously. The indicated four addresses are the numbers of cells located by one in each of four SM branches. For example; "a122,3,67,90" - to readout data and to dump on screen from the 122-th cell of the zero branch, the 3-th cell of the 1-st branch, the 67-th cell of the 2-nd branch and the 90-th cell of the 3-rd branch.

b<bran> - load a block of data into specified branch cells. For convenience one can use the data loading from a file by means of the option "upload" from some program emulating the terminal (e.g. TERM90). File format is: **<adr>,<val>**
....
<adr>,<val>

c<bran>,<cell> - HVC readout and dumping on screen of the data from a single specified cell.

d<bran>,<cell> - to set address of a default cell. This command is shared with commands “m”, “v”, “u”, "l", to be described below.

e<bran> - to enable high voltage in the HVC's of a specified branch.

f<bran>,<val> - to fill all cells of a specified branch (from 0 up to 255) with some specified data.

g<bran> - to show a data buffer of microcontroller at some specified branch. The data will be dumped on screen as a table of 16x16 cells.

i - check of state of the HV switch located on the front panel of the system module. "0" corresponds to a switched off state.

m - readout of a cell with the default address set by the "d" command.

o<bran> - to switch-off high voltage at the specified SM branch.

p - to measure the voltage in all the -200V power lines, and to dump them on screen. The SM built-in microcontroller measures voltages (-200V) in each of 4 branches. Microcontroller readings are related with power line voltages as:

$$\mathbf{N = 1023 - 5 \times Up}$$

The nominal power line voltages, i.e. -200V, corresponds to the reading N = 23±2. The microcontroller MONITOR has a built-in program to track the state of these power lines. Each 4s after the high voltage enabling the microcontroller checks up the power lines voltage for conformity against the nominal. If the data readout for some -200V line exceeds 100, the microcontroller disconnects the given line.

s<bran>,<cell>,<val> - to load some data into a cell with the specified address. For example; "S2,129,203" - means to load the data valued 203 into the 129-th cell of the 2-nd SM branch. This command, as well as "c<bran>,<cell>", can be used for addressing a cell in the case of the readout without changing the data.

t - check of state of the automatic short circuit protection of the -200V power supply lines of the system bus. Four digits reflecting the states of protection at each branch are dumped on screen. Digit "0" corresponds to the case of protection operation. Thus HV on this branch will be switched off.

v<val> - to load the specified data into a cell with the default address set by command "d".

u - to increase by unity the data in a cell with default address.

l - to reduce by unity the data in a cell with default address. Both last commands need to be used for hand-operated adjustment of HVC output voltage. During a continuous pressing of one of these keys, the command is repeated in a keyboard cycle, thus resulting in a gradual voltage increase or decrease.

x - command of an initial phase clearing of frequency dividers of the CDS unit of microcircuits (see. Fig.3).

MAIN TIMING CONSTANTS OF HVS.

The effective control of the HV system needs to know the time spent for function execution.

All the commands of data interchange in system's digital part last less than 100 mks. However, the response of the HVS analog part is characterised by much longer times. Transient times of the HVS analog part are exposed below.

The voltage rise time of the -200V power lines after their enabling is set by hardware of the ESW circuit (Fig.2). The full rise time of the nominal power voltage is 2 s. The fall down time after disabling is much less and amounts to 0.2 s.

In a somewhat different way behaves the high voltage at the HVC output after its enabling by command "e". The rise time depends on the HVC voltage nominal value, but does not exceed 2 s. The fall of this voltage strongly depends on the current consumed by PMT. Without PMT current and switching off by the command "o", the time of the full voltage falling is to be up to 15 s.

The rise times of the HVC output voltage in a working mode, when the -200V power is enabled, are essentially less. The rise times for the worst case, when the output voltage varies from minimum up to maximum, is about 0.2 s. The fall down time is 0.5 s.

There are timing parities at HVC readout. Four SM readout receivers serve each own branch and work independently. The transient time of the line receiver is 0.2 s. This is the time necessary for getting an authentic readout, measured from the moment of the cell addressing. It is naturally assumed that the addressed cell is in a stationary state. If one needs to readout a cell after its data change, it is necessary to bear in mind the time of the HVC output voltage setting.

The maximum time necessary for reading 256 cells will take 12.8 s. For the greatest possible number of HVC's, i.e. 1020, this time will amount to 51 s.

MAIN RECOMMENDATIONS ON HVS PROGRAMMING.

Here we will consider in a step-by-step way main modes of handling the HVS by means of microcontroller commands.

To simplify explanations we will take an HVS example with one SM, while the high-voltage cells are connected to all its four branches.

HVS switch-on and boot-up. Before the mains power supply switch-on of an SM module it is necessary to be sure of the correctness of HVC connections and the serviceability of system bus lines. After mounting the system bus cable it is important to be sure, whether the flat cable lines were not damaged or short-circuited.

On enabling the SM, the microcontroller automatically executes initial sets in the system: disables the -200V power supply lines and initiates the "x" command for resetting the initial phase of HVC counters.

On enabling power supply, HVC cells contain some random data. Therefore the next step needs to write into cells the necessary data. For the first start these must be zero data. This operation is better to be done by means of the "f" command, when the cells of all SM branches are filled with data "0":

("f0,0"; "f1,0"; "f2,0"; "f3,0")

Configuring the HVS. We have also to do one very important preparatory procedure: to obtain "zero" settings of cells within the whole HVS address space. This procedure will help us to solve simultaneously the following three tasks:

1. To reveal the addresses of all physically existing HVS cells (i.e. all the cells, which SM microcontroller "sees" at the given moment as connected to system bus);
2. To reveal the addresses of faulty cells and of conflicts along system bus;
3. To fix values of zero settings for all the really existing cells.

The first two tasks are solved by the logical analysis of readout data. The normally functioning cell has zero setting within 0-120. On addressing a cell, which is physically absent, the readout receiver will produce 1023. This is the basis for identifying a serviceable and physically existing cell. If some address settings lay within (120 - 1022), then the cells located at these addresses are faulty or these latter are the addresses of system bus conflicts. Such a conflict occurs, if one branch of system bus is connected with several HVC's having identical addresses. The address map of all the physically existing cells and their zero settings must be stored during the whole cycle of HVS operation. These N0 settings will be necessary afterwards for the correct determination of real values of output HVC voltage.

To save the time, the reading of the whole array of cells is better to be done by the "a" command. Thereby in each reading cycle 4 cells will be readout at once. The time saving occurs due to the parallel operation of SM line readout receivers. The time necessary for reading one cell is 0.2 s. Thus, the reading of all the HVS cells, with 64 cells per branch, will take some 13 s.

Now HVS is prepared for high voltage to be enabled, and we can pass to the following step.

Enabling the high voltage. To enable high voltage at some HVS branch needs the command "e<branch>". On executing this command, the HVC outputs of the given branch will show the voltages corresponding to the data written in these HVC's. If at the boot-up step the cells were filled by data "0", then these voltages will be minimum. One can check the execution of that command by reading voltages of the -200V power supply lines or by reading the output HVC voltages. The first variant comes true by the "p" command. As the result of execution of this command, the microcontroller communicates four settings appropriate to each of the HVS branches. The nominal voltage of a -200V power supply line corresponds to a setting within 23 ±2. For the second check variant see section "Readout of output HVC voltages" below.

Loading the data into HVC's. The way of data loading depends on the task.

At the initial start step of physical set-up more preferable may be the mode of "hand-operated" rise and adjustment of high voltage. The boot-up of all the cells corresponds to Ds=0. On defining the nominal values of working voltages by a "hand-operated" tuning of all HVC's, the data will written into the special file of data storage. For the "hand-operated" regulation of cell voltages it is convenient to use the commands with default address: "d<bran>,<cell>"; "v< val > "; "u"; "l".

In a step of physical set-up debugging, a mode of smooth rise of high voltage is more preferable. The boot-up of all the cells also corresponds to Ds=0. On enabling the high voltage the data are incremented with some step, until they achieve their nominal value. These nominal data values, obtained at the step of the initial start, are taken from the data storage file.

At the step of routine operation, preferable is a mode of fast rise of high voltage. Here one already has a sufficient confidence in the normal operation of physical set-up. Therefore, at the boot-up step nominal data values are transferred at once. This done, one enables high voltage.

The value of HVC output voltage (Uout) and control data (Ds) are related as:

$$\mathbf{Uout = Ds \times Ks + Umin; \quad Ks = (Umax - Umin)/255;}$$

where Umax and Umin are limiting values of output voltage of the given type of HVC.

The HVC output voltage error depends on the tolerances of the measuring resistors Rfb and Ro used in the HVC circuit (see. Fig.3) and can amount to 5%. Therefore, the weight coefficient of the control channel, Ks, is taken to be equal to its average value for the given type of cell.

HVC output voltage readout. This procedure is one of the most frequently used during HVS operation. The correctness of organisation of the readout procedure effects the reliability of the information about HVS operation.

The readout of one of the HVS cells can be executed by means of the command "c<bran>,<cell>". One has to remember that for obtaining an authentic setting, the analog channel of cells readout needs the time of some 0.2 s. Besides, for obtaining the true values of readout data, Dr, it is necessary to subtract zero values N0, obtained for each channel in the HVS configuring (with high voltage switched off). Then one can find the PMT cathode voltage expressed in volts according to the following relation:

$$\mathbf{Uout = Dr \times Kr;}$$

where Kr - transmission factor of the readout channel for the given HVC type. Again, we deal with the average values of readout channel transmission factor, since their individual values for each HVC are a little bit different and dependent on the tolerances of measuring resistors Rfb and Ro, used in the HVC circuit (see. Fig.3).

Digit capacity of the data readout channel is Dr = 10-bit. The inherent error of the readout channel amounts to ±1-bit. As the value of Kr usually lays within (1.5-2.5), and its individual spread over cells can be up to ±5%, the systematic error of the readout channel can reach up to ± 100 Volt.

It is obvious that the reading of the whole HVC array will be used much more often. To save the time in reading all the HVS cells, it will be more preferable to use the command "a<adr0>,<adr1>,<adr2>,<adr3> ". Before the beginning of the reading procedure of the whole cell array the "x" command must be executed.

Table 3

THE MAIN HVS CHARACTERISTICS FOR the WASA EXPERIMENT

1. Number of channels per one system module 256
2. Number of system modules .... no limitation
3. Range of the photocathode voltage, V.
   cell for PMT-84 .... 1150 - 2280
   cell for Hamamatsu R1924 .... 650 - 1300
   cell for PMT-115 .... 1000 - 2000
4. Systematic error of the output voltage definition, % 5
5. Maximum of average current at the PMT anode, mkA
   cell for PMT-84 2000
   cell for Hamamatsu R1924 200
   cell for PMT-115 500
6. Step of voltage regulation at the photocathode, V .... (Umax - Umin)/256
7. Stability of voltages supplied to PMT, % 0.05
8. Temperature factor of the output voltage, PPM / K 200
9. Oscillator/signal crosstalk, injected charge, pC .... < 0.1
10. Power dissipation for one HV cell, W 0.15
11. Maximum length of the system bus from HVS crate to the last HVC, m 30
12. Full diagnostic system of the HVS functioning .... YES
13. Power, 220v, (180 - 250 V); 50-60 Hz; VA 100
14. System module standard EUROMEKHANICS-6Ux40
15. Size of the HVC
    cell for PMT-84 (Fig.6), mm .... diam. 38x30
    cell for Hamamatsu R1924 (Fig.6), mm .... diam. 38x34
    cell for PMT-115 (Fig.7), mm .... diam. 30x50

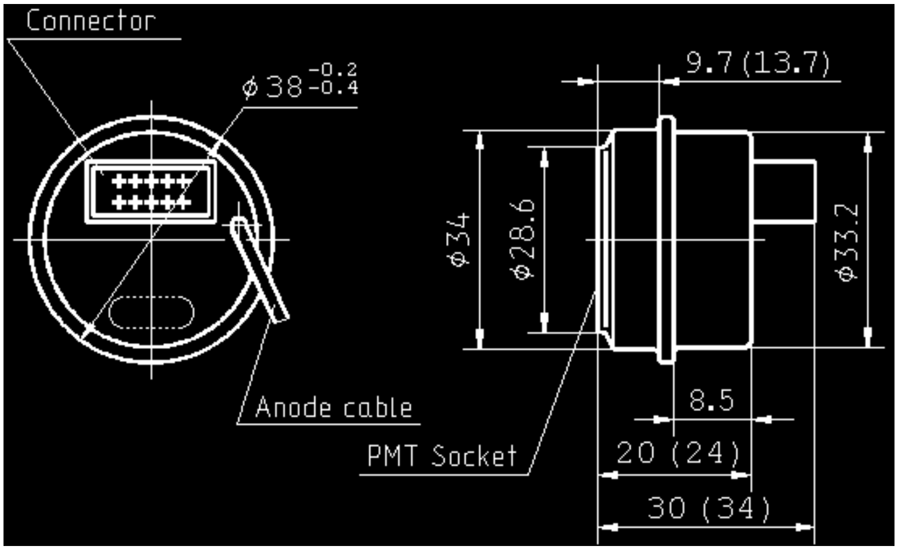

Fig.6 HVC for PMT-84 and (PMT R1924).

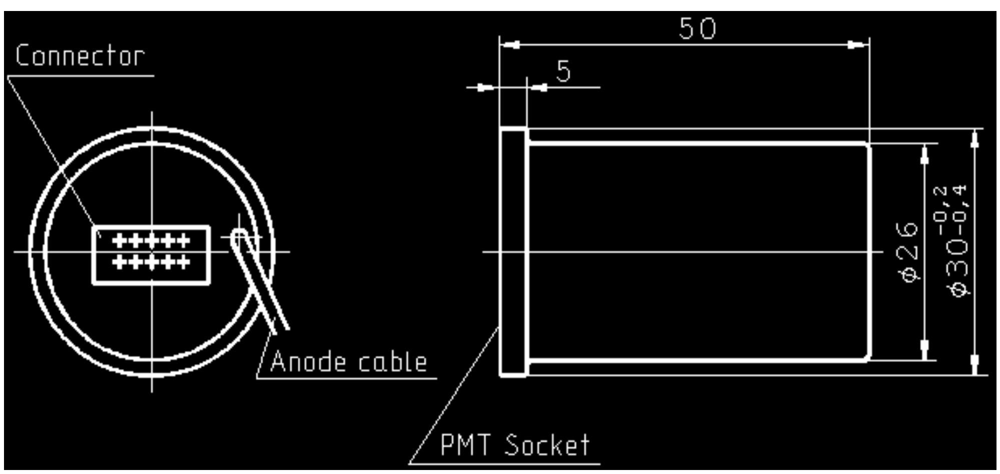

Fig.7 HVC for PMT-115.

INDEX OF ABBREVIATION AND NOTATIONS

A/D - interface of system bus; address/data transfer line

ADC - analog-to-digital converter

BUFF - functional IC unit; buffer of driver control signals

CDS - functional IC unit; clock driver of signal. Performs both frequency and phase synchronisation of driver control signals

DAC - functional IC unit; digital-to-analog converter

Ds - notation of data loaded into HV cells (0-255)

Dr - notation of data received from HV cells (0-255)

ESW - functional unit of system module ;
electronics switch for HV enabling/disabling

HV - high voltage

HVC - high voltage cell

HVS - high voltage system

Kr - transfer ratio of HVC readout channel

Ks - transfer ratio of HV control channel of HVC's:

$$Ks = (Umax - Umin)/255$$

N0 - zero count of HVC readout channel, i.e. the count corresponding to the zero HVC output voltage

OA - functional system unit; operational amplifier

PMT - photomultiplier tube

ROM - programmable read-only memory

RS-232-C - interface of digital serial communication line

RVS - functional system unit; reference voltage supply

SA - interface of system bus; address synchronisation line

SC - short-circuit

SD - interface of system bus; data synchronisation line

SM - HVS system module

SW - IC functional unit;

SW1 - analog switch of HVC readout multiplexer

SW2 - analog switch for controlling driver operation and signal modulation in HVC readout system

Umax - maximum feasible value of HVC output voltage

Umin - minimum feasible value of HVC output voltage

Uout - HVC output voltage

CONTENTS