Multi-Aperture Scintillation Sensor. Detailed design

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Introduction

This document is an appedix to Final Design Document (Main document). The document contains the detailed information on MASS device, which will be needed in a case of device malfunctions or fault. The information will be useful for exact understanding the device possibilities and potentials.

Features of electronics — circuit diagrams, printed circuit board views, their specifications are provided in Appendix 1. Next Appendix contains detailed description of the module command set. The low level commands can be used during handling of non-standard situatons, which can arise in test, adjust or repair process.

Appendix 3 presents a specification on optical elements of the MASS device and optical drawings for all elements, commercially available or specially manufactured.

Appendix 4 contains a specification on the all mechanical parts, assembly drawing and detailed drawing for information only.

Appendix 1

Electronics

The electronics design is performed as the base of the modular conception explained in the Main Document earlier. In the next sections the circuit diagrams of the modules are presented. Generally accepted designations of schematic elements are used, except designation for resistors (we used a russian symbolic for them).

The connectors are also marked in a special way. Connectors to external cable and wires are denoted by a letter "X", Internal connectors are divided into four groups: 1) Soldered connectors are marked with a letter "S", 2) Inter-board connectors, which link different parts of the same module — with "I", 3) Connectors to internal bus, which links the different modules — "Y", 4) Special connectors for In System Programming technique are denoted as "ISP".

The nominal values of passive elements are shown on the schemes. The active element features are shown in specification tables which are included, too. Component manufacturer are not shown in cases of wide spread parts.

Also, this Appendix contains the schematic views of the module PCBs with the component placement for easy identification of the schematic element with the real component used.

1.1 Photometric modules

The circuit diagrams of the photometric module are shown in Fig. 1.1, 1.2, 1.3. PCB views are presented in Fig. 1.4.

Table 1.1: Specification for a Photometric module (see SCH01A, SCH01B, SCH01C).

Item	Part	Name	Manufacturer	Q-ty	Rem
1	D1	IC LMC7221BIM5	Nat.Semicond.	1	
2	D2	IC SA5205AD	Philips	1	
3	D3	IC AD8561AR	Analog Dev.	1	
4	D4	IC AD1580ART	Analog Dev.	1	
5	D5	IC AD8400AR1	Analog Dev.	1	
6	D6	IC HC4520D	Philips	1	SOIC-16
7	D7	IC AT90S2313-10SI	Atmel	1	
8	D8	IC ADM1485AR	Analog Dev.	1	
9	Z1	Quartz 7.138MHz	—	1	HC49S
10	R1-R11	Chip resistors	—	11	0805 size
11	L1,L2	Chip inductances	Bourns	2	1812 size
12	C1-C5	Chip capacitors	—	5	0503 size
13	C6,C7	Chip capacitors	—	2	1208 size
14	C8	Tantal chip capac.	—	1	A size
15	C9-C12	Chip capacitors	—	6	1208 size
16	C13	Tantal chip capac.	—	1	B size
17	C14,C15	Chip capacitors	—	2	0805 size
18	ISP	ISP connector	—	1	PLD-6
19	S1	Input connector	Custom	1	Soldering
20	X2	Line conn. RJ12	—	1	TJ6-6P6C
21	I1(B)	Pins conn.(pins)	—	1	PLS-8
22	I1(A)	Pins conn.(sockets)	—	1	PBS-8
23	R12-R23	Chip resistors	—	12	1208 size
24	C16	Ceramic capac.	—	1	1.6 KV
25	X3	PC75-110 conn.	—	1	for HV
26	S4	Out conn.	Custom	1	Soldering
27	X5	Pins conn.(pins)	—	1	PLSR-2
28	PCB01A	Printed board	Custom	1	
29	PCB01B	Printed board	Custom	1	
30	PCB01C	Printed board	Custom	1	

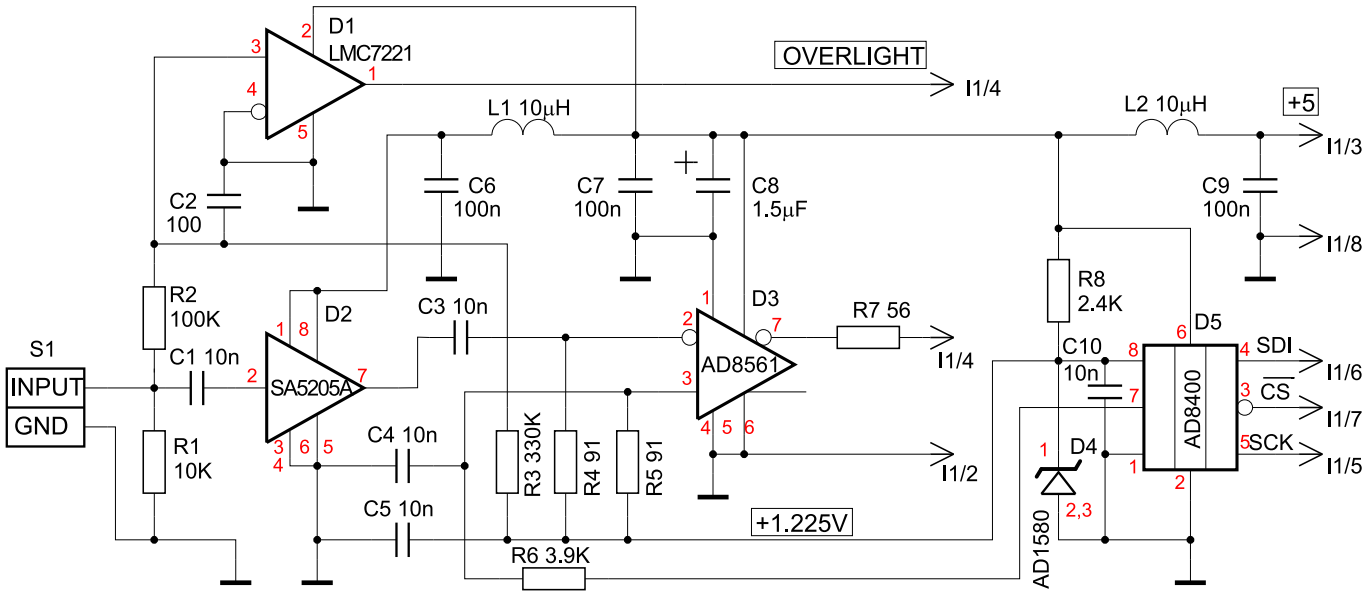


Figure 1.1: Circuit diagram of the Photometric module electronics. SCH01A. Pulse amplifier and discriminator with level control.

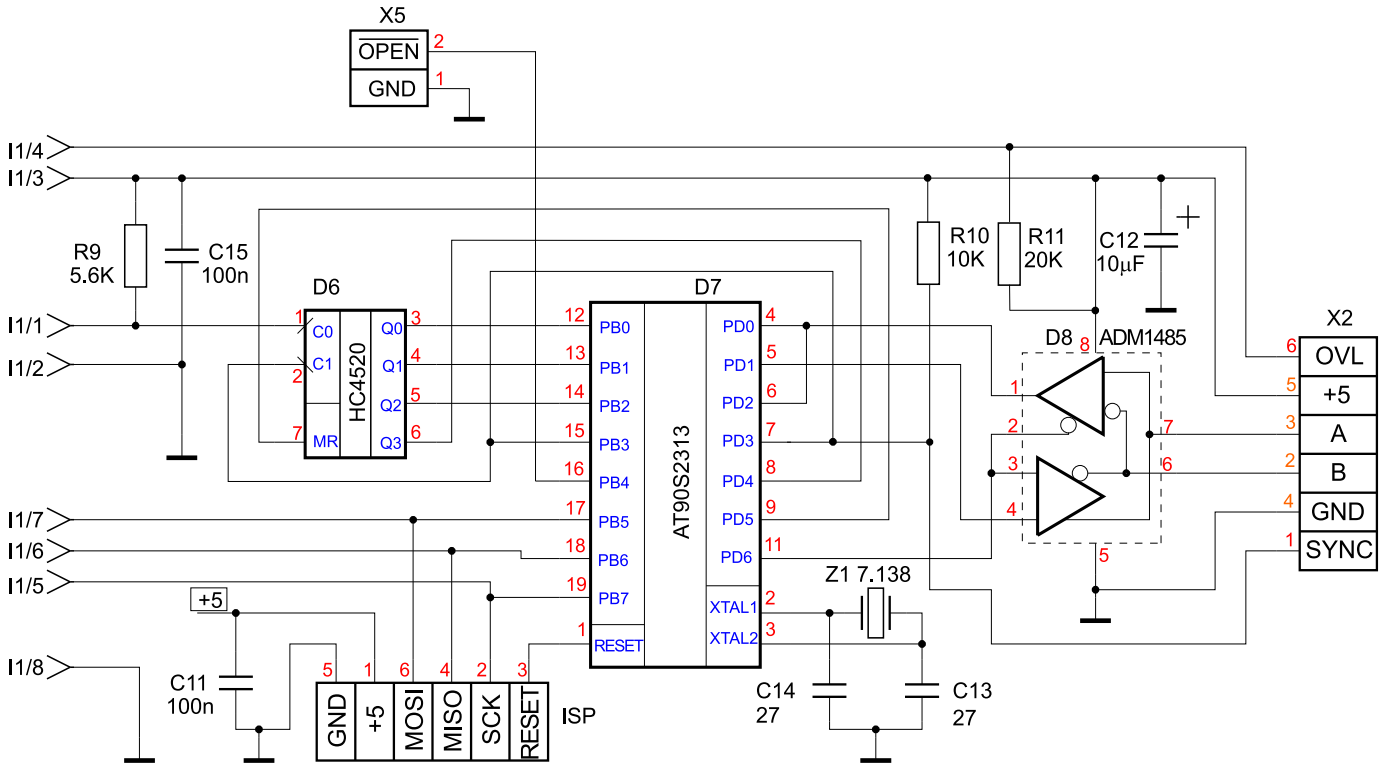
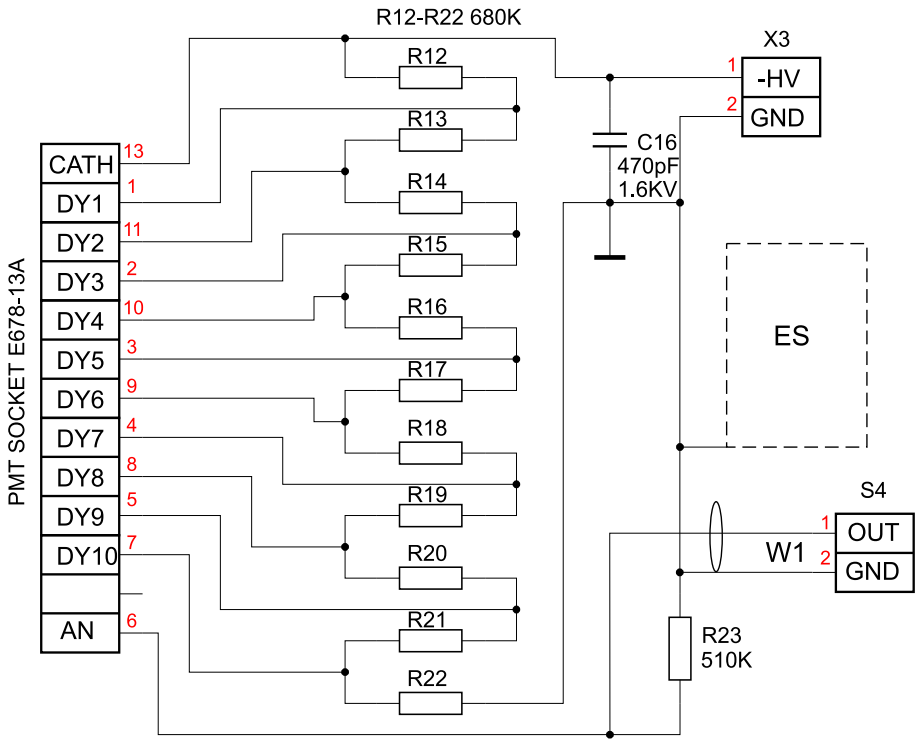


Figure 1.2: Circuit diagram of the Photometric module electronics. SCH01B. Controller and line interface.



1. Stub W1 — coaxial cable 50Ω, Ø2.0 mm, l = 65 mm.
2. Electrostatic shield ES see PH01H.

Figure 1.3: Circuit diagram of the Photometric module electronics. SCH01C. High voltage divider for PMT.

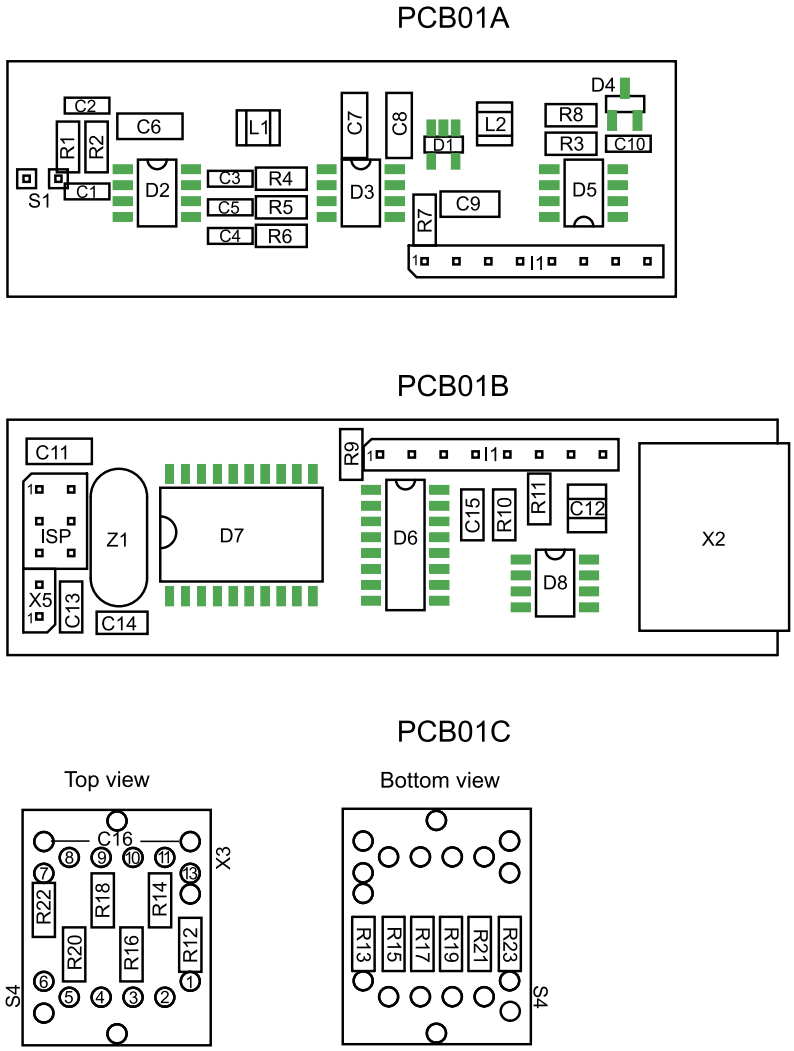


Figure 1.4: Placement of the components on printed circuit boards of the Photometric module electronics. Designation are the same as in circuit diagrams in Fig. 1.1, Fig. 1.2 and Fig. 1.3

1.2 Crossing board and cables

The circuit diagrams of the cross board and cables are shown in Fig. 1.5, Fig. 1.6, and Fig. 1.7. PCB view and crossing flat cable dimensions are presented in Fig. 1.8 and Fig. 1.9.

Table 1.2: Specification for the Crossing board and cables (see SCH02A, SCH02B, SCH02C).

Item	Part	Name	Manufacturer	Q-ty	Rem
1	D1	Mod. TEM2-1211	Traco Power	1	DIP-24 size
2	V1	LED Yellow	—	1	D=3mm
3	V2	LED Red	—	1	D=3mm
4	V3	LED Green	—	1	D=3mm
5	R1-R8	Chip resistors	—	8	0805 size
6	L1	Chip inductances	Bourns	1	1812 size
7	C1,C2	Chip capacitors	—	2	1208 size
8	C3	Alum.capacitor	—	2	6 mm
9	C4,C6	Chip capacitors	—	2	1208 size
10	C7	Chip capacitors	—	1	1208 size
11	C5,C8	Tantal chip capac.	—	2	B size
12	X1-X6	Line conn. RJ12	—	6	TJ6-6P6C
13	Y7	Pins conn.(pins)	—	1	PLD-10
14	X8, X9	Power conn. DJK-01A	—	2	Updated
15	Y11-Y14	Cable conn IDC10	—	4	IDC-10
16	W1	Flat cable 10 wire	—	1	about 15 cm
17	S10	Solder conn.	Custom	1	soldering
18	X16, X17	Pins connectors	—	2	BLS-2
19	W3, W4	Wires	—	4	about 70 cm
20	W5	Cable	—	4	about 100 cm
21	X18, X19	Connect. RJ12	—	8	RJ12-6P6C
22	X20	Connect. RJ12	—	1	RJ12-6P4C
23	W6	Shielded cable STP2	—	1	15 m
24	X21	Connector DB9F	—	1	
25	PCB02A	Printed board	Custom	1	

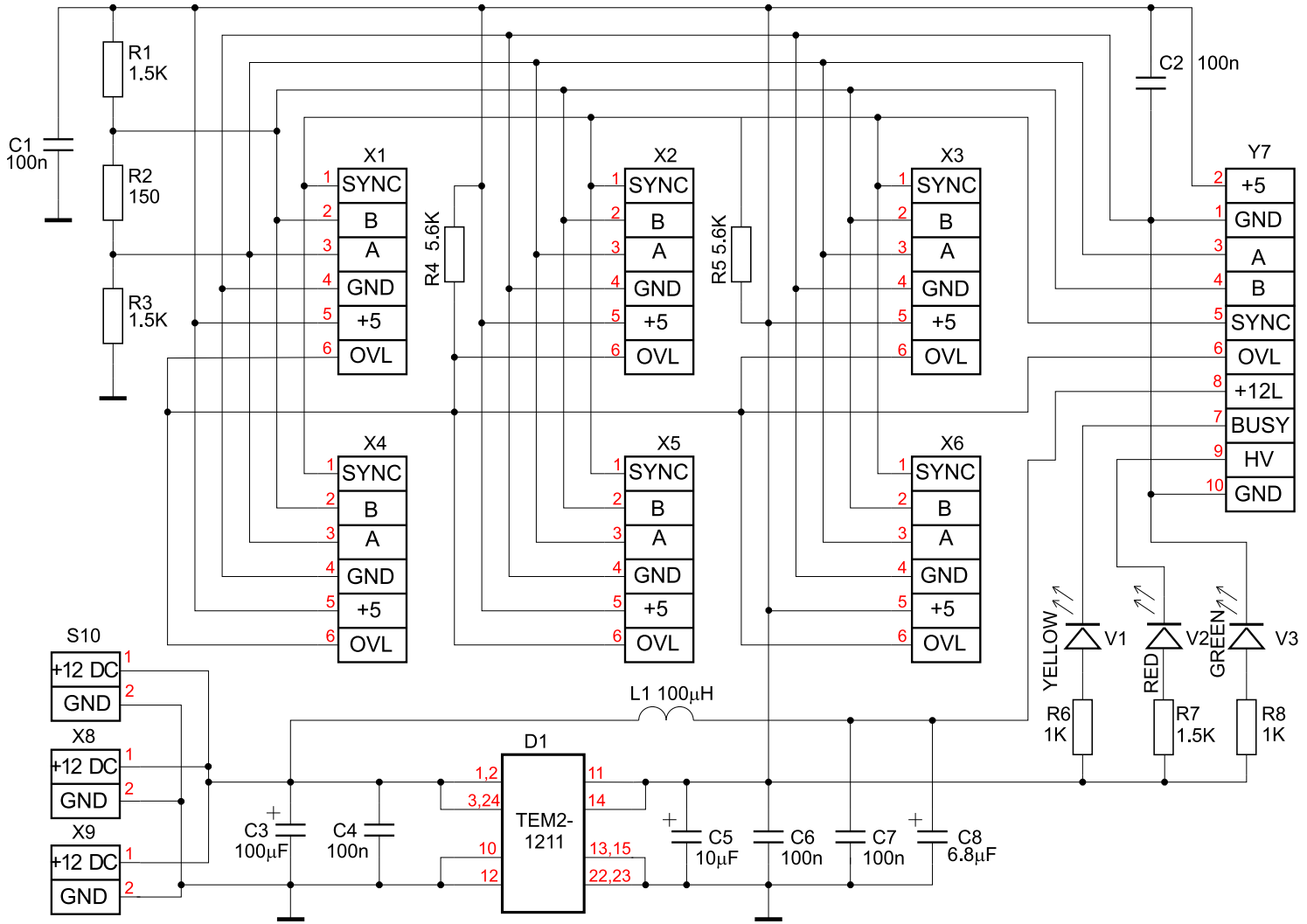
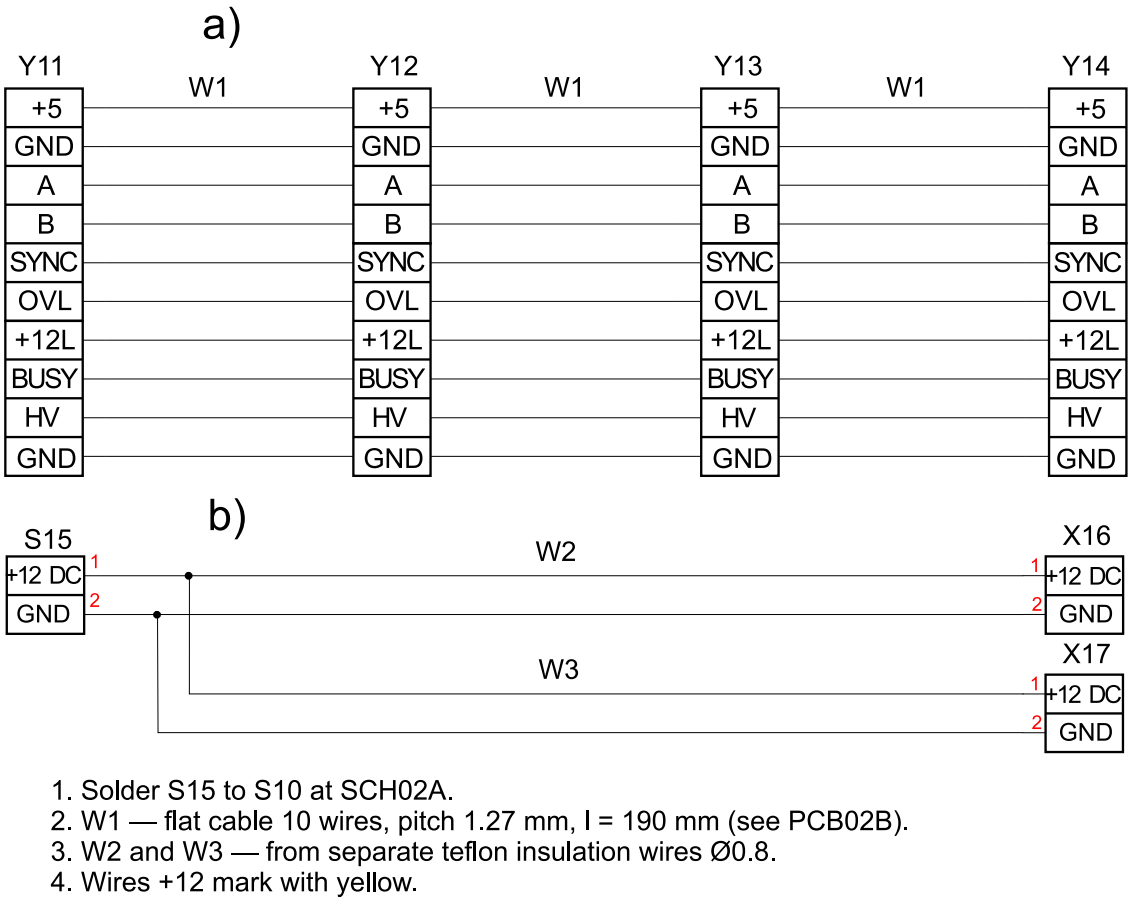
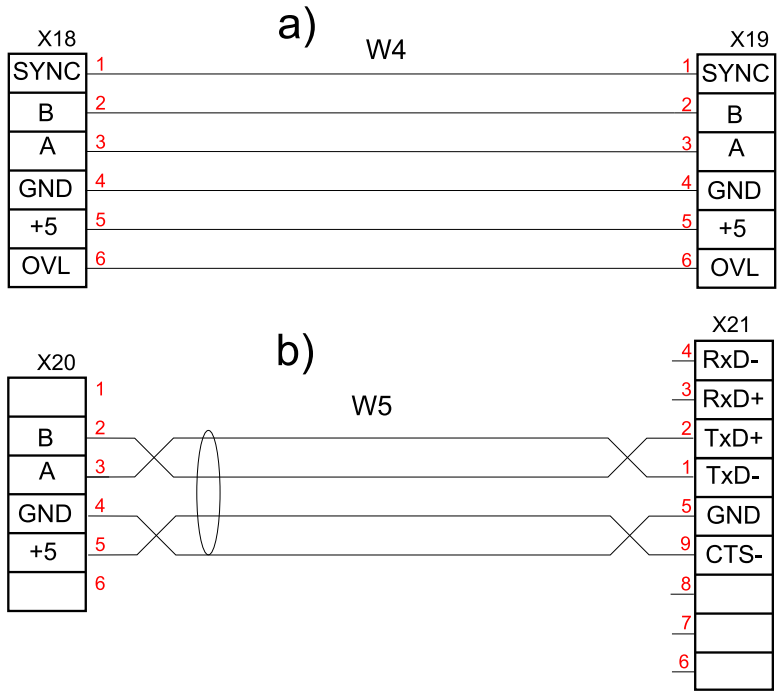


Figure 1.5: Circuit diagram of the Cross board electronics. SCH02A. Input and internal connectors, DC–DC converter and MASS status indicators.



1. Solder S15 to S10 at SCH02A.
2. W1 — flat cable 10 wires, pitch 1.27 mm, l = 190 mm (see PCB02B).
3. W2 and W3 — from separate teflon insulation wires Ø0.8.
4. Wires +12 mark with yellow.

Figure 1.6: Circuit diagram of the Crossing flat cable (SCH02B) which connects together all the electronic modules of the MASS device (a). The power cables for +12 DC for motor and HV converter supply. (b).



1. Line stub W4 — telephone flat cable 6 wires, l = 25 - 35 cm.
2. Line W5 — shielded 2 twisted pair cable STP2, l = 15 m.
3. X21 connector DB9F for MOXA CP132 board
4. X21 signals is marked as in MOXA User's Manual

Figure 1.7: Circuit diagram of the line stub for connection of the photometric modules to crossing plate (a). Line for connection of a MASS device to a MOXA board (b).

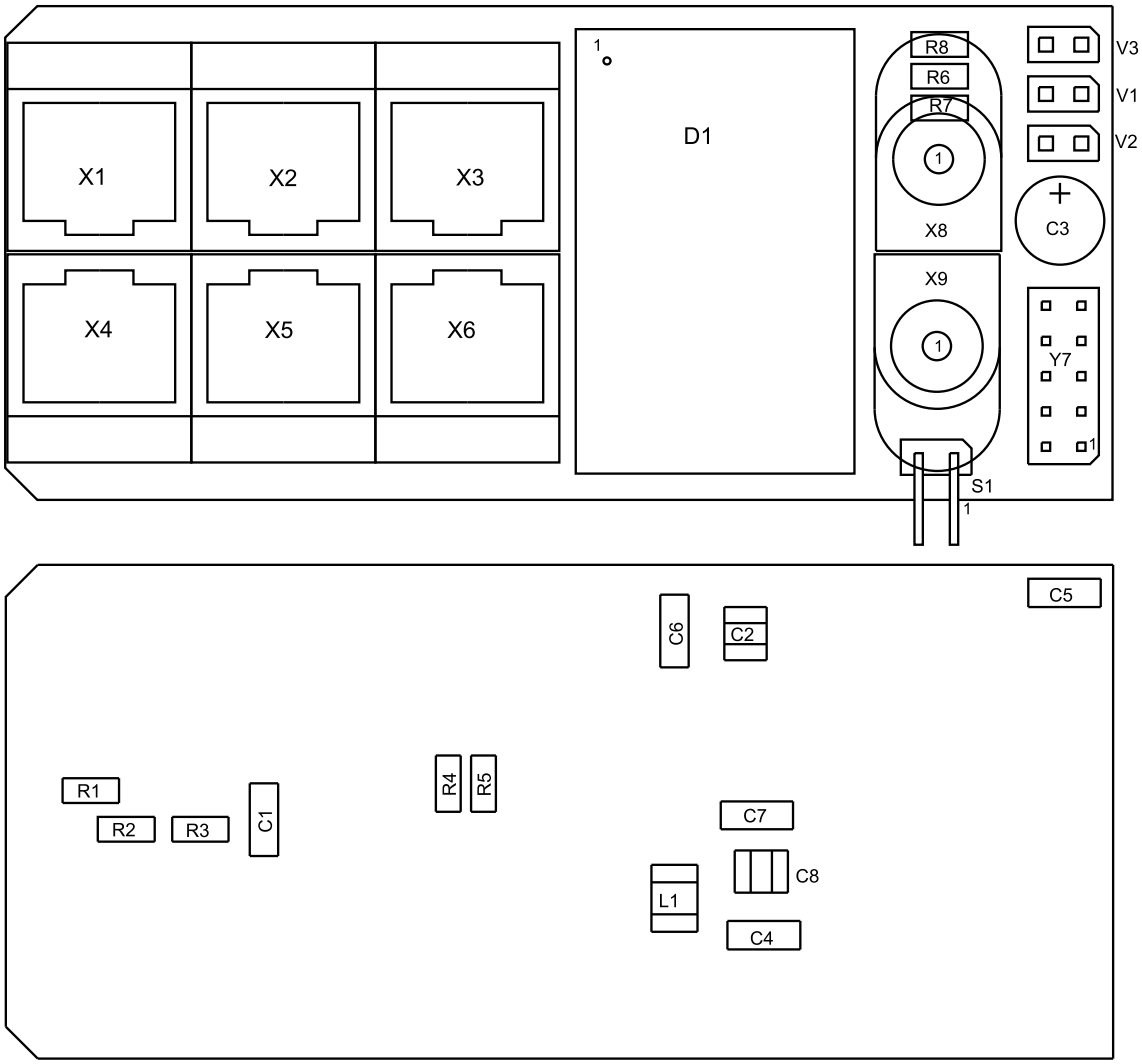


Figure 1.8: Placement of components on the printed circuit boards for the Cross board. Designations are the same as in circuit diagrams in Fig. 1.5

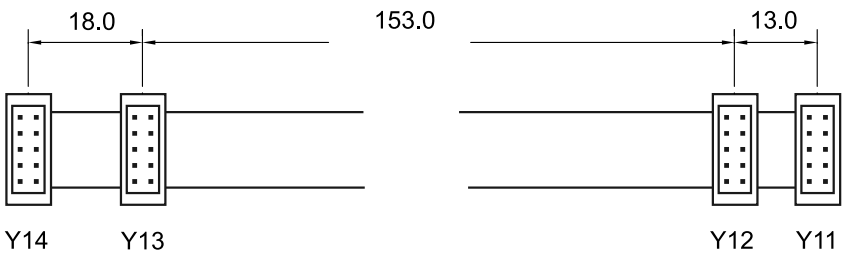


Figure 1.9: Dimensions of the Crossing flat cable. Designation are the same as in circuit diagrams in Fig. 1.6

1.3 Light control and buttons service electronics

The circuit diagrams of this module are shown in Fig. 1.10 and Fig. 1.11. PCB views are presented in Fig. 1.12.

Table 1.3: Specification for the Light and Buttons controller (see SCH03A, SCH03B, SCH03C).

Item	Part	Name	Manufacturer	Q-ty	Rem
1	D1	IC AD1580ART	Analog Dev.	1	
2	D2	IC AD8402AR10	Analog Dev.	1	
3	D3	IC LM2904M	Nat.Semicond.	1	
4	D4	IC AT90S2313-10SI	Atmel	1	
5	D5	IC ADM1485AR	Analog Dev.	1	
6	Z1	Quartz 7.138MHz	—	1	HC49S
7	V1	LED L1002GD	Kingbright	1	Green
8	V2-V6	LED L1002HD	Kingbright	5	Red
9	V7	LED L1002GD	Kingbright	1	Green
10	R1-R12	Chip resistors	—	12	0805 size
11	C1-C3	Chip capacitors	—	3	1208 size
12	C4,C5	Chip capacitors	—	2	0805 size
13	C6,C7	Tantal chip capac.	—	1	B and A size
14	C8-C10	Chip capacitors	—	3	0805 size
15	ISP	ISP connector	—	1	PLD-6
16	B1-B3	SWT-9 buttons	—	3	12x12 mm
17	I1(C)	Pins conn. (pins)	—	1	PLDR-4
18	I1(A)	Pins conn.(sockets)	—	1	PBD-4
19	I2(B)	Pins conn.(pins)	—	1	PLD-8
20	I2(A)	Pins conn.(sockets)	—	1	PBDR-8
21	Y1	Pins conn.(pins)	—	1	PLD-10
22	PCB03A	Printed board	Custom	1	
23	PCB03B	Printed board	Custom	1	
24	PCB03C	Printed board	Custom	1	

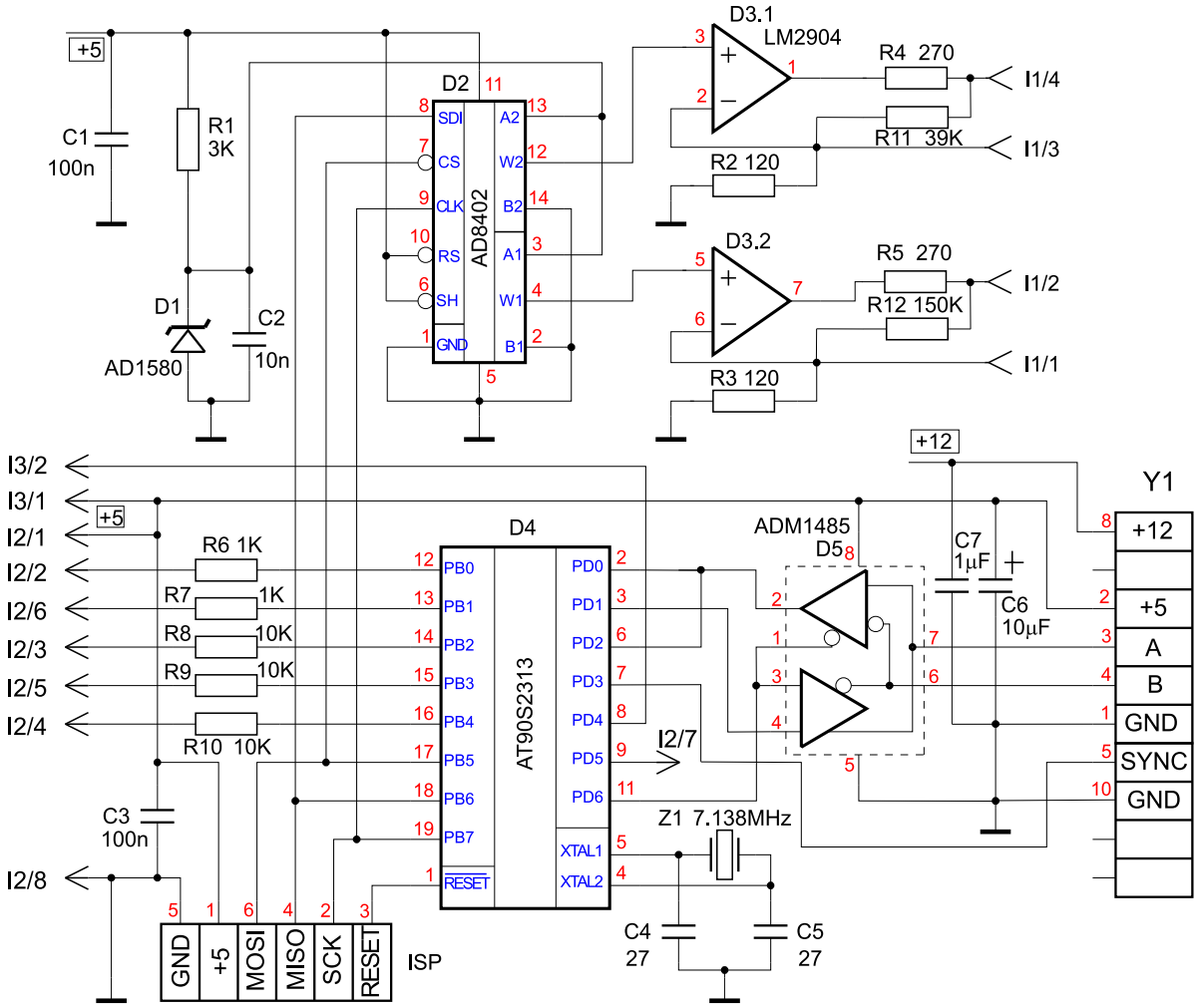


Figure 1.10: Circuit diagram of the Light and Buttons controller. SCH03A. Controller and line interface.

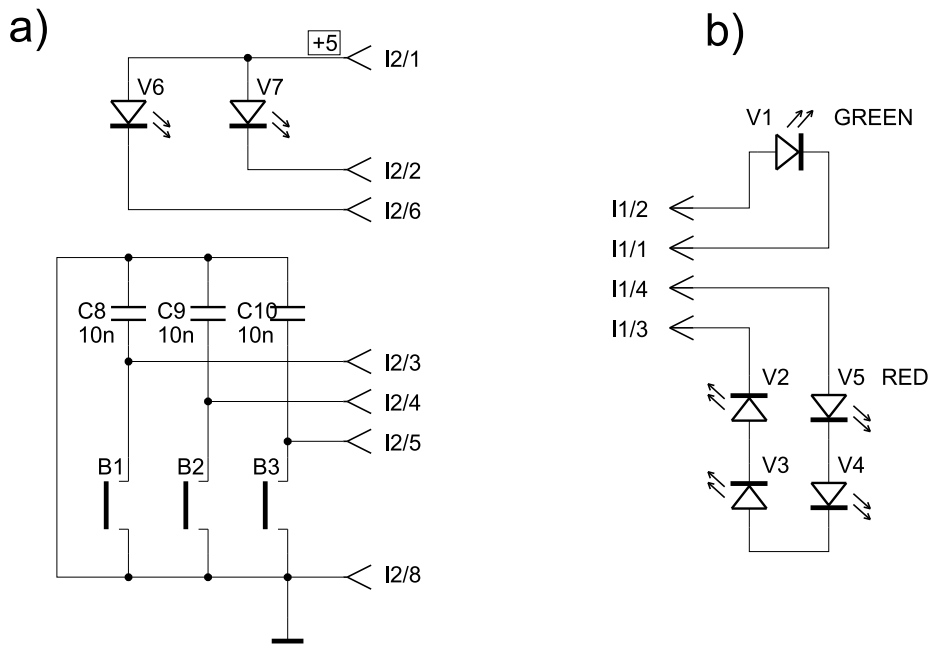


Figure 1.11: a) Circuit diagram of the detachable buttons mini-case (SCH03B). b) Aperture illumination and control light circuit (SCH03C).

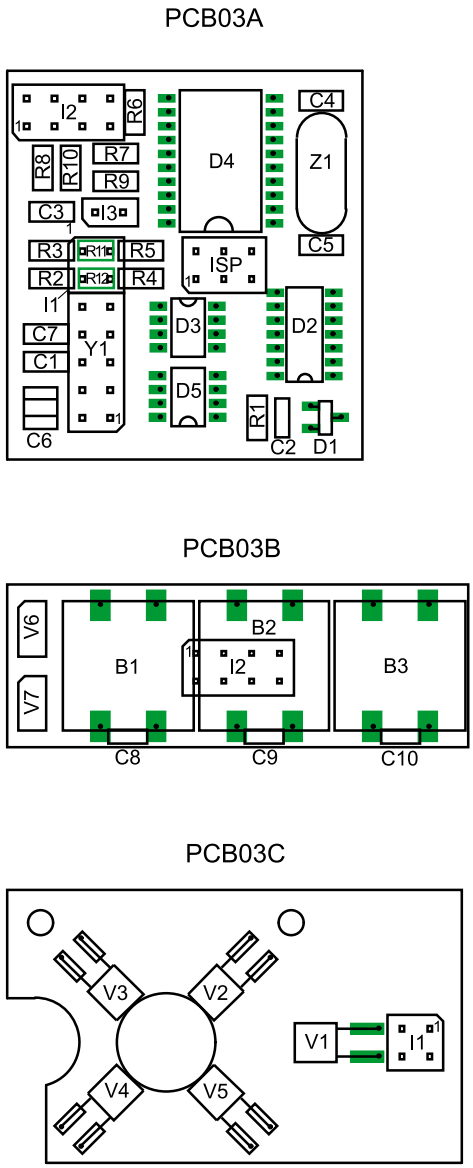


Figure 1.12: Printed circuit boards for the Light and Button controller top view. Placement of all components is shown. Designations correspond to that shown in Fig. 1.10 and Fig. 1.11

1.4 Stepper motor controller

The circuit diagrams of the stepper motor controller module are shown in Fig. 1.13 and Fig. 1.14. PCB views are presented in Fig. 1.15.

Table 1.4: Specification for the Stepper motor controller (see SCH04A, SCH04B, SCH04C).

Item	Part	Name	Manufacturer	Q-ty	Rem
1	D1	IC SS141A	Honewell	1	SMD
2	D2	IC PBL3777SI	Ericcson	1	
3	D3	IC LM2904M	Nat.Semicond.	1	
4	D4	IC AT90S2313-10SI	Atmel	1	
5	D5	IC ADM1485AR	Analog Dev.	1	
6	D6	IC AD8402AR10	Analog Dev.	1	
7	D7	IC SS41	Honewell	1	Bipolar
8	Z1	Quartz 7.138MHz	—	1	HC49S
9	R1	Chip resistors	—	1	0805 size
10	R2, R4	Chip resistors	—	2	1510 size
11	R3, R5	Chip resistors	—	2	0805 size
12	R6, R7	Chip resistors	—	2	0805 size
13	C1	Tantal chip capac.	—	1	A size
14	C2–C4	Chip capacitors	—	3	0805 size
15	C5, C6	Chip capacitors	—	2	1208 size
16	C7	Alum.capacitor	—	1	6 mm
17	C8–C11	Chip capacitors	—	4	0805 size
18	C12	Tantal chip capac.	—	1	B size
19	C13, C14	Chip capacitors	—	1	1208 size
20	ISP	ISP connector	—	1	PLD-6
21	I2(C)	Pins conn. (pins)	—	1	PLDR-4
22	I2(A)	Pins conn.(sockets)	—	1	PBD-4
23	I1(B)	Pins conn. (pins)	—	1	PLS-8
24	I1(A)	Pins conn.(sockets)	—	1	PBS-8
25	X1	Pins conn.(pins)	—	1	PLSR-4
26	X2	Pins conn.(pins)	—	1	PLSR-2
27	Y3	Pins conn.(pins)	—	1	PLD-10
28	PCB04A	Printed board	Custom	1	
29	PCB04B	Printed board	Custom	1	
30	PCB04C	Printed board	Custom	1	

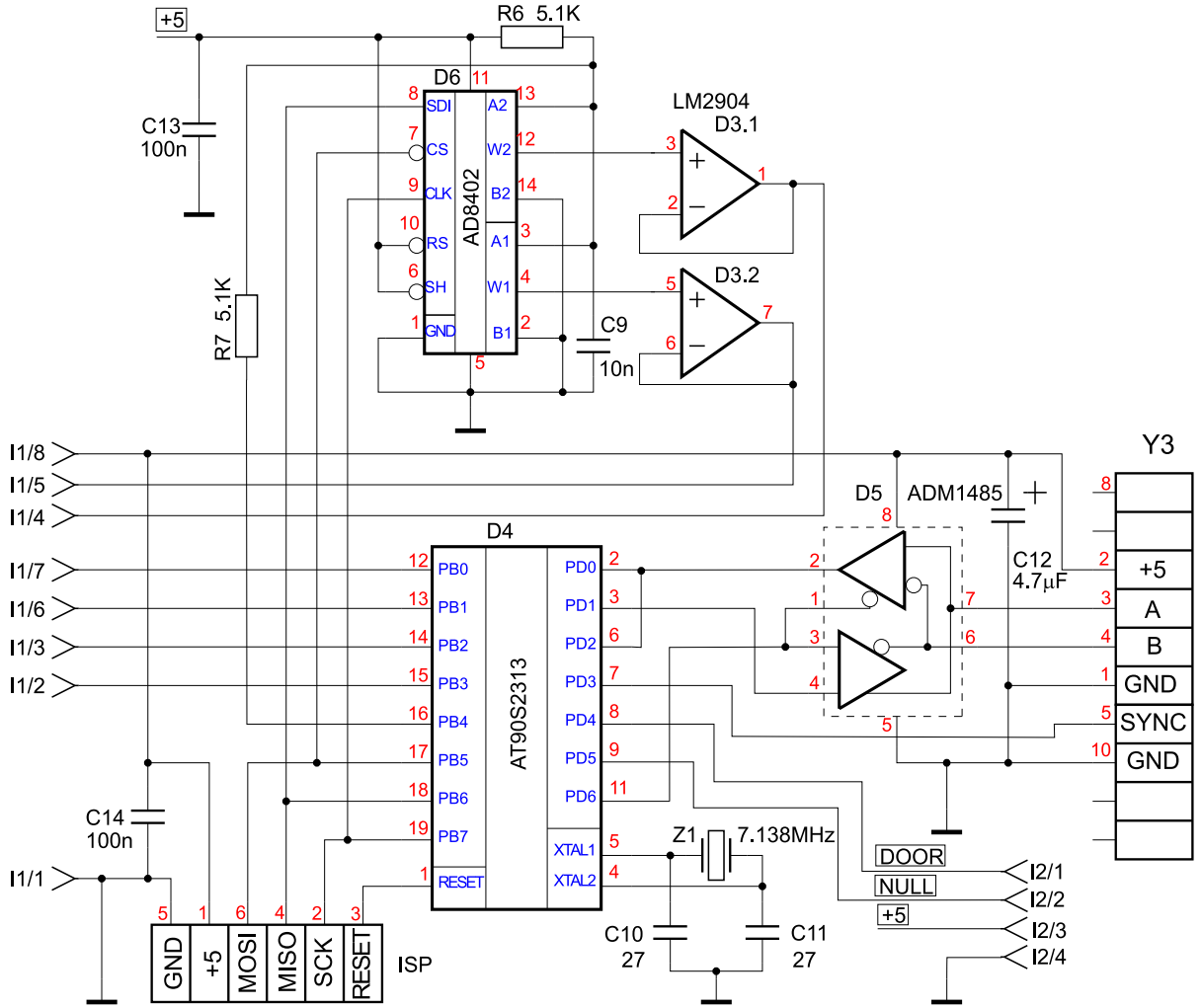
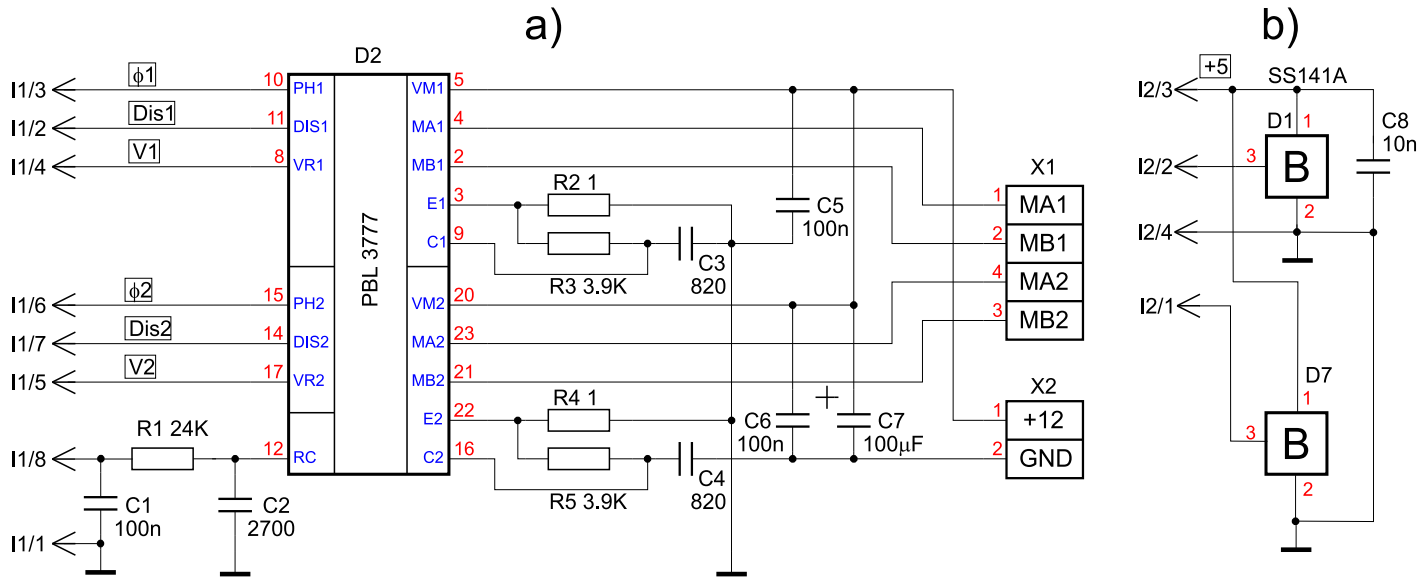


Figure 1.13: Circuit diagram of the Stepper motor controller module. SCH04A. Controller and line interface.



1. MC D7 placed at PCB04C2, connects with PCB04C1 by 3 separate wires.

Figure 1.14: Circuit diagram of the Stepper motor controller module. a) Motor driver (SCH04B). b) Null-point and Door Hall sensor (SCH04C).

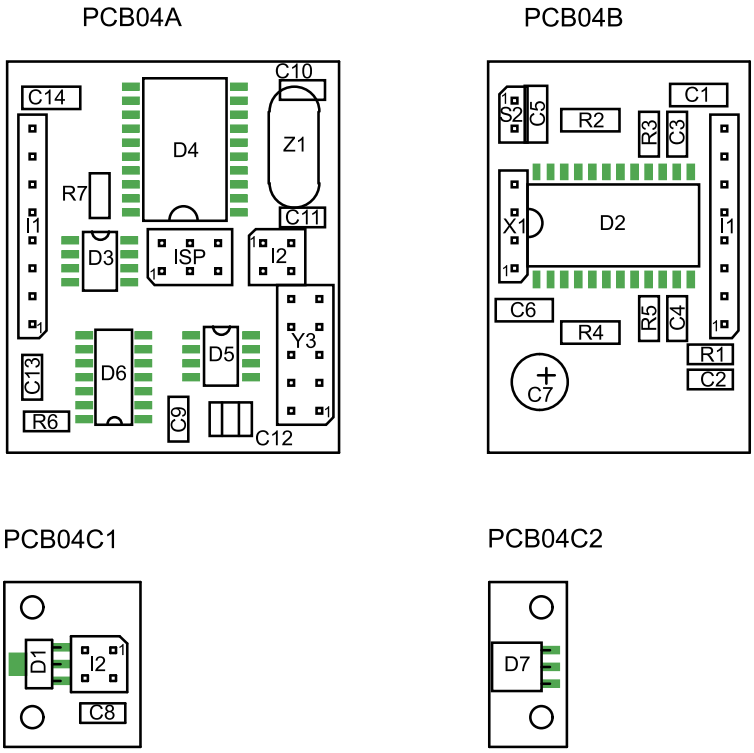


Figure 1.15: Printed circuit boards for the Stepper motor controller top view. Placement of the components is shown. Designations correspond to circuit diagrams in Fig. 1.13 and Fig. 1.14

1.5 High voltage controller, Line and temperature monitor

The circuit diagrams of the high voltage module are shown in Fig. 1.16, Fig. 1.17 and Fig. 1.18. PCB views are presented in Fig. 1.19.

Table 1.5: Specification for the High voltage circuits (see SCH05A, SCH05B, SCH05C).

Item	Part	Name	Manufacturer	Q-ty	Rem
1	D1	Mod. TA-1.5N-12LS	WME	1	See spec.
2	D2	IC AD8400AR10	Analog Dev.	1	
3	D3	IC LM2904M	Nat.Semicond.	1	
4	D4	IC AD7818AR	Analog Dev.	1	
5	D5	IC AT90S2313-10SI	Atmel	1	
6	D6	IC ADM1485AR	Analog Dev.	1	
7	Z1	Quartz 7.138MHz	—	1	HC49S
8	R1, R2	Chip resistors	—	1	0805 size
9	C1	Chip capacitors	—	1	1208 size
10	C2	Alum.capacitor	—	1	6 mm
11	C3–C6	Chip capacitors	—	4	1208 size
12	C7, C8	Chip capacitors	—	2	0805 size
13	C9	Tantal chip capac.	—	1	B size
14	ISP	ISP connector	—	1	PLD-6
15	I1(B)	Pins conn. (pins)	—	1	PLD-8
16	I1(A)	Pins conn.(sockets)	—	1	PBDR-8
17	X1	Pins conn. (pins)	—	1	PLSR-2
18	S2	Solder conn.	Custom	1	Soldering
19	Y3	Pins conn.(pins)	—	1	PLD-10
20	S4	Solder conn.	Custom	1	Soldering
21	X5	HV conn. socket	Custom	1	Distr.unit
22	X6	HV conn. plug	Custom	1	Distr.unit
23	X7-X10	PC75-109 conn.	Russia	4	PMT connect.
24	W1	Coax.cable	Custom	1	See SCH05C
25	W2–W5	Coax.cable	—	4	See SCH05C
26	PCB05A	Printed board	Custom	1	
27	PCB05B	Printed board	Custom	1	

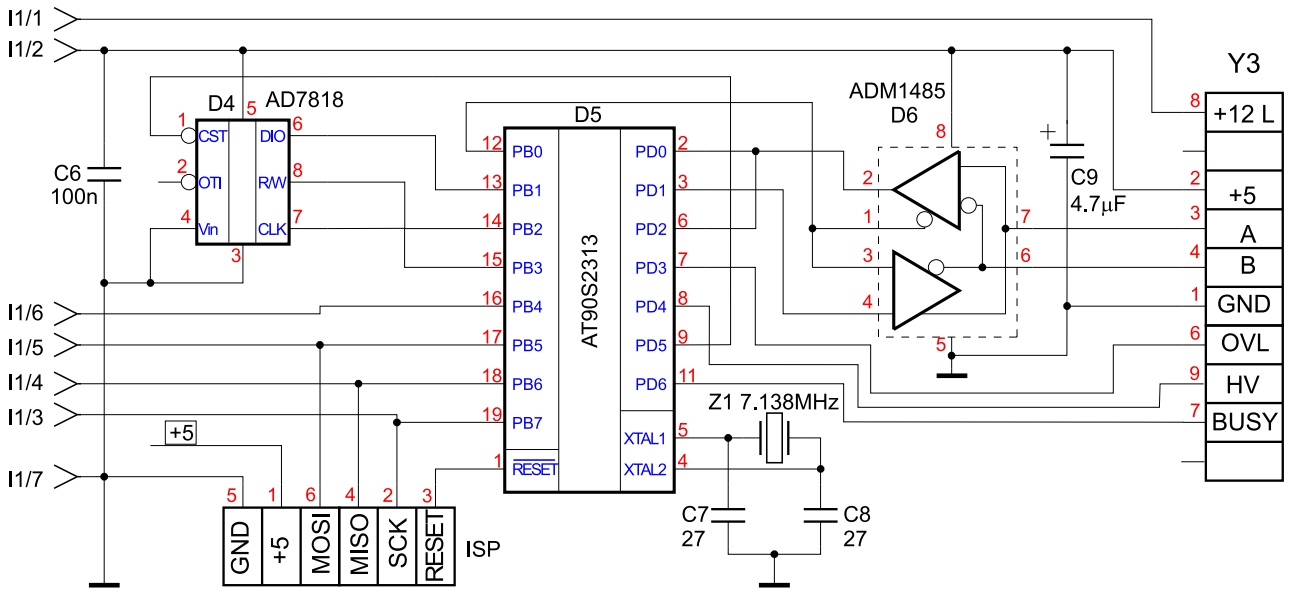


Figure 1.16: Circuit diagram of the High voltage controller, Line and Temperature monitor. SCH05A. Controller, Line and temperature monitor and line interface.

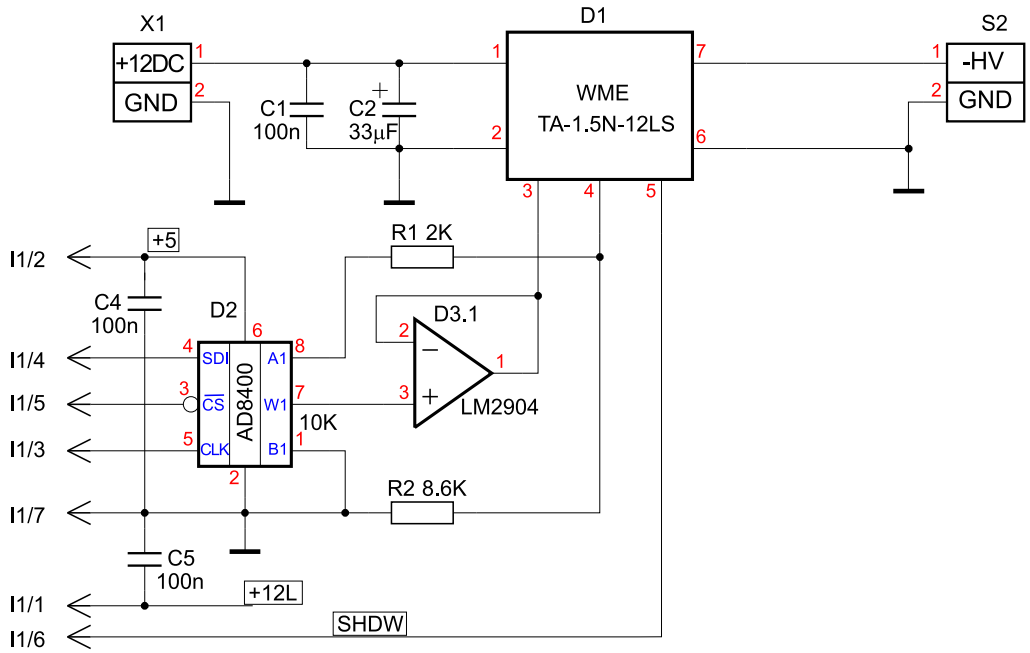
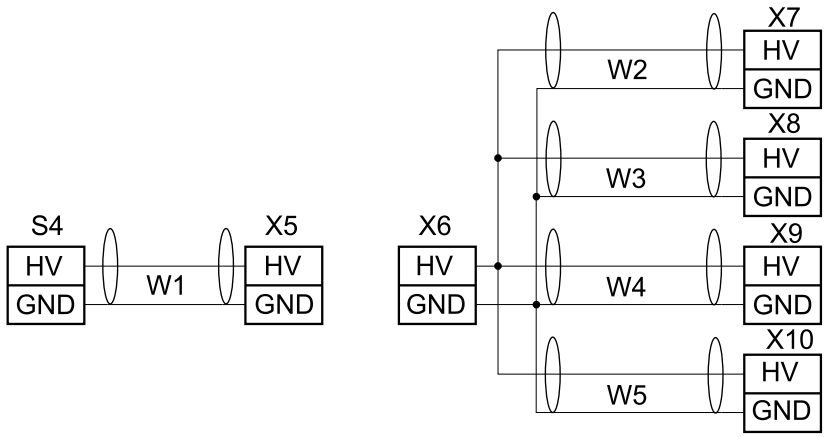


Figure 1.17: Circuit diagram of the High voltage controller, Line and Temperature monitor. SCH05B. High voltage converter board.



1. W1 — coaxial cable Ø2.5 with teflon dielectric, l = 130 mm.
2. W2, W3, W4, W5 — coaxial cable Ø3.0, l = 150 mm.
3. Solder S4 to S2 at SCH05B.
4. X7 - X10 for X3 at SCH01C of any photometric module.

Figure 1.18: Circuit diagram of the High voltage controller. SCH05C. High voltage distributing circuit.

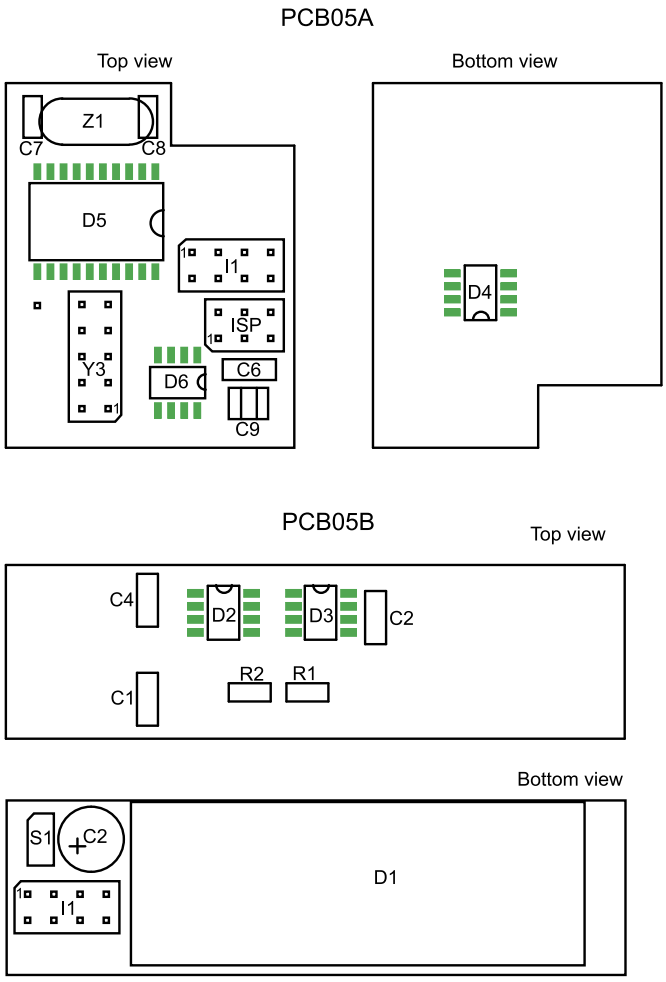


Figure 1.19: Printed circuit boards for High voltage controller. Placement of the components and HV converter is shown. Designations correspond to circuit diagrams in Fig. 1.16 and Fig. 1.17

Appendix 2

Microprogramming and Instructions set

General structure of data exchange between a host computer and a separate module (or between two modules during autonomous period) is described in the Main document. Since a cyclic residual control byte (CRC byte) is appended during transmission and cut off during receiving by a system driver, in the further description of the commands (instructions), CRC byte is omitted. Also, the first byte of a transmitted packet (header byte) is not shown as a rule. Additionally, a fault transmission cases are not considered, correct situations are presented only.

Recall that the used logical protocol includes several additional signals to provide a larger information transmission rate. The signals contain self-checked code with 8 possible value. All the signals are listed in Table 2.1.

Table 2.1: Used signal bytes.

Signal	Hex. code	Meaning
ACK	0x87	Successful receiving of data
NAK	0x96	Damaged packet was received
NOD	0xA5	Required data are not ready
ACN	0xB4	Command is successfully received but such a command does not exist
ACY	0xC3	Command is successfully received and executed
ACW	0xD2	Command is successfully received but can not be executed right now
SINC	0xE1	Synchronization signal
DNG	0xF0	Danger signal

Last two signals are not used in MASS exchange protocol and included for a further extension.

The instruction sets for the all the modules in use are presented below. For each instruction, a name (and its code in parentheses), used arguments (if exist) are written. Normal reply from a module is shown after a left arrow. The response alternatives are put in brackets.

2.1 Photometric module

Main problem for photometric modules is the syncronization of integration and of subsequent transmissions. To solve this, one module out of four (Master) generates a synchronization clock at a separate line. Three other modules (Slaves) use this signal to organize their work at the same rate.

To avoid line collisions, the data transmission procedure works in inductive mode. One module is set in Active mode of data transmission and starts the transmission as soon as the block of data is ready. Other modules are set in Inductive mode, each of them starts the transmission of integrated data after the packet from its module-Inductor has passed in the line. If four modules have addresses like MOD1, MOD2, MOD3, MOD4, and MOD1 is set as Active, it is needed to set Inductor address to MOD1 for MOD2, to MOD2 for MOD3 and to MOD3 for MOD4. The sequence may be different, it is important that to all the modules are included in this chain.

Current status of the photometric module is indicated by its Status word accessible for reading. It has the following format:

```
Bit 0  active mode on
Bit 1  inductive mode on
Bit 2  short format of data transmission on
Bit 3  integration using external clock
Bit 4  PMT module shutter open
Bit 5  decremental test on
Bit 7  integration in progress.
```

The instructions set is presented below.

- Pulse discrimination threshold setting:
  `SET_LEVEL (0x41) level <- ACY`,
  where `level` is obtained from threshold T in mV with help of 2 constants programmed in the module:
  `level = low(max(0,min(255,255+const2-T*(255+const2-const1))))`

- Current threshold request:
  `GET_LEVEL (0xE1) <- level`,
  then `T = (255+const2-level)/(255+const2-const1)`.

- Micro-exposition (integration time) setting:
  `SET_EXPOS (0x52) low(exposition) high(exposition) <- ACY`
  where `exposition` is calculated from microexposition t in ms with help of 2 constants programmed in the module: `exposition = (t*(const3+const4<<8)-1)/8`

- Current micro-exposition request:
  `GET_EXPOS (0xF2) <- low(exposition) high(exposition)`
  then `t` in ms is equal `(8*exposition+1)/(const3+const4<<8)`

- Series length setting:
  `SET_NUMBER (0x34) low(number) high(number) <- ACY`
  where `number` from 1 to 32767, in the case of `number = 0` the infinite series is set.

- Current series length request:
  `GET_NUMBER (0xF4) <- low(number) high(number).`
- Module status request (see the meaning of the Status bits above):
  `GET_STATUS (0xE0) <- status.`
- EEPROM CRC check:
  `GET_CRC (0xEF) <- crc.`
  There are no errors if `crc = 0`.
- Data block size setting:
  `SET_BLSIZE (0x26) size <- ACY`,
  where `size` can be from 1 to 16, recomended value is 16.
- Data block size request:
  `GET_BLSIZE (0xE6) <- size.`
- Inductor address setting:
  `SET_INDUC (0x27) address <- ACY.`
- Inductor address request:
  `GET_INDUC (0xE7) <- address.`
- Request of a new data block:
  `GET_DATA (0xA0) <- data block (NOD).`
  Returns NOD if no new data ready.
- Module identification request:
  `GET_IDENT (0xA2) <- id1 id2 id3 id4.`
  Returns unique identification of the module.
- Module constants request :
  `GET_CONST (0xA3) <- const1 const2 const3 const4.`
  Returns four constants for threshold and exposition calculations.
- Start up exposition series:
  `RUN (0x80) <- ACY (ACW).`
  Returns `ACW` when integration does not finish yet.
- Halt of exposition series:
  `STOP (0x81) <- ACY.`
  Used to terminate infinite series or to break current integration.
- Generation of synchro clock on:
  `MASTER_ON (0x83) <- ACY (ACW).`
- Use an extenal synchro clock on:
  `MASTER_OFF (0x82) <- ACY (ACW).`
- Active mode on:
  `ACTIVE_ON (0x88) <- ACY (ACW).`

- Active mode off:
  `ACTIVE_OFF (0x89) <- ACY (ACW).`
- Inductive mode on:
  `INDUCE_ON (0x8A) <- ACY (ACW).`
- Inductive mode off:
  `INDUCE_OFF (0x8B) <- ACY (ACW).`
- One byte per count format on:
  `SHORTER (0x84) <- ACY (ACW).`
- Two byte per count format on:
  `LONGER (0x85) <- ACY (ACW).`
- Start up decremental test:
  `RUN_TEST (0x86) <- ACY (ACW).`
  The `numbers` from `number-1` to 0 are generated instead of normal counts to check exchange faultness.

  Previous instructions return ACW signal if the integration is in progress.
- Software restart:
  `RESET (0x87) <- no reply`

2.2 Light control and Buttons service module

After powering on, the module works in autonomous mode and is able to send some instructions to other modules (e.g. to aperture module). To make it computer-controled, the instruction GET_IDENT (see below) is used. A brightness of the aperture illumination is changed step by step and is described by a following equation:
`illumination = floor(2^(8*n/15.01)+0.5) if n` $\neq$ `0,`
`illumination = 0 if n = 0.`

Current status of this module is indicated by its Status word accessible for reading. It has the following format:

```
Bit 0  lock of buttons
Bit 1  mode change button is pressed
Bit 2  "+" button is pressed
Bit 3  "-" button is pressed
Bit 4  control light on
Bit 5  illumination on
Bit 6  modulation of the control light on
Bit 7  autonomous work indicator
```

The instructions set is presented below.

- Illumination brightness setting:
  `SET_ILLUM (0x41) illumination <- ACY`
  `illumination` is calculated from relative brightness IL (from 0 to 1.0): `illumination = low(max(0,min(255,256*IL)))`

- Illumination brightness request:
  `GET_ILLUM (0xE1) <- illumination`
  where `IL = illumination/256`

- Control light brightness setting:
  `SET_LIGHT (0x42) light <- ACY`
  `light` is calculated from relative brightness CL (from 0 to 1.0)
  `light = low(max(0,min(255,256*IL)))`.
  The brightness setting instructions do not turn on light.

- Control light brightness request:
  `GET_LIGHT (0xE2) <- light`
  where `CL = light/256`

- Module status request (see the meaning of the Status bits above).
  `GET_STATUS (0xE0) <- status`

- EEPROM CRC check
  `GET_CRC (0xEF) <- crc`.
  There are no errors if `crc = 0`.

- Control light modulation amplitude setting:
  `SET_VAMPL (0x23) delta <- ACY`
  where `delta = low(max(0,min(255,256*DL*CL)))` and `DL` is a relative amplitude.

- Control light modulation amplitude request:
  `GET_VAMPL (0xE3) <- delta`,
  then `DL = (delta/256)/CL`.

- Button mode setting:
  `SET_BMODE (0x48) moda <- ACY`,
  where `moda` is from 0 to 7

- Button mode request:
  `GET_BMODE (0xE8) <- moda`

- Current mode parameter setting:
  `SET_PARAM (0x29) value <- ACY`,
  where the meaning of `value` depends on the current mode.

- Current mode parameter request:
  `GET_PARAM (0xE9) <- value`
  Where `value = 0` if buttons were not pressed since previous request, `value = 1` if the button "+" was pressed, and `value = -1` if the button "-" was pressed.

- Illumination turn on:
  `ILLUM_ON (0x80) <- ACY (ACW)`
- Illumination turn off:
  `ILLUM_OFF (0x81) <- ACY (ACW).`
- Control light turn on:
  `LIGHT_ON (0x82) <- ACY (ACW).`
- Control light turn off:
  `LIGHT_OFF (0x83) <- ACY (ACW).`
- Control light nodulation turn on:
  `VARY_ON (0x84) <- ACY (ACW).`
- Control light nodulation turn off:
  `VARY_OFF (0x85) <- ACY (ACW).`
- Handle control lock:
  `BUTT_LOCK (0x8A) <- ACY (ACW).`
- Handle control unlock:
  `BUTT_UNLOCK (0x8B) <- ACY (ACW).`
- Module identification request:
  `GET_IDENT (0xA2) <- id1 id2 id3 id4.`
  Returns unique identification of the module. Also, this instruction switches module from autonomous work to under computer control.
- Module constants request:
  `GET_CONST (0xA3) <- const1 const2 const3 const4.`
  Returns four constants. Not used now.
- Software restart:
  `RESET (0x87) <- no reply.`

2.3 Stepper motor controller module

After powering on, input door (main shutter) must be closed, and Null-point setting is doing. This status is normal. If the input door is opened, its closing first done and Null-point setting is made afterwords. Full microstep number is equal to 3200 and the wheel position can be from 0 to 3199. Preliminary positions for aperture are:

```
WideAperture   267
ConjLens1      800
WorkAperture  1333
CentringHole  1867
ConjLens2     2400
ControlPrism  2933
Dark          1600
Close         3000
```

Real positions differ from table values. These positions are programmed in the controller. Additionally, aperture stops can be varied with the help of corrections from host computer. Correction value can be from -127 to +127 microsteps (±3mm of aperture shift).

Current status of this module is indicated by its Status word accessible for reading. It has the following format:

```
Bit 0  new microstep is done
Bit 2  door is close
Bit 3  null-point is set
Bit 4  accelerated  motion
Bit 5  forward motion
Bit 6  synchronized motion
Bit 7   motor is moving
```

The instructions set is presented below.

- Module status request (see the meaning of the Status bits above):
  `GET_STATUS (0xE0) <- status`
- Sensors status request:
  `GET_SENSOR (0xE1) <- sensor` where Bit 1 — null-point sensor is low. Bit 2 — input door sensor is low.
- EEPROM CRC check
  `GET_CRC (0xEF) <- crc`.
  There are no errors if `crc = 0`.
- Current position request:
  `GET_POSITION (0xF2) <- low(position) high(position)`.
  `position` changes during motion.
- Initiate the motion to the absolute position:
  `MOVE_TO (0x54) low(position) high(position) <- ACY (ACW)`.
  Motion is doing in a free way.
- Free relative shift start up:
  `SHIFT_AT (0x46) shift <- ACY (ACW)`,
  where `shift` is a signed value.
- Synchronized relative shift start up:
  `SYNCH_AT (0x47) shift <- ACY (ACW)`,
  where motion is done using step factor (see below). E.g. with a step factor 2, real shift limits are ±254.
- Load the corrections to K-stop (K = 0..7):
  `LOAD_STOPS (0x5A) K Delta_position_K <- ACY`.
- Corrections request:
  `GET_STOPS (0xA1) <- corr0, corr1, ....  corr6, corr7`.

- Start the motion to the needed aperture position:
  `SET_APERTURE (0x49) apert <- ACY (ACW).`
- Current aperture request:
  `GET_APERTURE (0xE9) apert <- ACY (ACW).`
- Step factor setting:
  `SET_STEP (0x28) value <- ACY`,
  where `value` is from 1 to 8. Step factor is used during a synchonized motion.
- Step factor request:
  `GET_STEP (0xE8) <- value.`
- Inpot door open:
  `OPEN_DOOR (0x80) <- ACY (ACW).`
  ACW when motor is moved, ACY otherwise.
- Inpot door open:
  `CLOSE_DOOR (0x81) <- ACY (ACW).`
  ACW when motor is moved, ACY otherwise.
- Motor status check:
  `TEST_MOTION (0x82) <- ACY (ACW).`
  ACW when motor is moved, ACY otherwise.
- Start up Null-point setting procedure:
  `NULL_SET (0x83) <- ACY (ACW).`
- Low power mode turn on:
  `POWER_DOWN (0x86) <- ACY (ACW).`
  The wings current decreases twice. Any instruction which starts a motion sets the normal current.
- Module identification request:
  `GET_IDENT (0xA2) <- id1 id2 id3 id4.`
  Returns unique identification of the module. Also, this instruction switches the module from autonomous work to the computer-controlled state.
- Module constants request:
  `GET_CONST (0xA3) <- const1 const2 const3 const4.`
  Returns four constants. Not used now.
- Software restart:
  `RESET (0x87) <- no reply.`

2.4 HV controller. Line and temperature monitor module

The procedure of a repetitive turning on of the high voltage after the overlight detection is following: HV turn off, Safety turn off, Safety turn on and then HV turn on. This procedure is made in such a complex way to protect from occasional turning on of the high voltage.

Current status of this module is indicated by its Status word accessible for reading. It has the following format:

```
Bit 0  high voltage turned on
Bit 1  safety on (overlight protection on)
Bit 2  overlight indicator
Bit 3  high voltage locking
Bit 6  temperature is accessible
```

The instructions set is presented below.

- High voltage value setting:
  `SET_VOLTAGE (0x41) high <- ACY`,
  where `high` is calculated from needed voltage in V with help of 2 programmed constants:
  `high = low( max( 0, min(255, 0.001*U*const1 -cons2)))`.
  The instruction does not turn on the high voltage.

- High voltage value request:
  `GET_VOLTAGE (0xE1) <- high`.
  Then `U = 1000*(high+const2)/const1`.

- Module status request (see the meaning of the Status bits above):
  `GET_STATUS (0xE0) <- status`

- EEPROM CRC check
  `GET_CRC (0xEF) <- crc`.
  There are no errors if `crc = 0`.

- High voltage turn on:
  `HIGH_ON (0x80) <- ACY (ACW)`.
  Returns ACW in a case of locking, and does not turn anything on the high voltage.

- High voltage turn off:
  `HIGH_OFF (0x81) <- ACY`.

- Safety turn on:
  `SAFETY_ON (0x82) <- ACY (ACW)`.
  Executes only if the HV is turned off.

- Safety turn off:
  `SAFETY_OFF (0x83) <- ACY (ACW)`.
  Executes only if the HV is turned off.

- Device temperature request:
  `GET_TEMPER (0xF8) <- low(temperature) high(temperature)`.
  Temperature in °C is equal to `-103+(temperature)/4`.

- Module identification request:
  `GET_IDENT (0xA2) <- id1 id2 id3 id4`.
  Returns unique identification of the module.

- Module constants request:
  `GET_CONST (0xA3) <- const1 const2 const3 const4`.
  Returns four constants. Not used now.

- Software restart:
  `RESET (0x87) <- no reply`.

Appendix 3

MASS device optics

3.1 Optical element specifications

The optical elements detailing has been done using the main parameters fixed in Chapter 2 of the Main document. As it is mentioned above, a second conjugating lens is added to provide a higher virtual altitude (1000 m) and the focal length of a Fabry lens is reduced down to 140 mm in comparison with parameters defined in Preliminary design report earlier. The folding prism in a viewer is replaced by aluminized mirror identical to the folding mirror in the focal section, too.

The protective coatings of the mirror element surfaces are provided to increase an overall transmission of the instrument and to diminish secondary reflections.

The drawings were created with help of AutoCAD system and are presented as files in PostScript format. All drawings are prepared according to russian technical standards.

Table below contains the whole list of optical elements for MASS instrument. Commercially available optical parts such as conjugating lenses or Fabry lens are also drawn for information.

Table 3.1: List of the optical elements.

Item	Part	Name	Q-ty	File	Rem
1	OP1	Re-imaging mirror	4	op1.dwg	aluminized and protected
2	OP2	Flat mirror	2	op2.dwg	aluminized and protected
3	OP3A	Rectang. prism No 1	1	op3.dwg	AR coating
4	OP3B	Rectang. prism No 2	1	op3.dwg	beam-splitting film
5	OP4A	Glass filter No 1	1	op4.dwg	Yellow glass
6	OP4B	Glass filter No 2	1	op4.dwg	blue-green glass
7	OP5A	Fabry lens 1 componemt	1	op5.dwg	achromatic doublet
8	OP5B	Fabry lens 2 component	1	op5.dwg	assembly with AR coating
9	OP6A	Viewer obj. 1 component	1	op6.dwg	achromatic doublet
10	OP6B	Viewer obj. 2 component	1	op6.dwg	assembly
11	OP7A	Conjugating lens No 1	1	op7.dwg	f = 18 mm
12	OP7B	Conjugating lens No 2	1	op7.dwg	f = 9 mm
13	OP8	Micro-prism	1	op8.dwg	plastic, for control light
14		Beam-splitter		op9.dwg	assembly drawing

Appendix 4

Mechanical parts

4.0.1 Mechanical parts

The mechanical parts detailing has been done using the general dimensions fixed early as well.

The drawings were created with help of AutoCAD system and are presented as files in PostScript format as it is done for optical drawings. All drawings are prepared according to russian technical standards.

Table 4.1 below contains the whole list of mechanical parts for MASS instrument. The drawings of separate parts related to main instrument box, have a designation with prefix "MC". The assembly drawings begin with "AS", and drawings for photometric modules details — with "PH". Parts are united in groups with single number and differed with help of suffix. As a rule, these groups correspond to separate functional units. Note, that the designations of the real parts do not coincide with the significations on the conceptual and general design drawings.

Some drawings have A3 paper format. This drawing united in separed archive file to print with apropriate printer. The order of drawings follows with its sheet number.

Table 4.1: List of the assembling drawing.

Item	Design.	Name	File	Sheet	Rem
1	AS00	MASS instrument	as00.dwg	1	
2	AS01	Photom. module assembly	as01.dwg	2	
3	AS02	Box assembly, Part I	as02.dwg	3	
4	AS03	Box assembly, Part II	as03.dwg	4	
5	AS04	Focal section assembly	as04.dwg	5	
6	AS05	Aperture wheel assembly	as05.dwg	6	
7	AS06	Fabry lens unit assembly	as06.dwg	7	
8	AS07	PSU assembly	as07.dwg	8	
9	AS08	Beam-splitter assembly	as08.dwg	9	
10	AS09	Viewer assembly	as09.dwg	10	
11	AS10	Electronics mounting (right)	as10.dwg	11	
12	AS11	Electronics mounting (left)	as11.dwg	12	
13	AS12	Input door and PCB installation	as12.dwg	13	

Table 4.2: List of the mechanical parts.

Item	Part	Name	Q-ty	File	Sheet	Rem
1	MC01A	Main flange	1	mc01a.dwg	14	Instrument
2	MC01B	Left main beam	1	mc01b.dwg	15	box force parts
3	MC01C	Right main beam	1	mc01c.dwg	16	Assembly see in
4	MC01D	Photometric modules base	1	mc01d.dwg	17	AS02 and AS03
5	MC01E	Struts for covers	8	mc01e.dwg	18	drawings
6	MC01F	Powls for PCB	10	mc01f.dwg	19	
7	MC01G	HV module pawl	1	mc01g.dwg	20	
8	MC02A	Bottom cover	1	mc02a.dwg	21	Instrument box
9	MC02B	Top cover	1	mc02b.dwg	22	cover parts
10	MC02C	End cover	1	mc02c.dwg	23	Assembly see on
11	MC02D	Right cover	1	mc02d.dwg	24	AS02, AS03, AS10,
12	MC02E	Left cover	1	mc02e.dwg	25	and AS11 drawings
13	MC02F	Buffel strut	4	mc02f.dwg	26	
14	MC02G	Left and right buffels	2	mc02g.dwg	27	
15	MC03A	Focal section base	1	mc03a.dwg	28	Focal section parts
16	MC03B	Clamp	1	mc03b.dwg	29	Assembly see on
17	MC03C	Folding mirror holder	1	mc03c.dwg	30	AS02, AS04 and
18	MC03D	Adjusting screw No 1	1	mc03d.dwg	31	AS12 drawings
19	MC03E	Mirror axis	1	mc03e.dwg	32	
20	MC03F	Hall sensor pillar	1	mc03f.dwg	33	
21	MC03G	Flat spring	1	mc03g.dwg	34	
22	MC04A	Aperture wheel	1	mc04a.dwg	35	Aperture wheel parts
23	MC04B	Aperture insert No 1	1	mc04b.dwg	36	Assembly see on
24	MC04C	Aperture insert No 2	1	mc04b.dwg	36	AS05 drawing
25	MC04D	Aperture insert No 3	1	mc04d.dwg	37	
26	MC04E	Aperture insert No 4	2	mc04e.dwg	38	
27	MC04F	Null sensor magnet	1	mc04f.dwg	39	
28	MC04G	Finger	1	mc04g.dwg	40	
29	MC05A	Fabry lens support	1	mc05a.dwg	41	Fabry lens unit
30	MC05B	Pressing ring	1	mc05b.dwg	42	Assembly see on
31	MC05C	Re-imaging mirror holder	4	mc05c.dwg	43	AS06 drawing
32	MC05D	Adjusting pad	4	mc05d.dwg	44	
33	MC05E	Adjusting screw No 2	2	mc05e.dwg	45	
34	MC05F	Flat spring No 2	1	mc05f.dwg	46	

Table 4.2: List of the mechanical parts (continued).

Item	Part	Name	Q-ty	File	Sheet	Rem
35	MC06A	Square nut	1	mc06a.dwg	47	Assembly see in
36	MC06B	Fabry lens holder	1	mc06b.dwg	48	AS06 drawing
37	MC06C	Locking nut	1	mc06c.dwg	49	
38	MC06D	Holder inserts	2	mc06d.dwg	50	
39	MC06E	Retaining nut	1	mc06e.dwg	51	
40	MC07A	Segmentator unit pit	1	mc07a.dwg	52	Pupil segmentation
41	MC07B	Segmentator holder	1	mc07b.dwg	53	unit parts
42	MC07C	PSU stopper	1	mc07c.dwg	54	Assembly see on
43	MC07D	Stopper ridge	1	mc07d.dwg	55	AS07 drawing
44	MC07E	Segmentator A	1	mc07e.dwg	56	
45	MC07F	Segmentator B	1	mc07f.dwg	57	
46	MC07G	Segmentator C	1	mc07g.dwg	58	
47	MC07H	Segmentator D	1	mc07h.dwg	59	
48	MC07I	Technolog. holder	1	mc07i.dwg	60	
49	MC08A	Blind No 1	1	mc08a.dwg	61	Beam-splitting unit
50	MC08B	Beam-splitter housing	1	mc08b.dwg	62	Assembly see on
51	MC08C	Cover plate	1	mc08c.dwg	63	AS08 drawing
52	MC08D	Blind No 2	1	mc08d.dwg	64	
53	MC08E	Beam-splitter base	1	mc08e.dwg	65	
54	MC08F	Adjusting plate	1	mc08f.dwg	66	
55	MC09A	Viewer bear	1	mc09a.dwg	67	Viewer parts
56	MC09B	Viewer head	1	mc09b.dwg	68	Assembly see on
57	MC09C	Viewer mirror plate	1	mc09c.dwg	69	AS09 drawing
58	MC09D	Fixing grip	2	mc09d.dwg	70	
59	MC09E	Elastic gasket	1	mc09e.dwg	71	
60	MC10A	Viewer obj. holder	1	mc10a.dwg	72	Assembly see on
61	MC10B	Locking nut No 2	1	mc10b.dwg	73	AS09 drawing
62	MC10C	Viewer tube	1	mc10c.dwg	74	
63	MC10D	Focuser tube	1	mc10d.dwg	75	
64	MC10E	Focuser nut	1	mc10e.dwg	76	
65	MC10F	Eyepiece adapter	1	mc10f.dwg	77	
66	MC10G	Viewer extension	1	mc10g.dwg	78	

Table 4.7: List of the mechanical parts (continued).

Item	Part	Name	Q-ty	File	Sheet	Rem
67	MC11A	PMT focusing tool No 1	1	mc11a.dwg	79	Additional parts
68	MC11B	Eyepiece update	1	mc11b.dwg	80	See AS07 drawing
69	MC11C	HV distributor case No 1	1	mc11c.dwg	81	
70	MC11D	HV distributor case No 2	1	mc11d.dwg	82	
71	MC11E	Buttons mini-case	1	mc11e.dwg	83	
72	MC11F	Buttons case panel	1	mc11f.dwg	84	
73	MC11G	Exit pupil tool No 2	1	mc11g.dwg	85	
74	MC11H	Cramp for PMT modules	5	mc11h.dwg	86	
75	MC12A	Input door back	1	mc12a.dwg	87	Input door unit
76	MC12B	Input door blade	1	mc12b.dwg	88	Assembly see on
77	MC12C	Magnets collar	1	mc12c.dwg	89	AS02, AS03 and
78	MC12D	Spring lever	1	mc12d.dwg	90	AS12 drawings
79	MC12E	Elastic press	1	mc12e.dwg	91	
80	MC12F	Input door cap	1	mc12f.dwg	92	
81	MC12G	Door sensor magnet	1	mc12g.dwg	93	
82	MC12H	Finger	1	mc12h.dwg	94	
83	PH01A	PMT module front	5	ph01a.dwg	95	Photometric
84	PH01B	PMT module back	5	ph01b.dwg	96	module parts
85	PH01C	PMT housing, main	5	ph01c.dwg	97	
86	PH01D	PMT housing, top	5	ph01d.dwg	98	Assembly see on
87	PH01E	PMT socket post	5	ph01e.dwg	99	AS01 drawing
88	PH01F	Teflon spacer	5	ph01f.dwg	100	
89	PH01G	PCB strut	10	ph01g.dwg	101	
90	PH01H	Shield	5	ph01h.dwg	102	
91	PH01I	Elastic gasket	5	ph01i.dwg	103	
92	PH02A	Shutter cramp	5	ph02a.dwg	104	Photometric
93	PH02B	Shutter blade	5	ph02b.dwg	105	module shutter
94	PH02C	Shutter axis	5	ph02c.dwg	106	parts
95	PH02D	Shutter lever	5	ph02d.dwg	107	See AS01 drawing
96	PH02E	Shutter cam	5	ph02e.dwg	108	
97	PH02F	Brass washer	5	ph02f.dwg	109	
98	PH02G	Spring No 3	5	ph02g.dwg	110	
99	PH02H	Restrictive bolt	10	ph02h.dwg	111	