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We have checked the content of this documentation for conformity with the hardware and software described. Nevertheless, discrepancies cannot be precluded, for which reason we are not able to guarantee total conformity. The information in this documentation is checked on a regular basis, however, and necessary corrections will be incorporated in subsequent editions.

Subject to technical alterations without an effect on the function.

PD Interleaf

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# 1 Control cabinet

## 1.1 General maintenance

With the exception of battery replacement, the controller (processor unit) is maintenance-free.

Preventive maintenance is recommended wherever dirt, corrosion and wear occur.



**Before maintenance or repair work is started, it must be ensured that the incoming power cable is deenergized and that measures have been taken to prevent it from being inadvertently energized again.**

**It must also be ensured that no current-carrying cables or components can be touched. In addition, the main switch must be turned to "OFF" and locked.**



**All supply conductors up to the main switch are still live even when the main switch is turned off.**



**Particularly important: maintenance and repair work may be performed only by trained personnel aware of the hazards involved.**

### 1.1.1 Cleaning



**Do not use compressed air to clean the system, as this could cause dirt to penetrate into electrical components. Compressed air may be used only when expressly specified.**

- Remove any dust deposits with a dry brush.
- Clean control cabinet with a cloth soaked with a mild cleaning agent.
- Clean cables, plastic parts and hoses with solvent-free cleaning agents.



**The manufacturer's instructions must be observed when using cleaning agents.**



**It must be ensured that no cleaning fluid enters electrical components.**

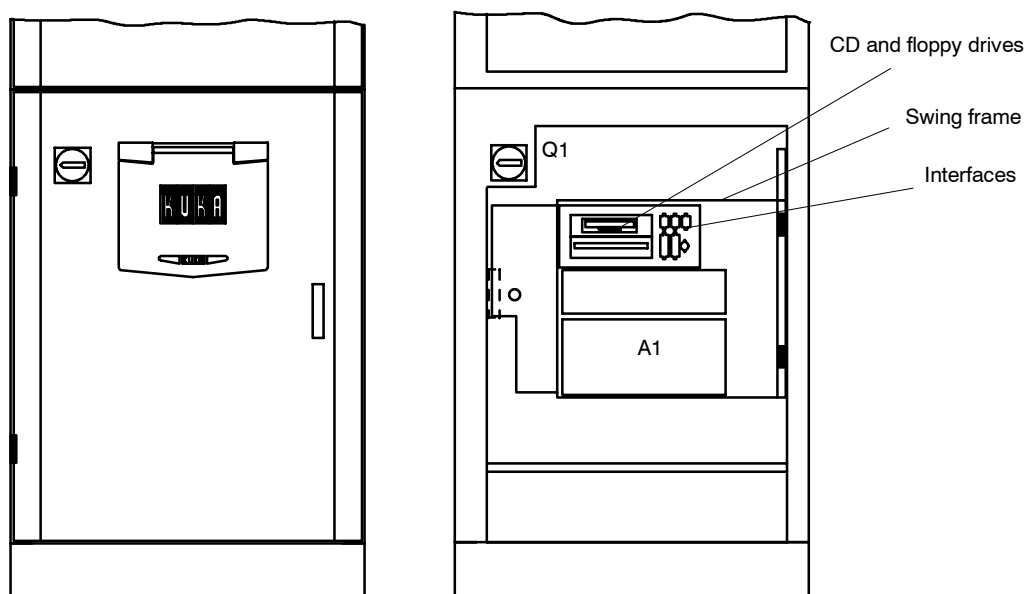
- Remove any corrosion and, where permissible, protect the affected areas with paint, grease or oil.
- Replace damaged, illegible or missing inscriptions, labels and plates.

## 1.2 Structure

The controller contains all the components and functions which are required to operate the robot. It comprises the processor and power units, which are both installed in a common control cabinet.

### 1.2.1 Processor unit

The processor unit includes the modules highlighted in Fig. 1.



**Fig. 1** Processor unit

With its fitted components, the processor unit performs all the functions of the control hardware. These are:

- Windows user interface with visual display and input
- Program creation, correction, archiving, and maintenance
- Diagnosis, start-up assistance
- Sequence control
- Trajectory planning
- Control of the servo power unit
- Monitoring functions
- Parts of the safety logic
- Communication with external units (other controllers, host computers, PCs, network)

The control hardware is composed of the following modules:

- Standard PC hardware with Pentium processor
- Multi-function card (MFC)
- Digital servo-electronics (DSEAT)
- Resolver/digital converter (RDC) on the robot

- **Standard PC Hardware**

With its powerful Pentium processor and main memory, the standard PC hardware forms the basis of the processor unit. The standard PC also includes a hard disk for storing the entire control software, including online help and online documentation, a floppy disk drive for archiving purposes and a CD-ROM drive for reading the CD-ROM supplied in the cabinet.

The CD-ROM contains the operating system, Windows, the control software including the relevant technological process, the online help and the complete documentation for the control cabinet and the robot.

- **Multi-function card**

The multi-function card incorporates the system and user I/Os and an Ethernet controller, and forms the interface between the KCP and the PC. The card is designed as a PC plug-in card and accommodates up to two DSEAT modules.

- **Digital servo-electronics (DSEAT)**

The DSEAT module fitted on the multi-function card with its own DSP (digital signal processor) is responsible for control of a servo power module with phase current command values and parameterization data, processing of the error and situation information read by the servo power module and communication with the module for R/D conversion.

- **Resolver/digital converter (RDC)**

Installed on the robot base, the R/D converter with its own DSP (digital signal processor) performs the functions of resolver power supply, R/D conversion, open-circuit monitoring of the resolvers and monitoring of the motor temperature. This converter communicates with the DSEAT via a serial interface.

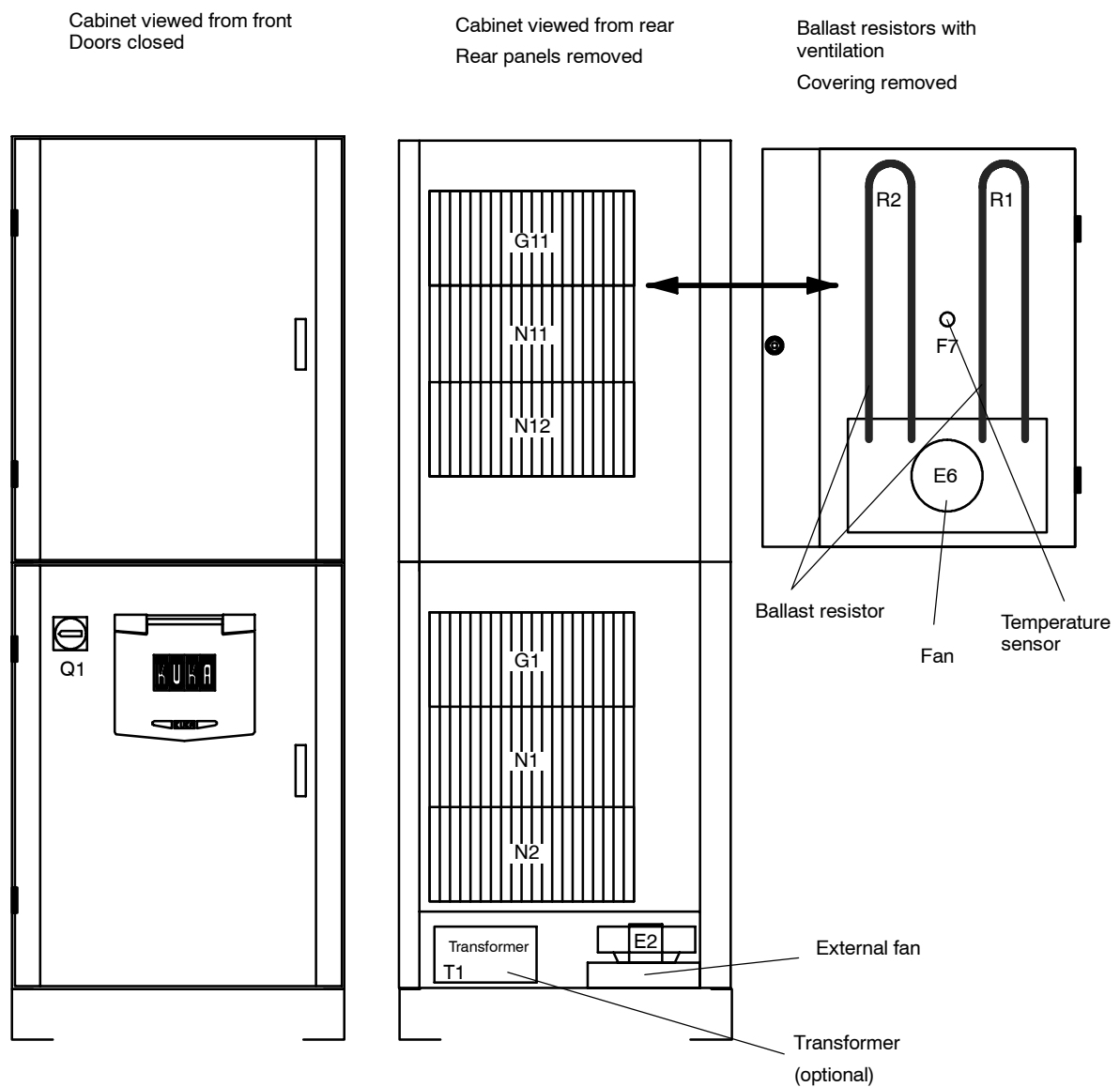
## 1.2.2 Power unit

The power unit comprises the areas highlighted in Fig. 2 and Fig. 3.

- Power infeed with mains filter, main switch with fuse and m.c.b.
- Basic modules and servo power modules
- Safety module (on processor unit)
- Back-up battery for control hardware

For data protection, the computer is supplied with power by a battery for a maximum of 10x1 minute in the event of power failure.

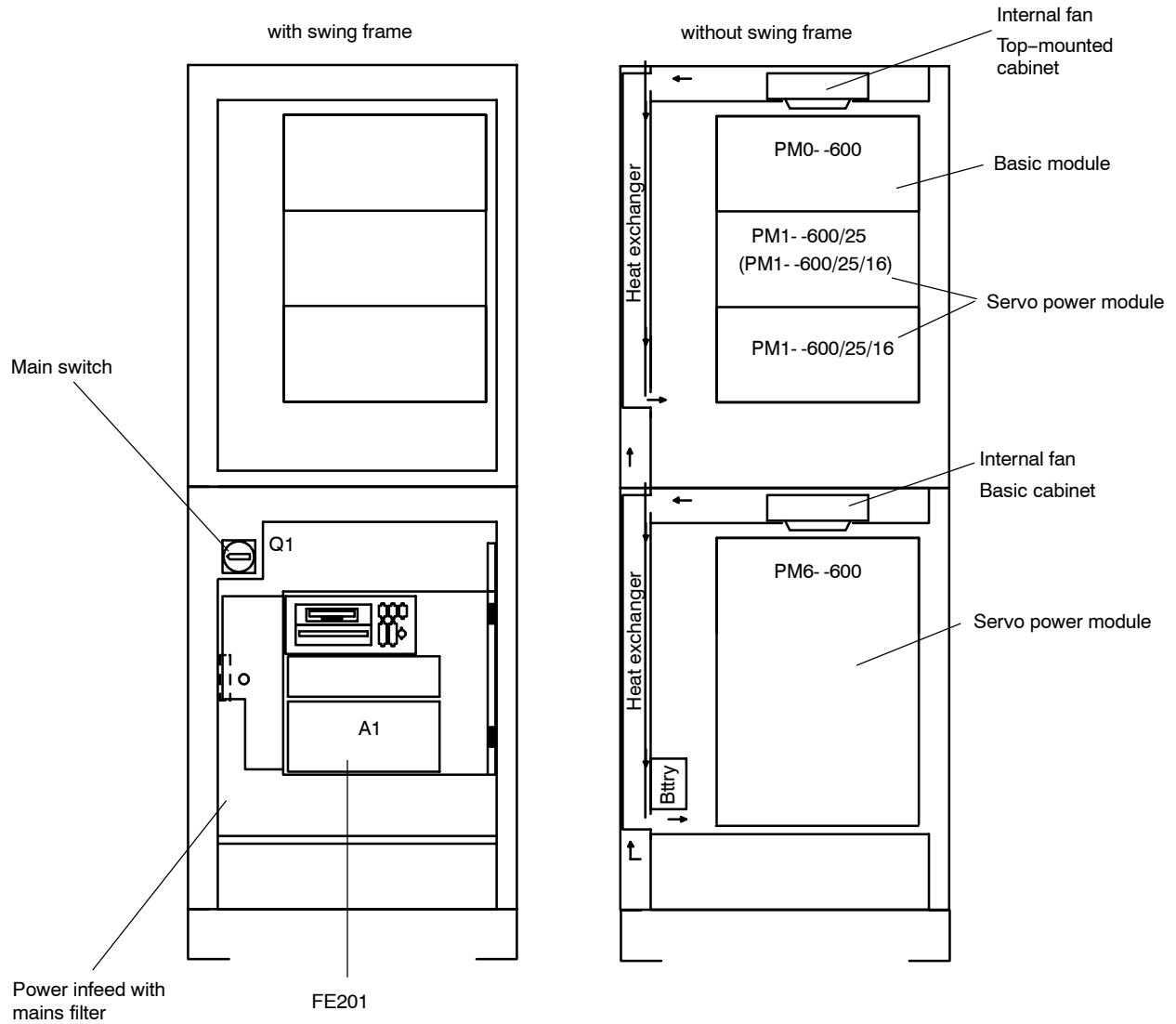
- Transformer (optional)
- Fans for cooling the cabinet



**Fig. 2** Control cabinet



Cabinet viewed from front



**Fig. 3** Control cabinet

The control cabinet is divided into two independent cooling zones. The inner zone, containing the entire control electronics, is cooled by a heat exchanger or an air conditioner (optional). In the outer zone, the transformer (optional) and the heat sinks of the power module and the power supply modules are cooled directly by ambient air.

The controller is designed for an ambient temperature of max. +45 °C with a heat exchanger or max. +55 °C with an air conditioner.

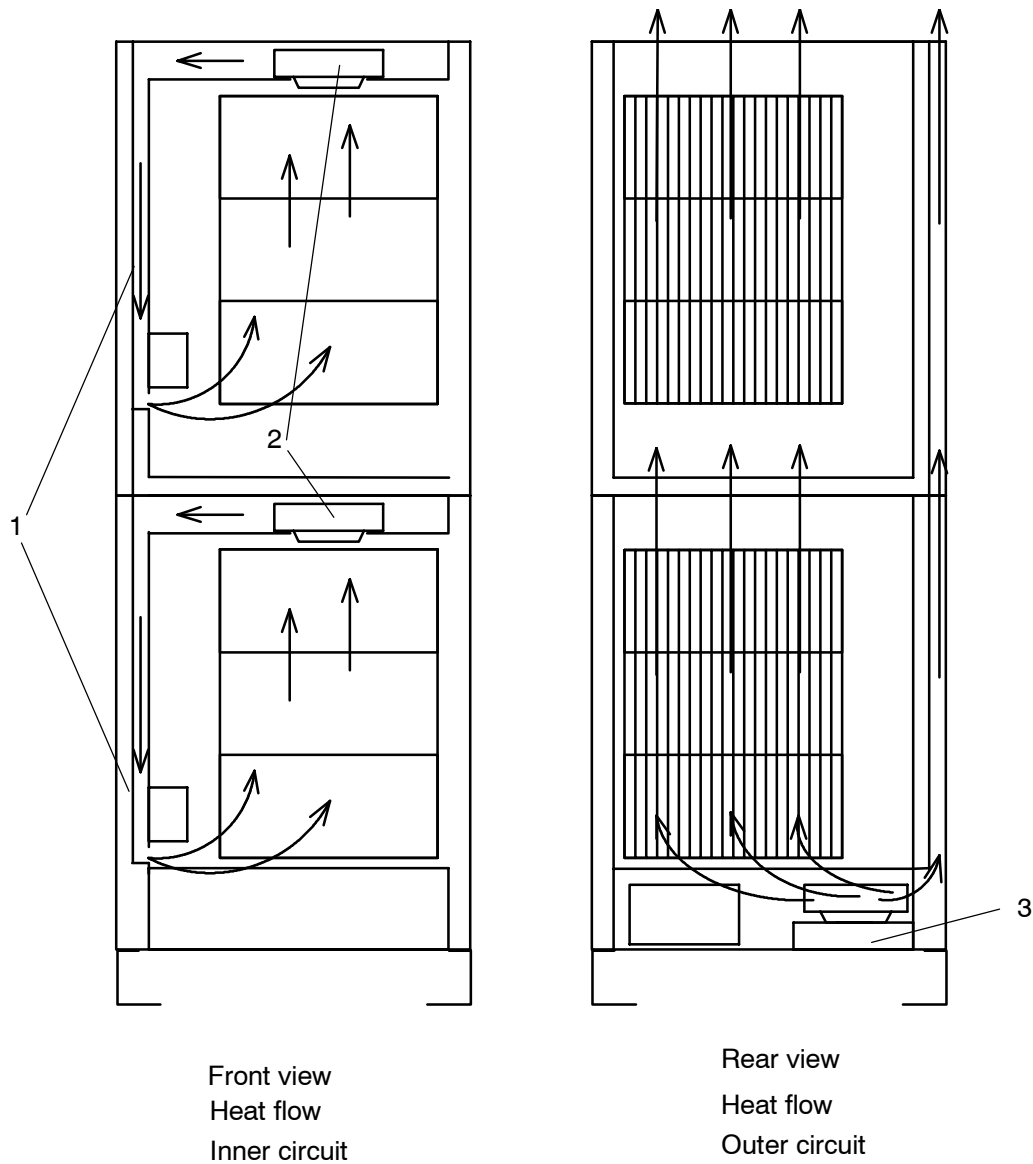


**Upstream installation of filter mats causes an excessive rise in temperature and hence a reduction in the life of the installed devices !**



**The heat exchanger covers on the side of the cabinet must be fitted in such a way that the plate with the ventilation slits is located on the lower cabinet with the ventilation slits at the bottom and therefore covered.**

### 1.2.3 Cooling by heat exchanger



- 1 = Heat exchanger
- 2 = Fan, inner circuit
- 3 = Fan, outer circuit

**Fig. 4** Cooling by heat exchanger

#### 1.2.4 Cooling by air conditioner

See air conditioner (optional) 69-000-456

### 1.3 Peripheral interfaces, general

See peripheral interfaces (optional)

### 1.4 Power unit interfaces

The connector panel in the control cabinet is available in a variety of configurations depending on the version concerned.

### 1.5 Power unit equipment



**When replacing the power modules it must be ensured that the motor connectors are re-inserted in the correct positions (see LEERER MERKER, LEERER MERKER).**

### 1.6 Replacing the basic and power modules



**Disconnect the mains cable before removal work is started and take measures to prevent it from being reconnected.**



**Voltages of over 60 V can be present in the basic and power modules up to 5 minutes after they have been switched off!**

Removing a module:

- Check that the module is completely de-energized
- Unplug connectors
- Release 4 rotary locks
- Pull out individual module towards the front

Installing a module:

- Check that the seals on the heat sink are complete
- Insert module together with the heat sink into the cut-out provided for this purpose in the rear panel
- Close 4 rotary locks
- Re-insert connectors

## 2 Basic modules and servo power modules

The basic and servo modules are designed for use as external axes or for special applications. The structure and internal parts are comparable with those of the six-axis power module PM6-600. Axis-independent and axis-specific functions are distributed between the basic and servo modules. A maximum of 4 axes can be assigned, in two 2-axis power modules, to one basic module.

## 2.1 Basic module PM0–600

The PM0–600 incorporates:

- Clocked, controlled low voltage supply for the following modules
  - Periphery (27 V DC / 6 A + 4 A, individually fused)
  - PC (27 V DC / 6 A, backed up by external batteries)
  - Equipment within the cabinet (27 V DC / 4 A)
  - Holding brake for motors (26.5 V DC / 7.5 A)
  - Lead battery for backing up the PC (26.8 V DC) incl. charging and discharging control
  - PM0–600 logic (15 V DC, –15 V DC, +5 V DC, with back-up)
  - PM1(2)–600 drivers (16 V AC / 100 kHz)
- 600 V supply module for output stages incl.
  - Main contactor and starting circuit
  - Mains overvoltage limiter
  - Intermediate circuit rectifier (600 V DC / 4 kW)
  - Ballast circuit 800 W (can be extended to 2 kW)
  - High-speed discharge of intermediate circuit
  - Temperature monitoring
  - Suppression elements
  - Interface with safety module (FE201)
- Logic module incl.
  - Bidirectional interface for parallel data transmission from/to DSEAT with parity check
  - Current controller and pulse width modulation
  - Logic operations (e.g. drive enables, brake control)
  - Fault detection: brake fault, overvoltage, undervoltage, battery charge, overtemperature, motor overcurrent, current controller limitation, transmission error, sumcheck error
  - Detection and signalling of: motor connector assignment, ready for operation

## 2.2 1-axis power module PM 1–600/.. , 2-axis power module PM 2–600/25–16

The power modules incorporate:

- IGBT servo output stages for 1 or 2 robot axes or external axes incl.
  - Intermediate circuit electrolytic capacitors
  - Driver boards with integrated short-circuit protection of the output stage
  - Potential-free motor current measurement
  - Short-circuit braking relay
  - Power adaptation to motor sizes via motor connector selection
  - Monitoring of heat sink temperature
  - Individual axis switch-off

## 2.3 Power supply module PM0-600

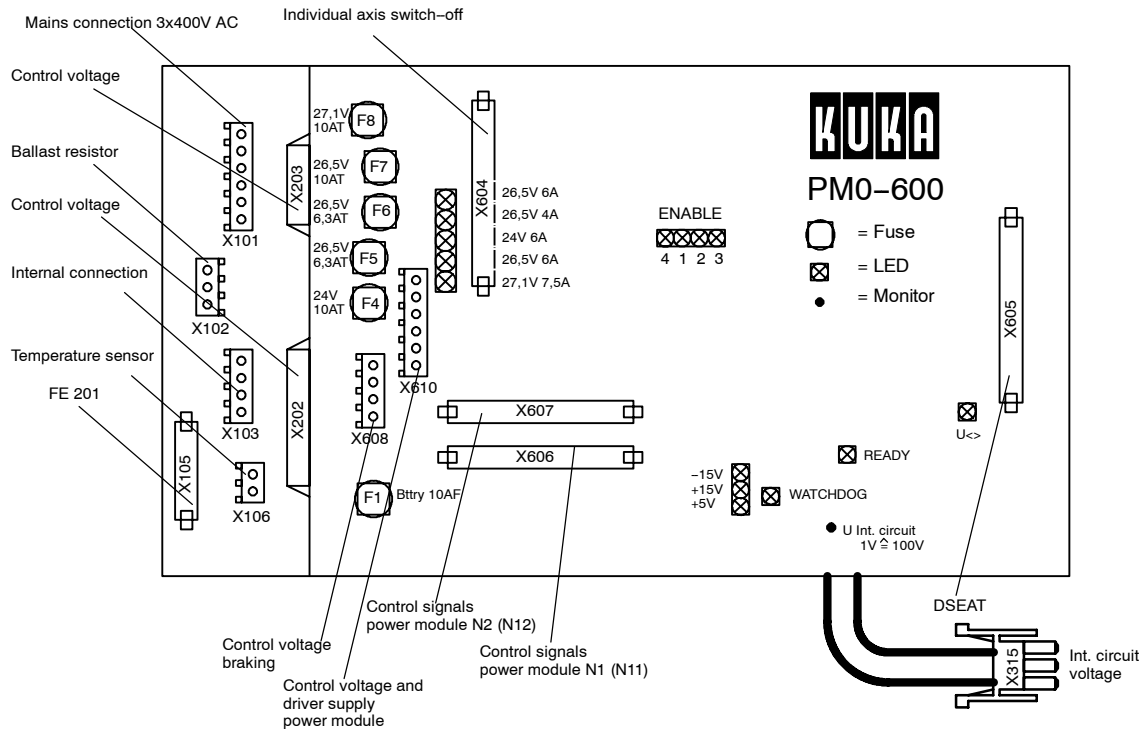
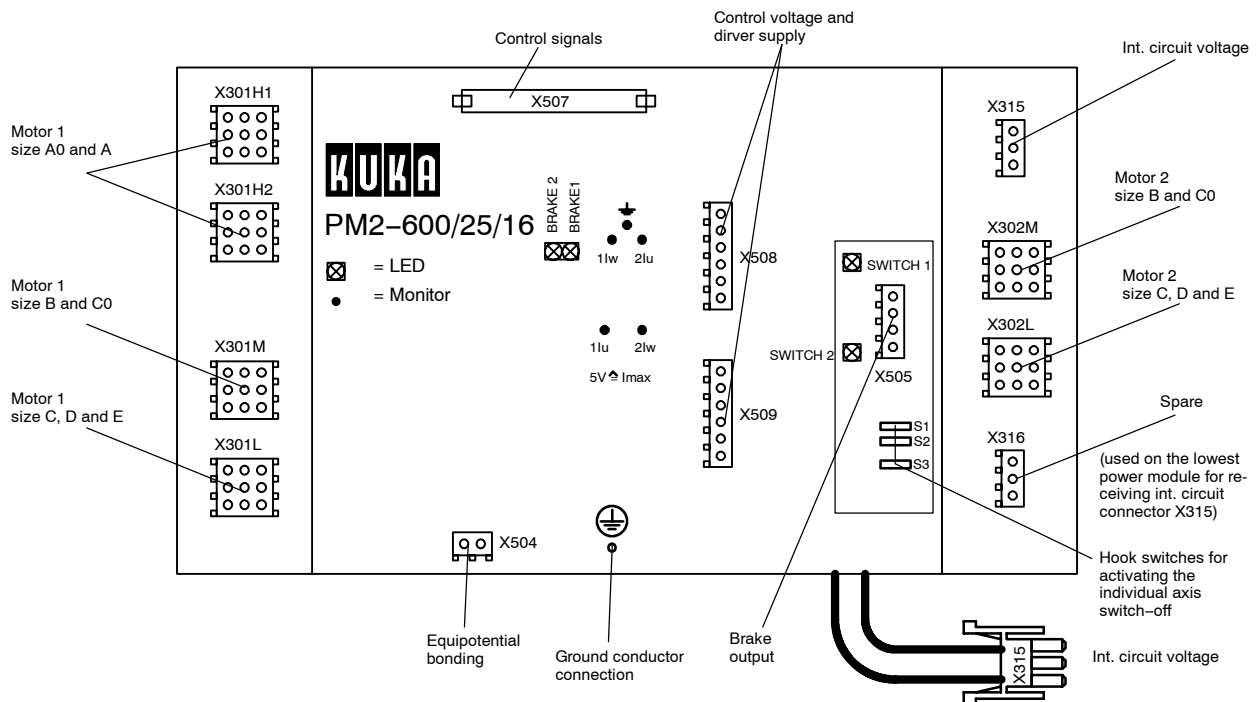


Fig. 5 PM 0-600 Front view

## 2.4 2-axis power module PM2-600/25/16



## 2.5 Individual axis power module PM1-600/25

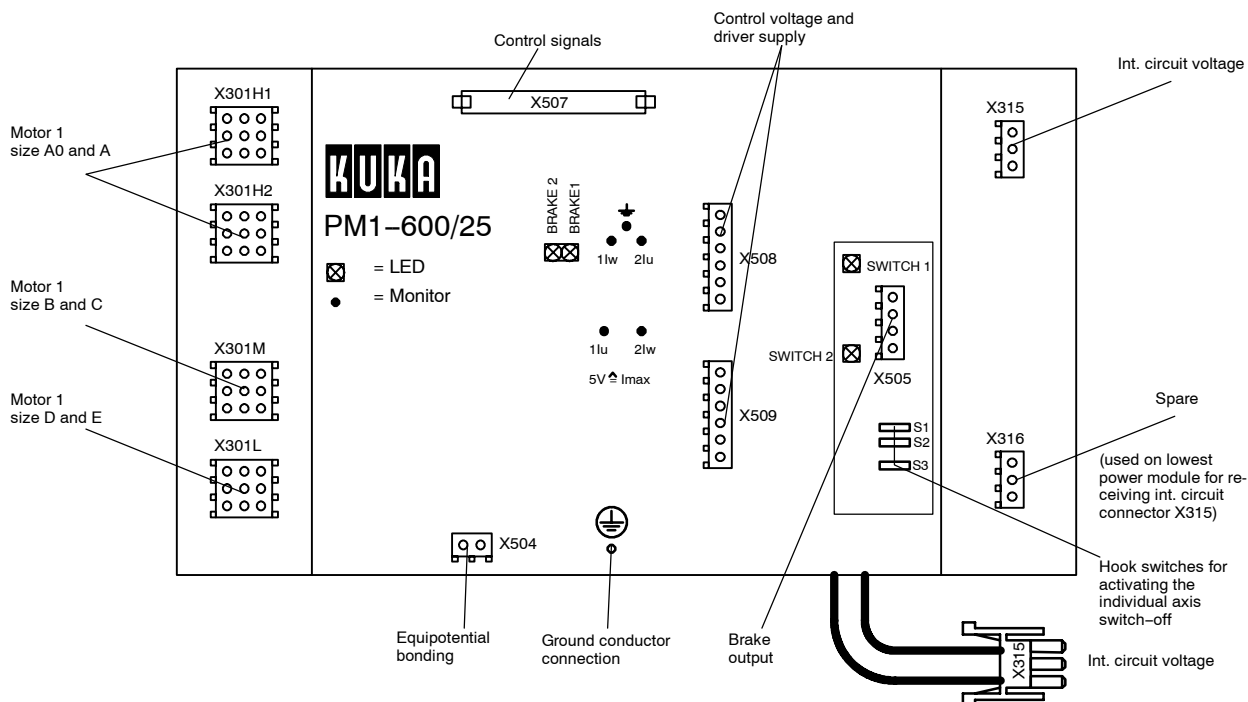


Fig. 6 PM 2-600/25/16 Front view

## 2.6 Individual axis power module PM1-600/16

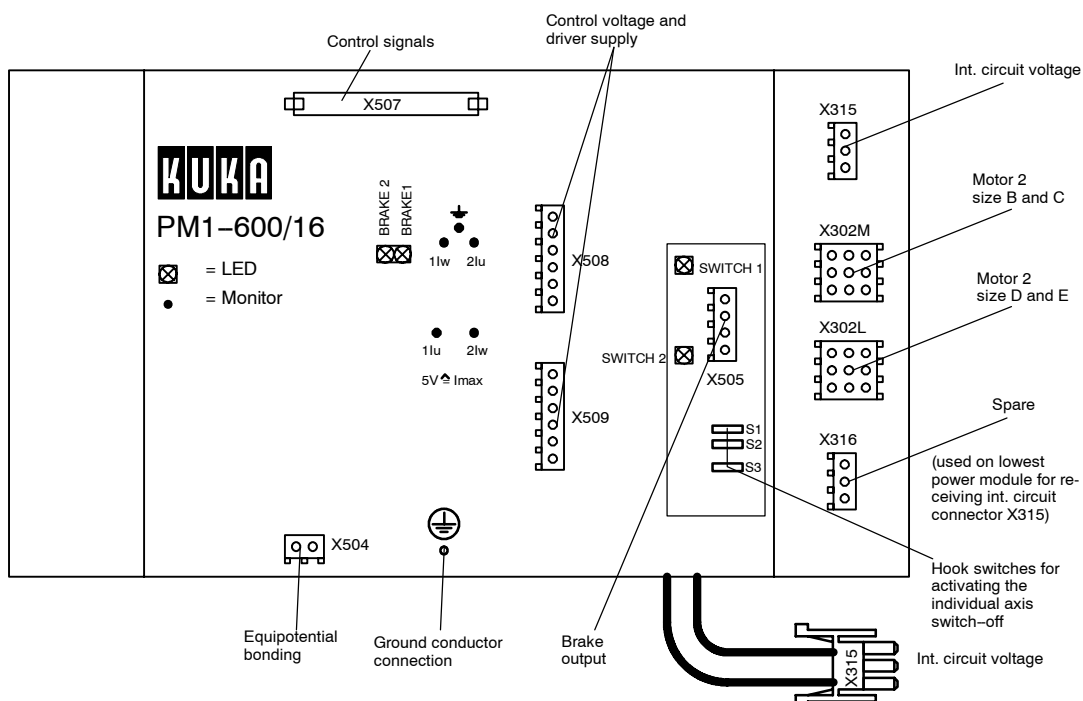


Fig. 7 PM 2-600/25/16 Front view



## 2.7 Connection diagram for PM 0 + PM2 (without PM6-600)

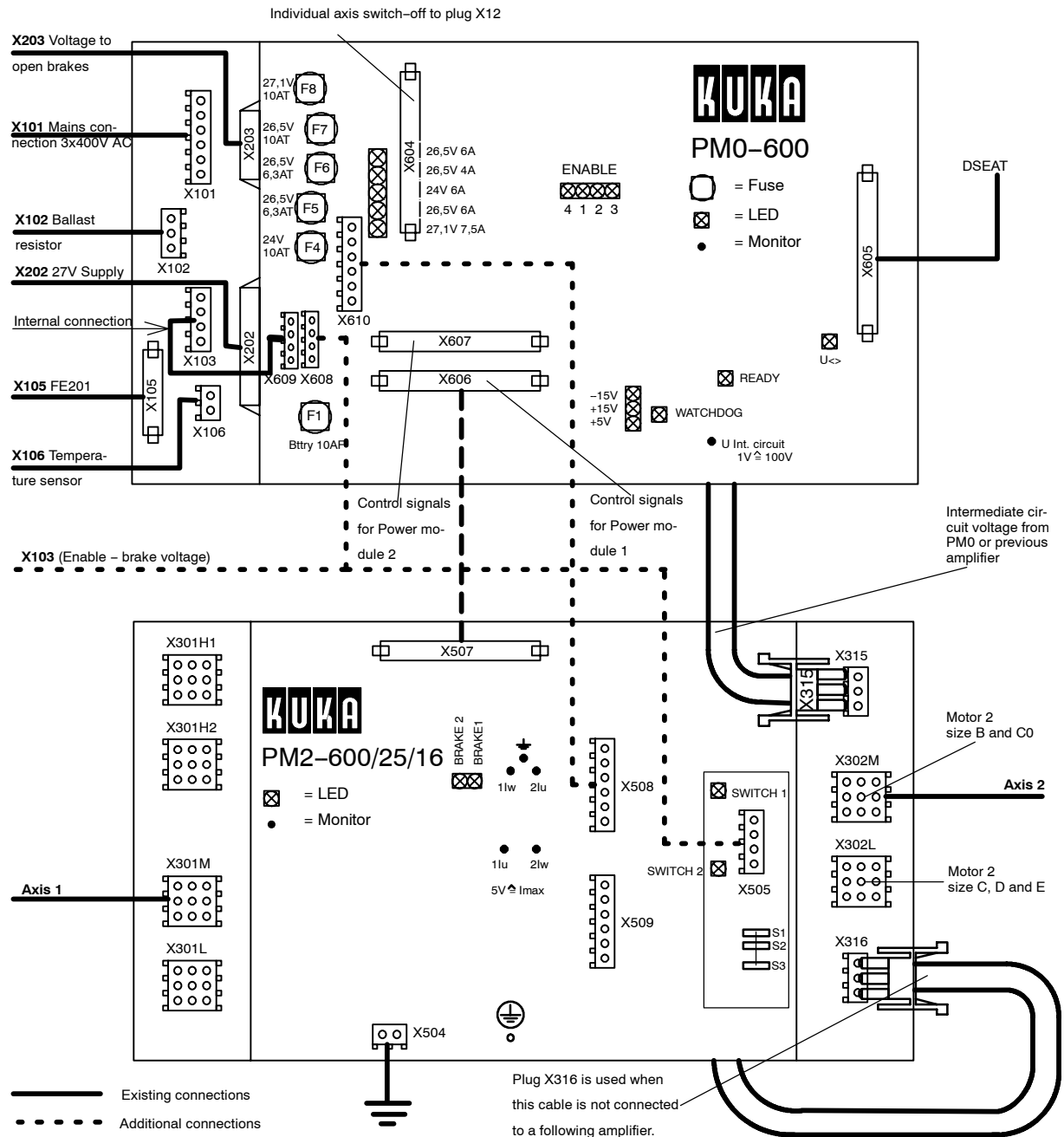


Fig. 8 Connection diagram for PM0 + PM2 (without PM6-600)

### 2.7.1 Jumpering of the motor connectors

The motor connectors are inserted in accordance with the robot type connected.

Plug position (H1 / H2) :  $I_{\max}$  (RMS) = 64 A

Plug position (M) :  $I_{\max}$  (RMS) = 32 A

Plug position (L) :  $I_{\max}$  (RMS) = 16 A

The controller detects the connector position and signals an incorrectly connected motor cable.

With plug position (H), both cables must always be connected.



**The controller does not detect whether the motor cables have been interchanged. It is important to maintain the correct assignment of the motor cables to the respective axes !**

## 2.8 Current regulator programming (\$G\_COE\_CUR) of the Powermodule

The powermodules PM0 and PM6 contain a programmable potentiometer (EEPot), with which the current regulator can be optimized for the appropriate robot type. The optimum value for this setting is entered in the machine data (\$G\_COE\_CUR).

When exchanging a PM0-600, PM6-600 or a KRC1-control cabinet with powermodule, the correct current settings should be taken over and saved on the new powermodule.

The following proceedings should be followed after a power module or control cabinet has been exchanged:

- (1) Switch on the KRC1-control cabinet and let it start up.



**[Only for power modules with write-protect jumpers:**

(visible from front under cutout in plate, lettering: "Betrieb/Programmierung") Put the jumper in the position "Programmierung"].

- (2) With the KCP on the BOF (GUI), call up the menu option HELP-> VERSION. Check if the displayed robot type corresponds with the actual installed machine. When this is not the case, the correct machine data has to be loaded.
- (3) Call up the menu option MONITOR-> VARIABLE -> MODIFY.  
A window for the entry of variables is displayed in the field "NAME" enter the following: \$PROG\_EEPOT
- (4) Press the softkey "NEW VALUE" and enter the value 1 (for axis no.1).

When the enter key is pressed, the current regulator of axis 1 is programmed with the value that is saved in the machine data.

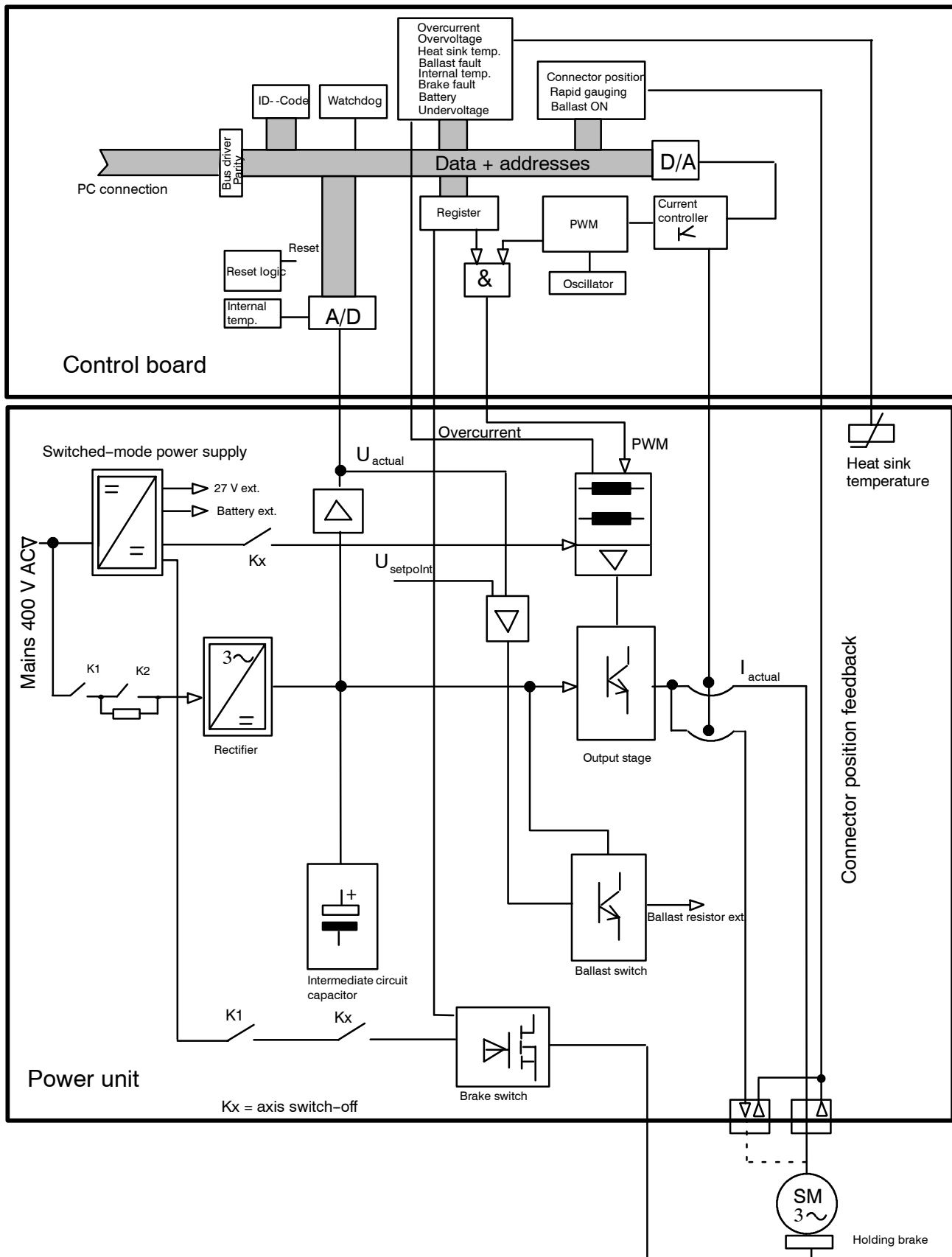
By entering "2" in the field "NEW VALUE", the axis 2 can be programmed and so on.

All the axes that are controlled by the robot including external axes, must be programmed in this way.



**Only for power modules with write-protect jumpers:**

when the current regulators of all axes have been programmed, the write-protect jumper must be replaced in the position "Betrieb".



**Fig. 9** Basic and servo power module

### 3 Safety logic module FE201



Incorrect settings of the DIP-FIX switches X1 –X10 can lead to dangerous malfunctions of the robot in certain circumstances ! Before switching the controller on, it is therefore imperative to check the settings of the DIP-FIX switches X1 – X10 again according to the adjustment instructions in this section!



If these instructions are not observed there is a risk of extensive damage to the robot !

#### 3.1 Function blocks

Module FE201 serves to implement the safe switch-off function and the Drives ON circuit. It comprises:

- Voltage monitoring for 27 V
- Dual-channel EMERGENCY STOP circuit
- EMERGENCY STOP delay
- Dual-channel user safeguard (operator safety and enabling circuit)
- Operating mode switchover (Test / Automatic)
- Drives ON circuit

##### 3.1.1 Settings

To ensure the safe functioning of the robot, it must be checked that the DIP-FIX switches have the following settings before the robot is put into operation:

###### –X1 – X6

These DIP-FIX switches serve the purpose of setting the EMERGENCY STOP delay in Automatic mode.

X1 and X4	X2 and X5	X3 and X6	Emergency Stop delay
closed	closed	closed	0.5 s
closed	closed	open	0.7 s
closed	open	open	1.0 s
open	open	open	1.3 s (default setting)

###### –X7 – X9

X7 – X9	External axes
closed	not present (default setting)
open	present

###### –X10 (version B only)

Position “b” (default setting)	Emergency Stop switch-off <u>without</u> path-oriented braking
Position “a”	Emergency Stop switch-off <u>with</u> path-oriented braking

### 3.2 View FE201 version A

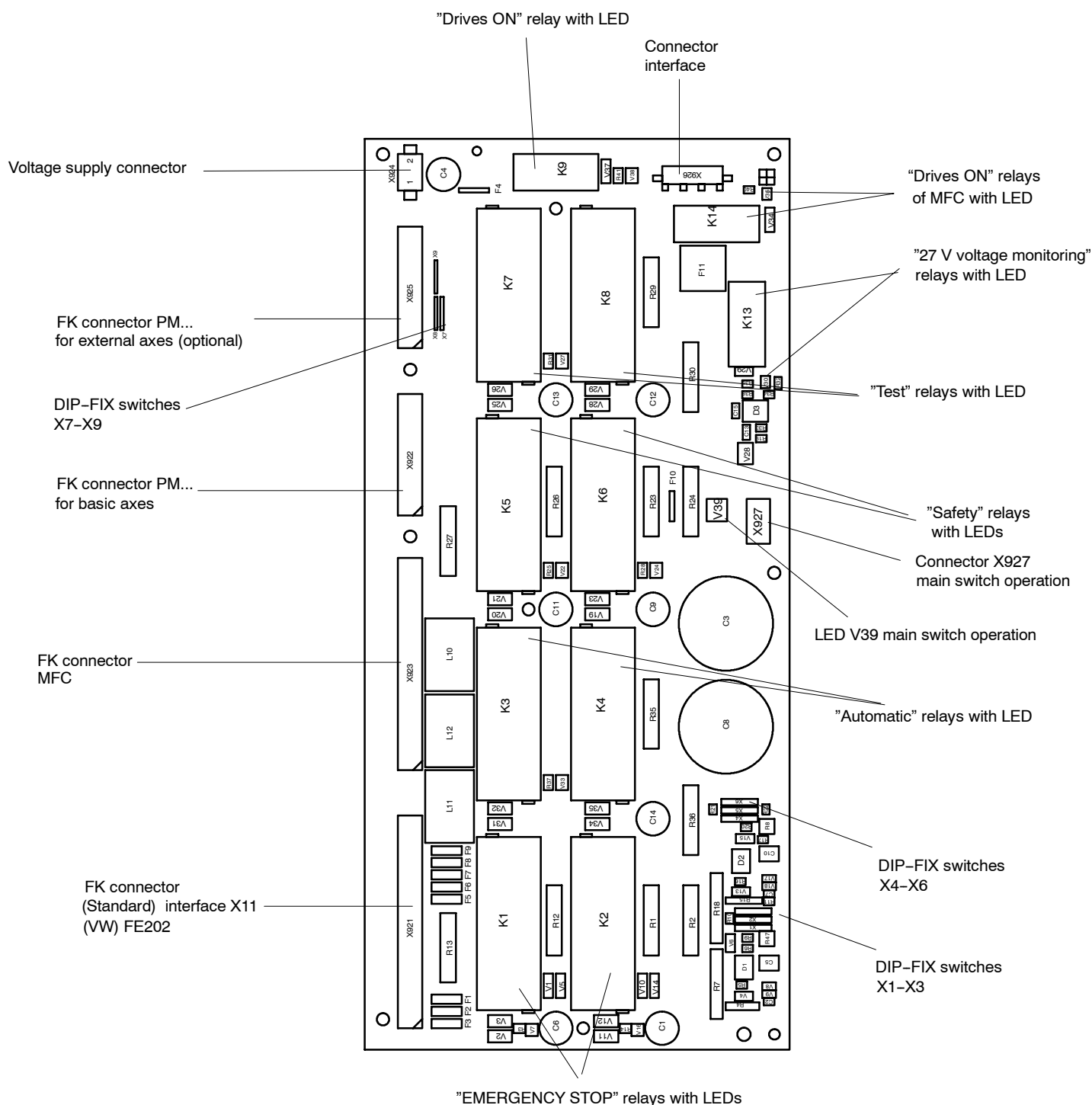
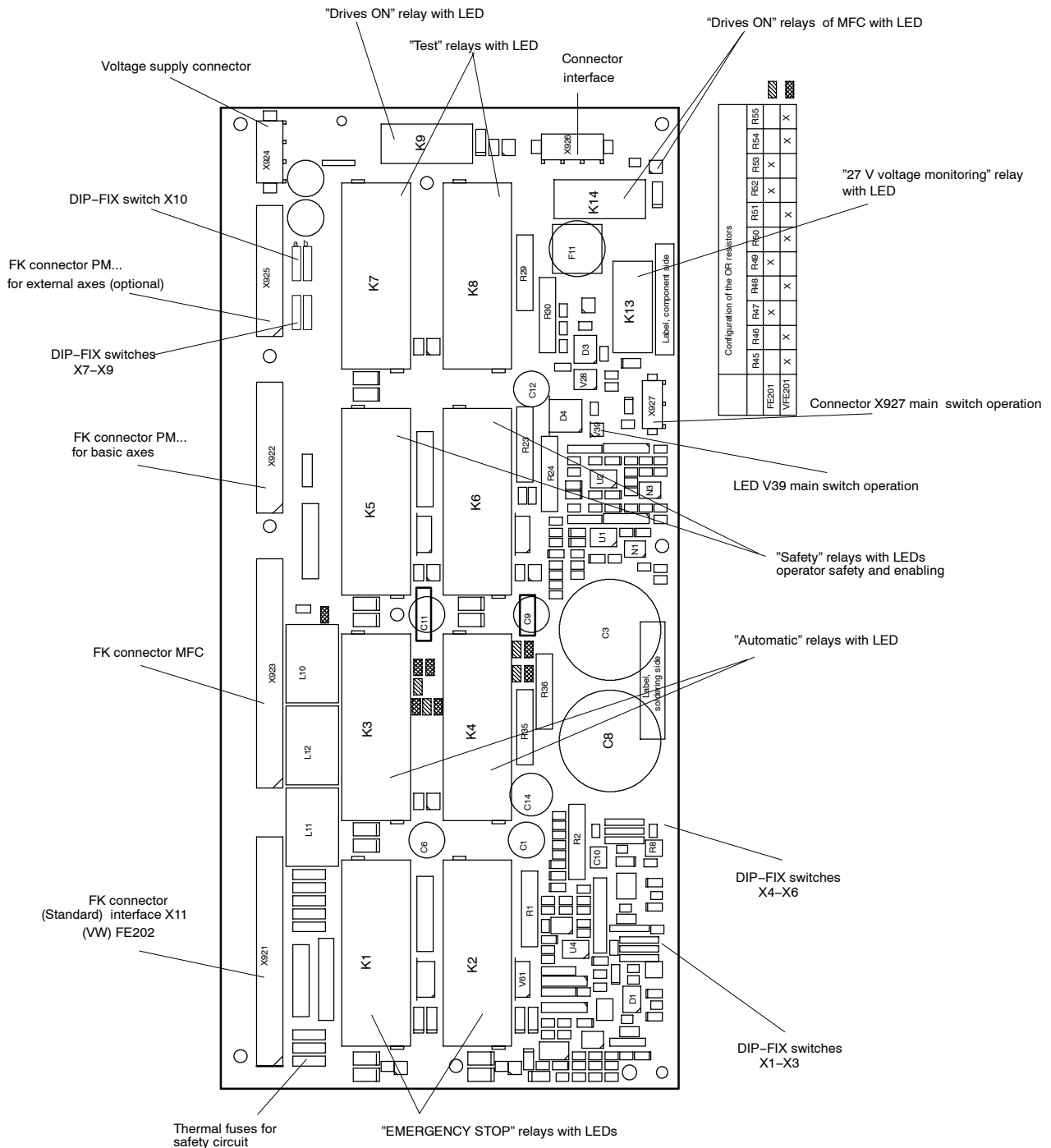


Fig. 10 FE201 version A

### 3.3 View FE201 version B



Jumpers :

X7 – X9

with 6 axes, closed  
with > 6 axes, open

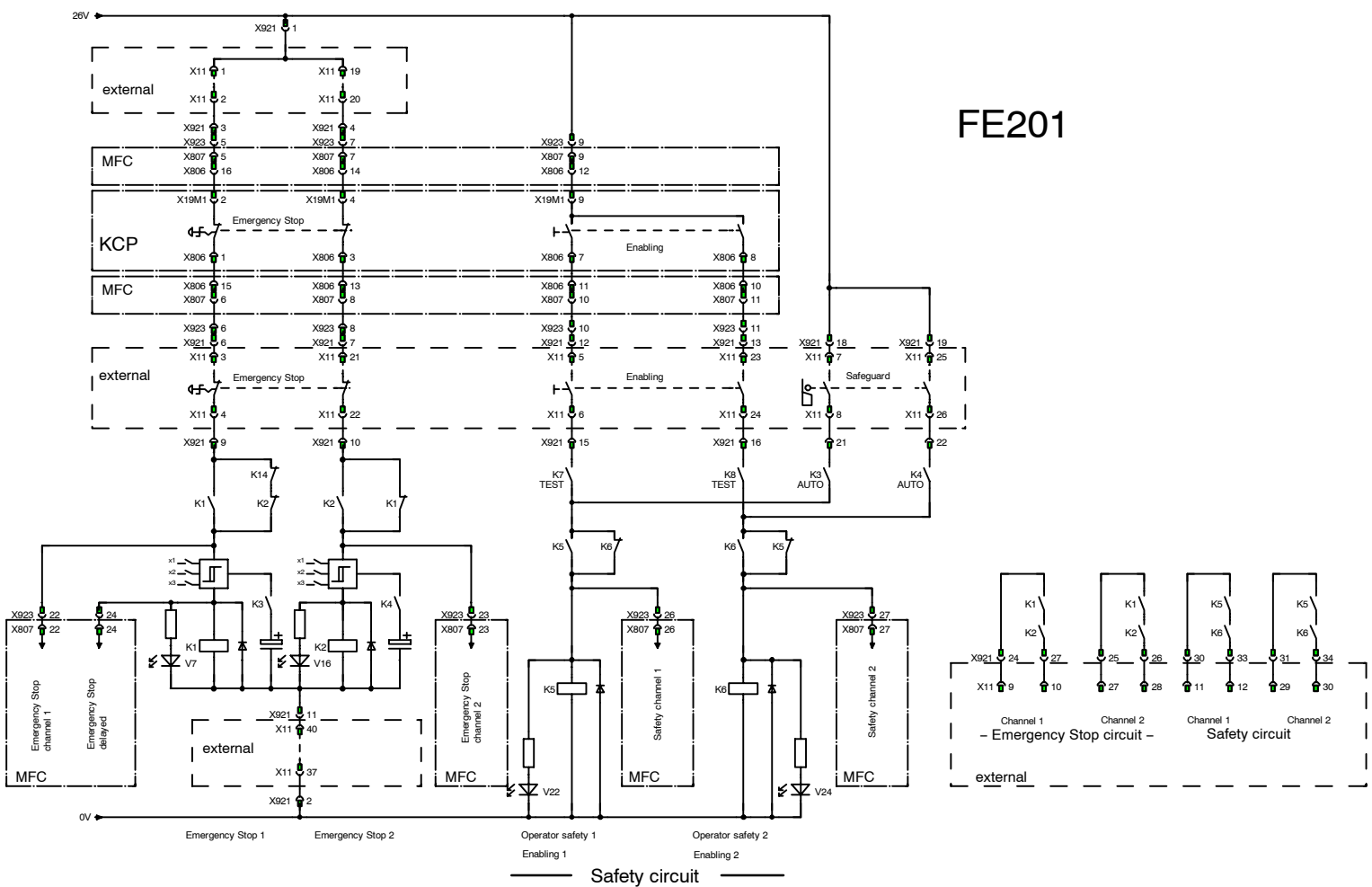
X1 – X6

EMERGENCY STOP delay approx.1.3s, open  
approx. 0.5s, closed

X10

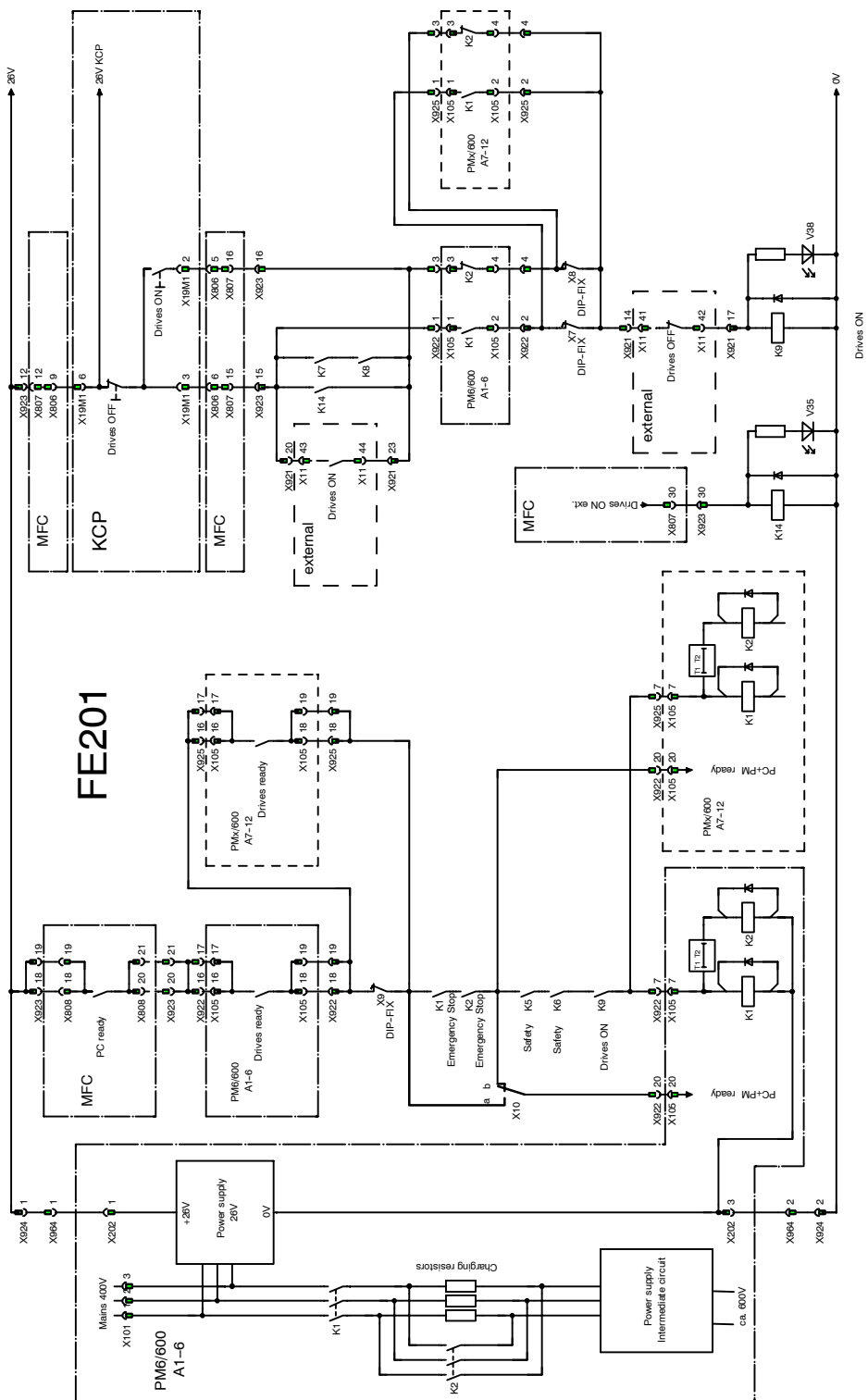
Pos. b: EMERGENCY STOP without path-oriented braking  
Pos. a: EMERGENCY STOP with path-oriented braking

## FE201

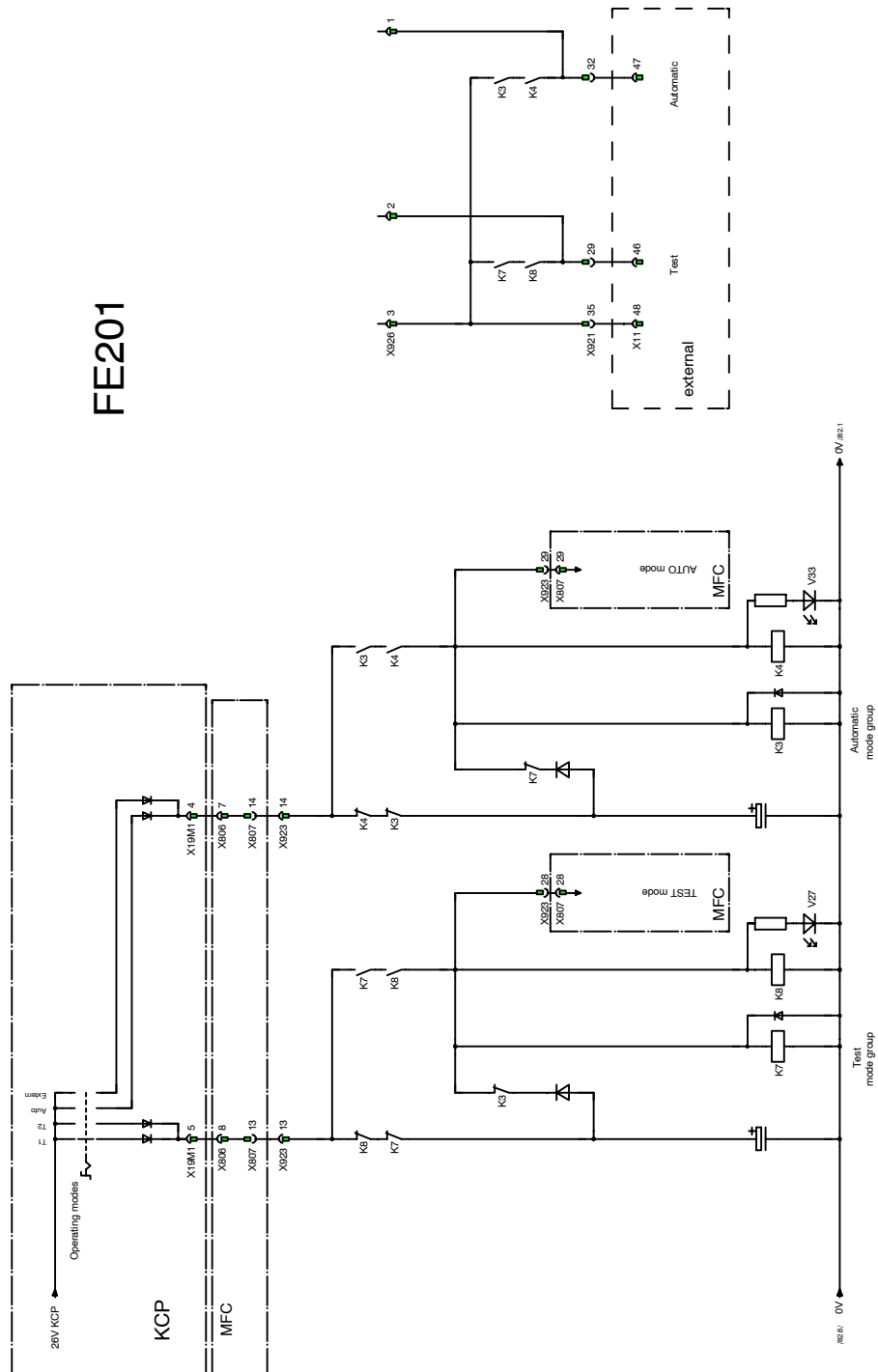




## 3.5 Drives ON/OFF circuit



### 3.6 Operating mode switchover



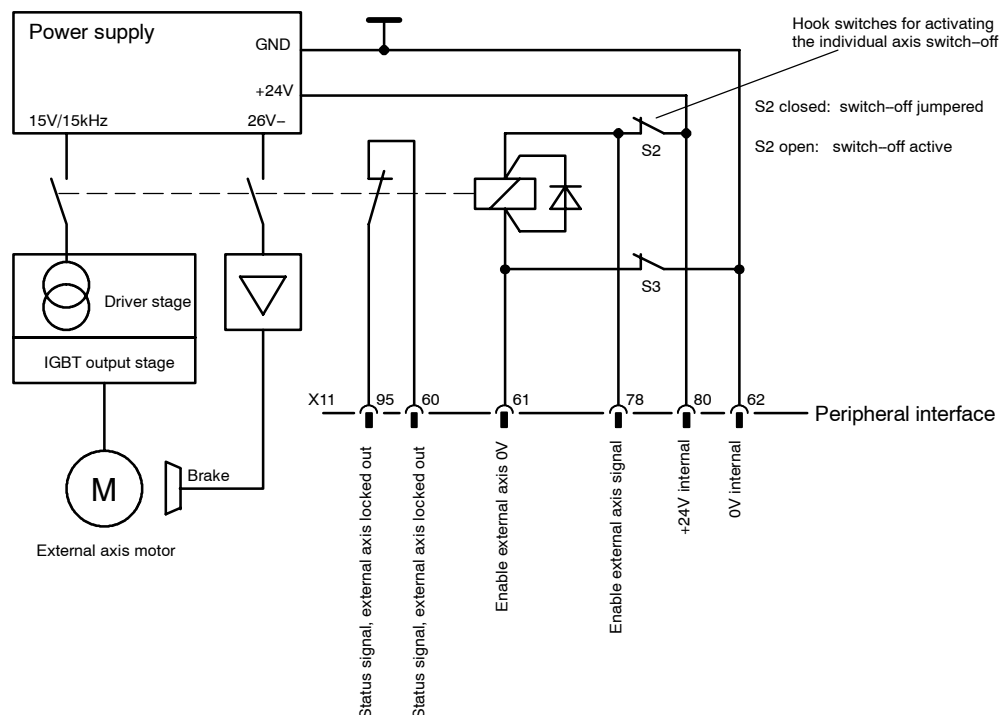
## 4 Individual axis switch-off for external axes

This unit allows the external axis to be switched off independently of the robot axes by means of hardware. For this purpose, the driver voltage for the converter output stage and the supply voltage to the brake are disconnected.

The relay of the switch-off unit must be operated and evaluated in a failsafe mode by a higher-level controller. The switch-off operates on a “low active” basis, i.e. if the relay of the individual axis switch-off is energized, the axes are enabled. A status signal is provided by a break contact.

As a precondition for switch-off, the external axis must be positioned in the active program, the servo enable must be inhibited and the brake applied. The axis may not be moved in the program for the duration of the axis switch-off.

If the axis switch-off is not required, the relay of the individual axis switch-off must be permanently energized or the hook switches N11 / S2 must be closed. (For the position, see Fig. 6)



**Fig. 11** Block diagram of individual axis switch-off

## 4.1 Fault with power unit PM0-600 series “1” and “2”

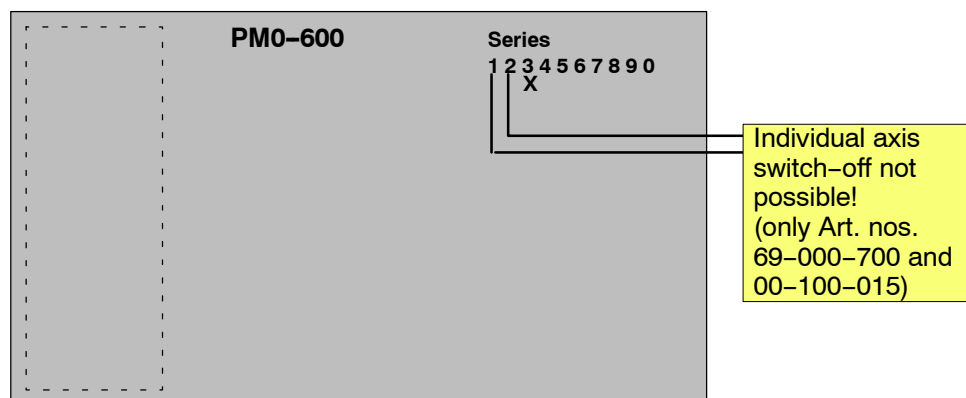
If, while an external axis is running, a second or third external axis is switched off and on again (with the aid of the individual axis switch-off function), an error message “Overcurrent axis X” is displayed at the time of switching on.

The error is caused by the common supply voltage for the driver stages of all external axes which temporarily drops to zero due to the current surge of an axis being switched on.

This error only takes place when the individual axis switch-off is activated and when two or more axes have to be switched individually.

### Remedial action:

In the case of two or more external axes with individual axis switch-off, the **series “3”** PM0-600 power unit must be used. This applies only to PM0 with Art. nos. 69-000-700 and 00-100-015.



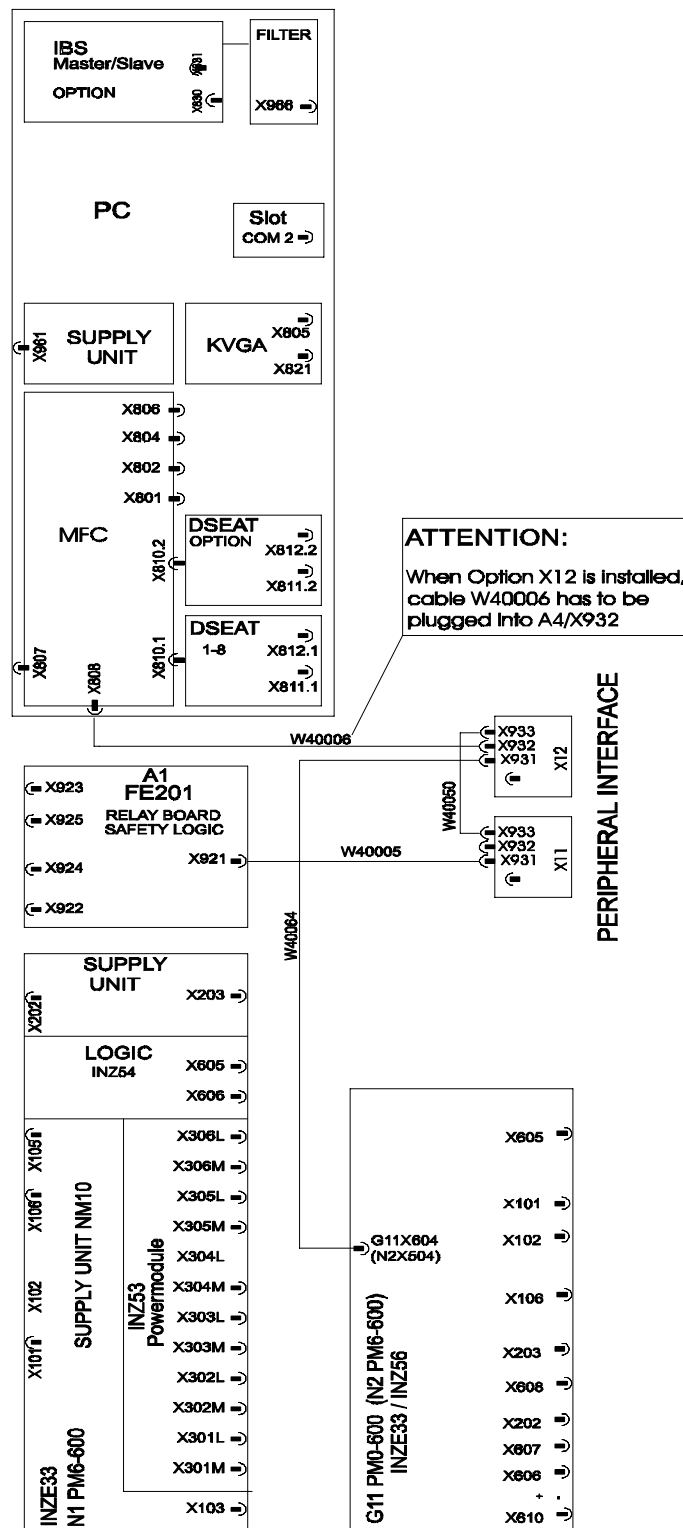


Fig. 12 Wiring diagram – switch-off for external axes

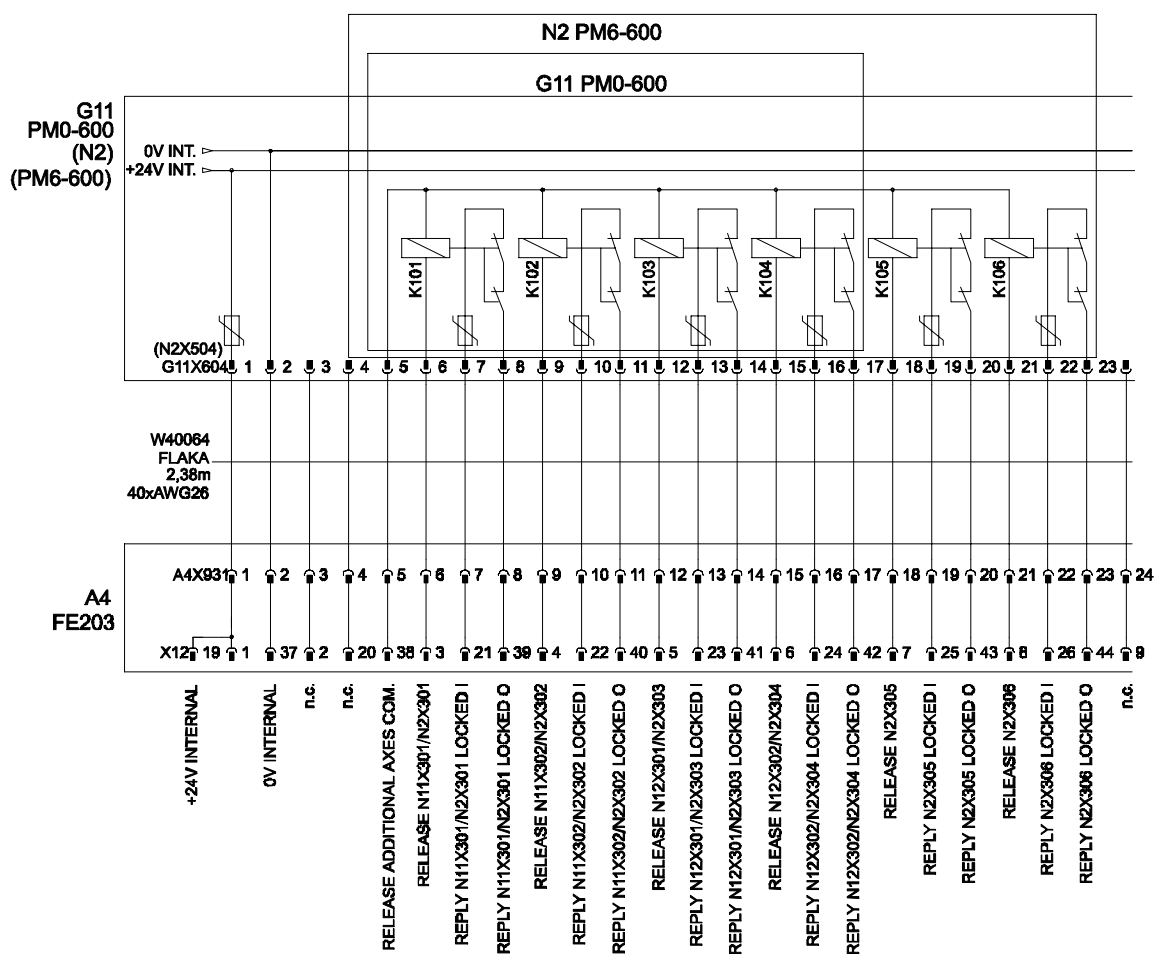


Fig. 13 Circuit diagram X931 - X604

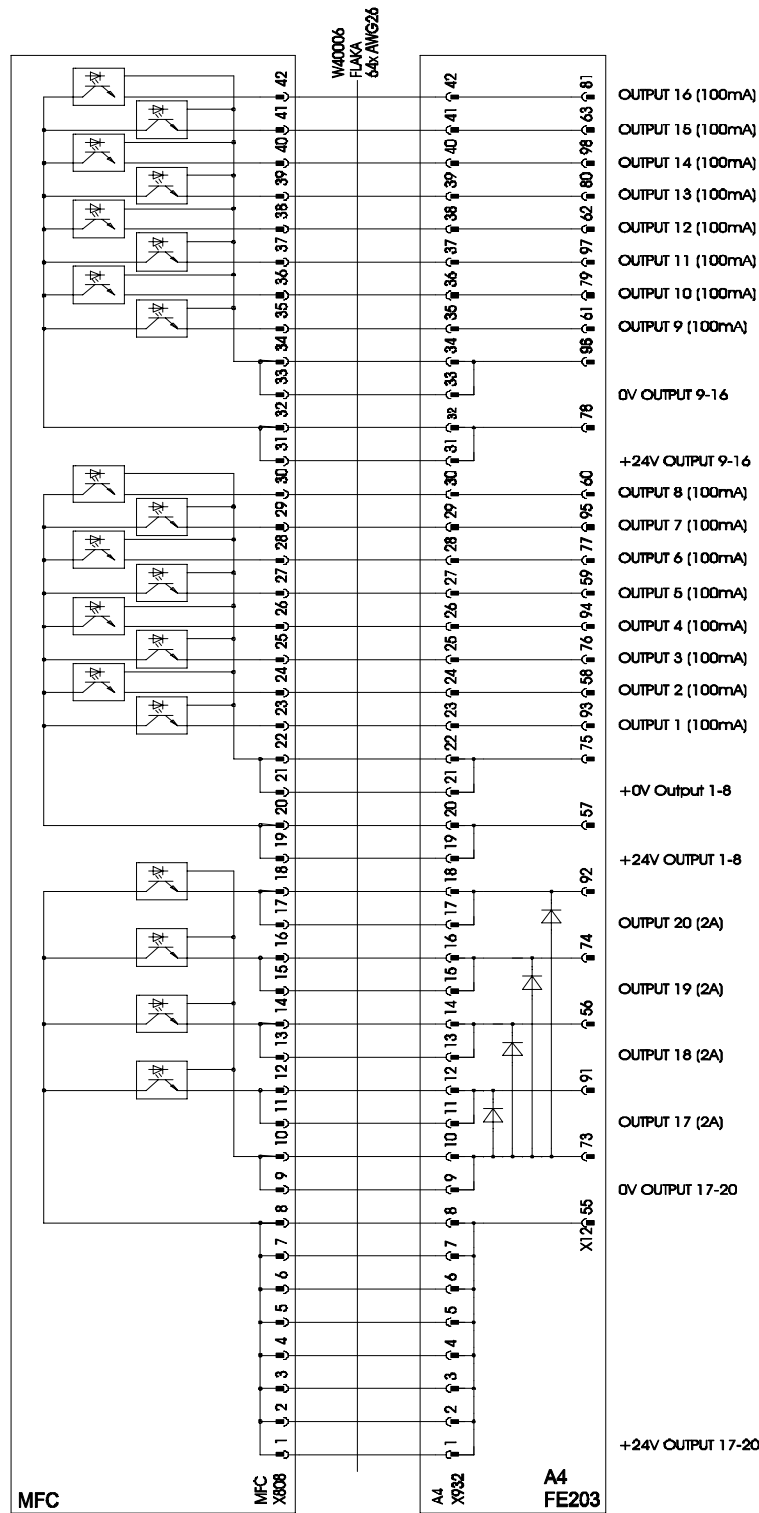


Fig. 14 Outputs

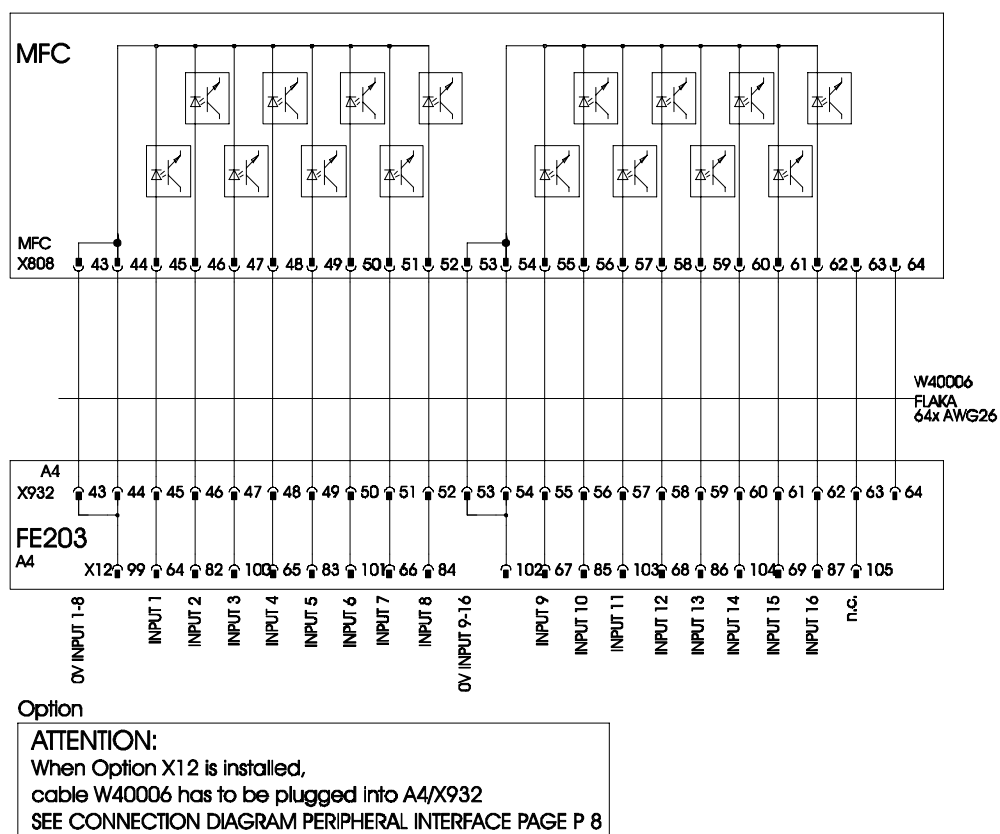


Fig. 15 Inputs



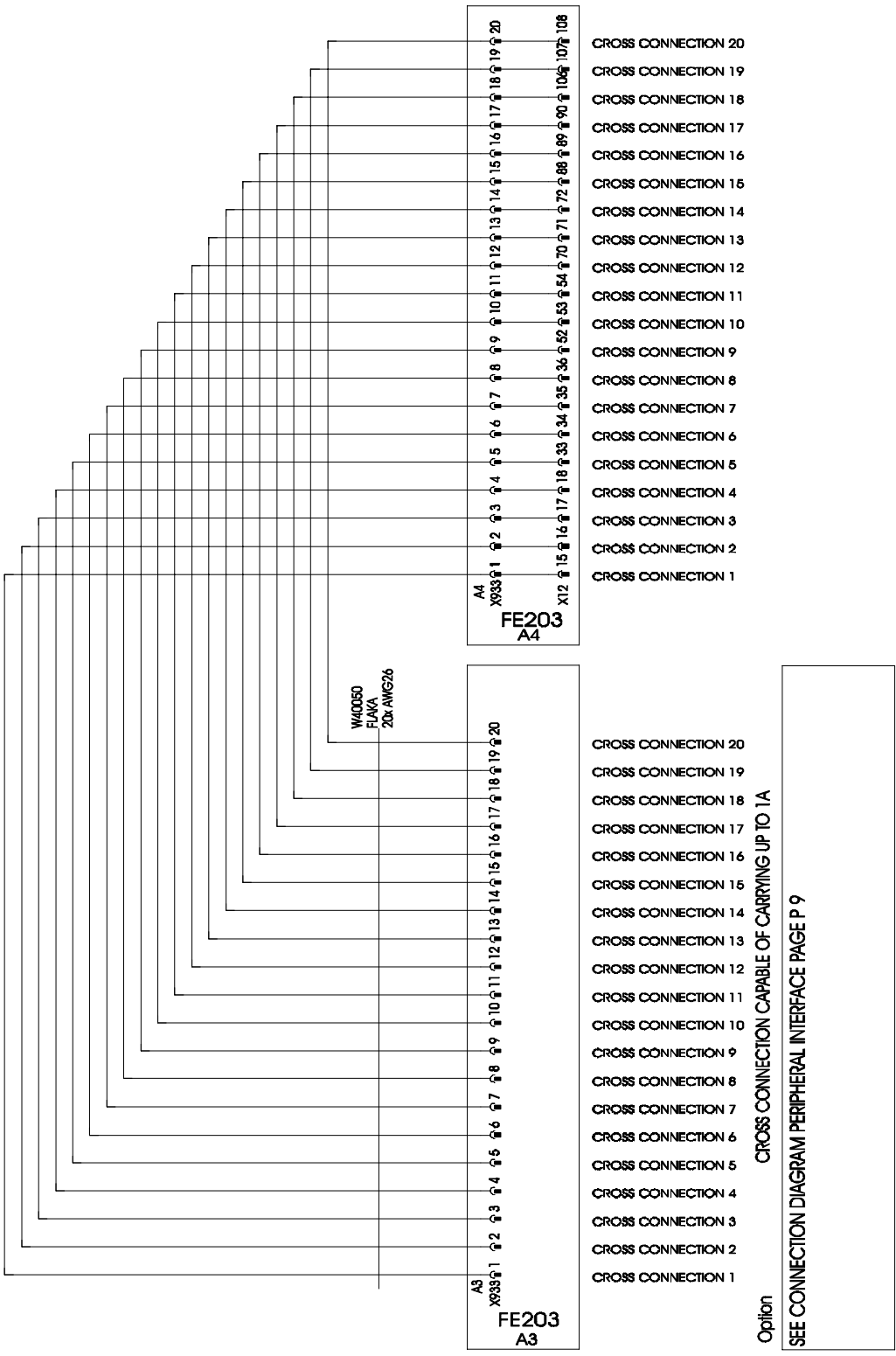


Fig. 16 Cross connections



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## 5 Connector panel / Peripheral interfaces

For the purpose of operating the robot in a stand-alone mode or with an external controller, or of controlling peripheral equipment through the robot system, the connectors X1, X20, X11, X21 and X19 are provided. These connectors have the following functions:

- X1: Supply connection Han6 HsB
- X01: Service socket (optional)
- X20: Motor connector, axes 1 to 6
- X7: Motor connector, axes 7 to 12 (optional)
- X11: Peripheral connector
- X12: Peripheral connector (optional)
- X13: Peripheral connector (optional)
- X21: Data cable connector, axes 1 to 8
- X8: Data cable connector, axes 7 to 12 (optional)
- X19: KCP connector

The pin assignment of the CAN bus and Ethernet interfaces is also described in this documentation.

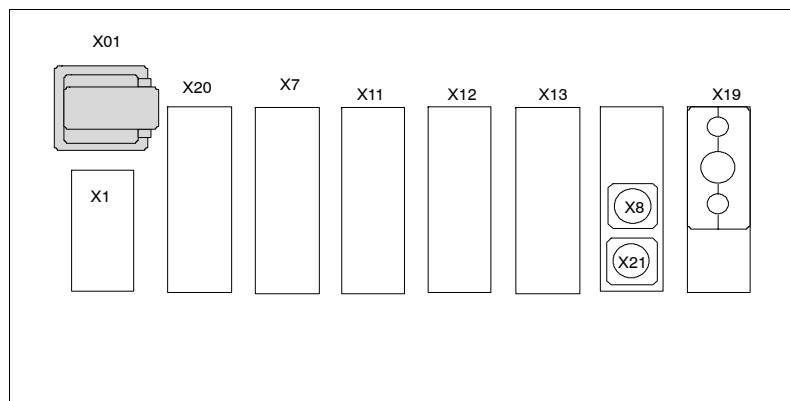








Fig. 17 Connector panel



**All contactor, relay and valve coils that are connected to the robot controller must be equipped with appropriate suppressor diodes (RC elements and VCR resistors are not suitable).**

## 5.1 Explanation of symbols

	=	electronic input, logic "1" 15 V -- 30 V (approx. 6.5 mA at 24 V)		=	electronic output 15V -- 30V DC load current for 2 A output min.: 0.02 A max.: 2 A
	=	relay coil 18 V -- 30 V		=	relay contact max. 500 mA / 30 V make contact
*	=	low active signal		=	relay contact max. 500 mA / 30 V break contact
	=	power protection 500 mA			

## 5.2 Interface signals X11

Interface signal	Pin	Description	Remarks
24V control voltage	37 1 / 19	0 V internal +24 V internal, max. 500 mA	Internal voltage supply for Emergency Stop circuit
Emergency Stop channels 1 and 2	2 / 3 20 / 21	Floating contacts of the Emergency Stop button on the KCP, 2-channel.	These contacts must be externally linked to the Emergency Stop relays.
Emergency Stop relay channels 1 and 2	4 22	Emergency Stop input, 2-channel	<b>CAUTION</b> Jumpering the two channels with one another is not permitted.
Emergency Stop relay 0V	40	0 V connection of the Emergency Stop relays for connection to the internal or external supply voltage.	
Ext. enabling channels 1 and 2	5 / 6 23 / 24	For connecting an external safety switch to 2 floating contacts.	If no supplementary switch is connected, pins 5 and 6 as well as 23 and 24 must be jumpered. <b>CAUTION</b> Jumpering the two channels with one another is not permitted.
Safeguard channels 1 and 2	7 / 8 25 / 26	For the 2-channel connection of the interlock of isolating safeguards.	<b>CAUTION</b> Jumpering the two channels with one another is not permitted.
Ext. drives OFF	41 / 42	A floating contact (break contact) can be connected to this input. The drives are switched off when the contact is opened.	If this input is not used, pins 41 / 42 must be jumpered.
Ext. drives ON	43 / 44	For connecting a floating contact. Pulse $\geq 200$ ms switches the drives on.	Signal must not be permanently active.
Emergency Stop contact channels 1 and 2	9 / 10 27 / 28	Floating contact of the Emergency Stop relays.	Contacts are closed if Emergency Stop is released.

Safety circuit channels 1 and 2	11 / 12 29 / 30	Floating contacts of the safety circuit	Is closed if the safeguard input is closed during automatic operation or if the safety switch is pressed in the Test mode.
Test and Automatic mode groups	48 / 46 48 / 47	Floating contacts of the operating mode relays.	Test contact is closed if Test1 or Test2 is selected on the KCP. Automatic contact is closed if Automatic or External is selected.
Rapid gauging channels 1 to 4	13 / 14 / 31 / 32 / 49	Inputs are read by the DSEAT at the 125 $\mu$ s clock rate.	When a 0/1 or 1/0 edge is detected, the actual axis values are stored by the software.



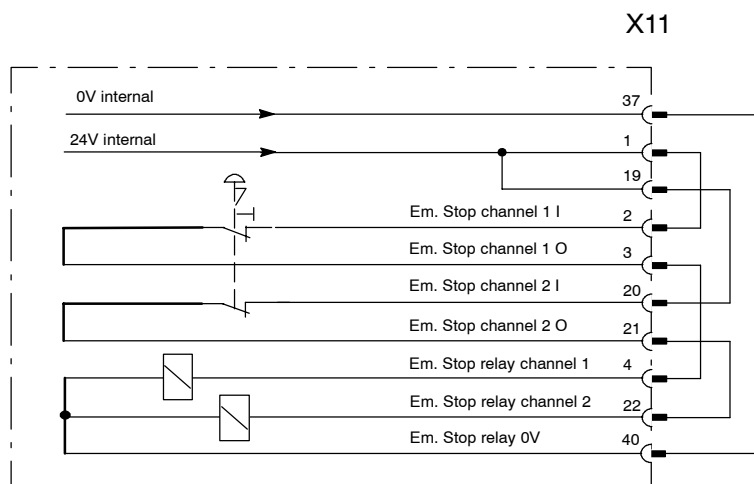
**All two-channel inputs must be set with a simultaneity of  $\leq 10$  ms. If this time is longer, a contact fault or open circuit will be detected and the relays interlocked. The interlock is cancelled again after both channels have been re-set.**



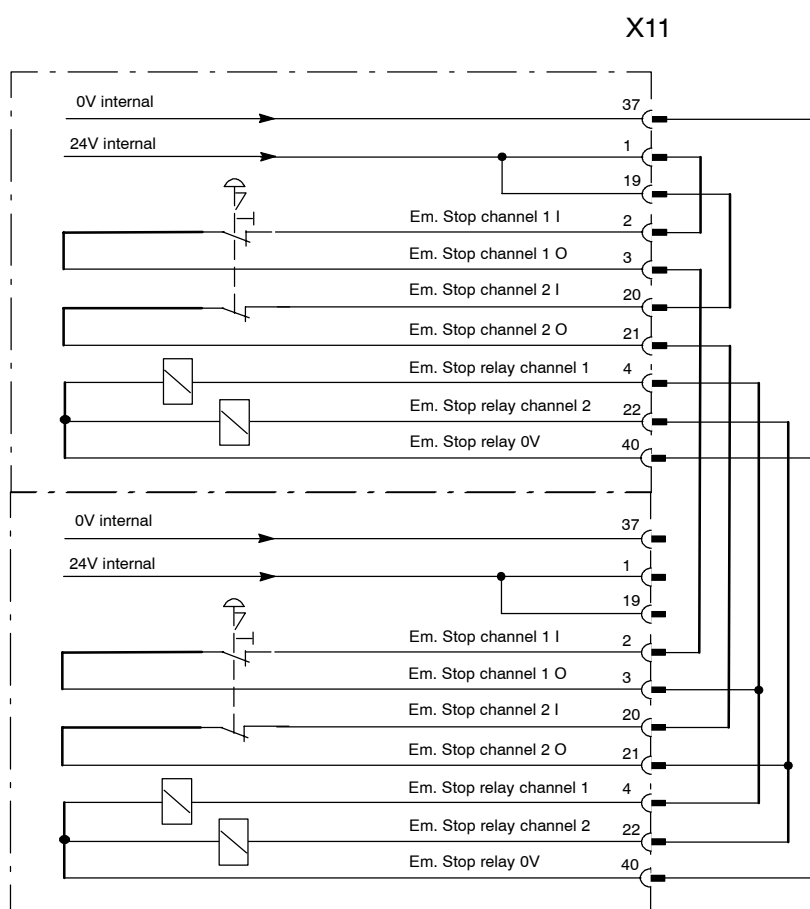
**Emergency Stop circuit, safeguard and ext. safety switch are signals that serve safety purposes and must be used in accordance with DIN EN 60204-1 and EN 775.**

### 5.3 Emergency Stop circuit

The following examples show how the robot Emergency Stop circuit can be linked to other robots or with the periphery.

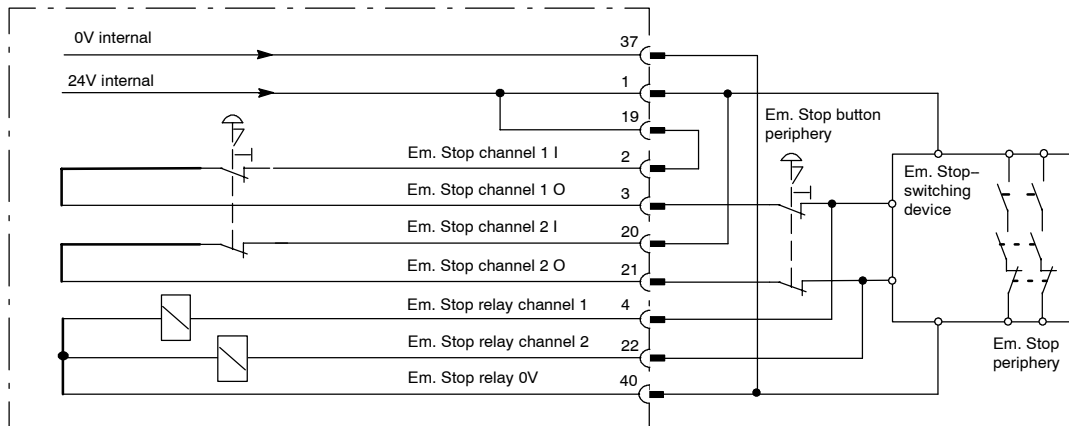


Emergency Stop circuit for a robot without periphery



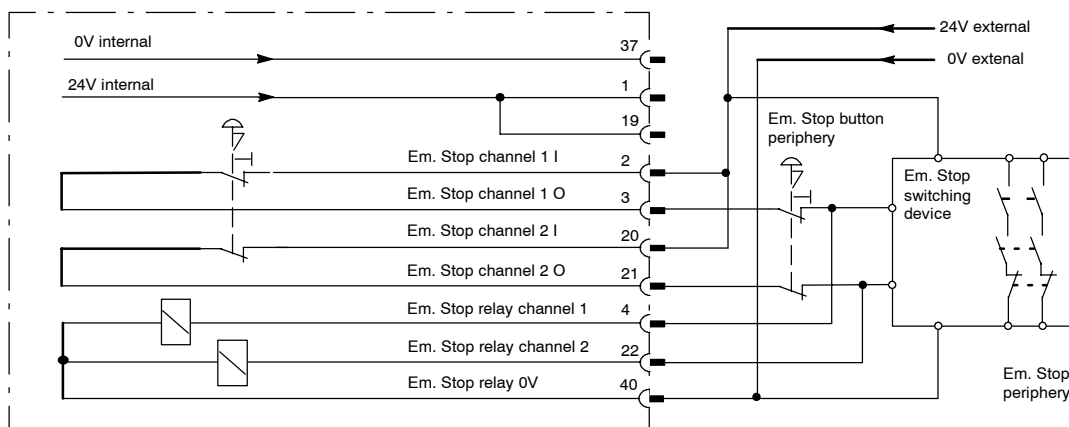
Emergency Stop circuit for two robots without periphery

X11



Emergency Stop circuit for a robot with periphery

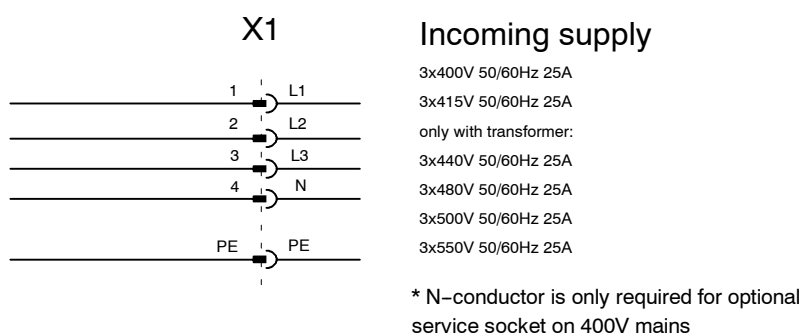
X11



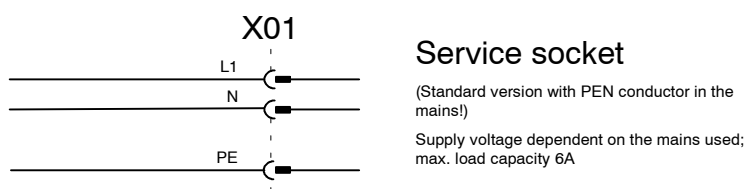
Emergency Stop circuit with external voltage supply and with periphery



## 5.4 Supply connection X1, service socket X01

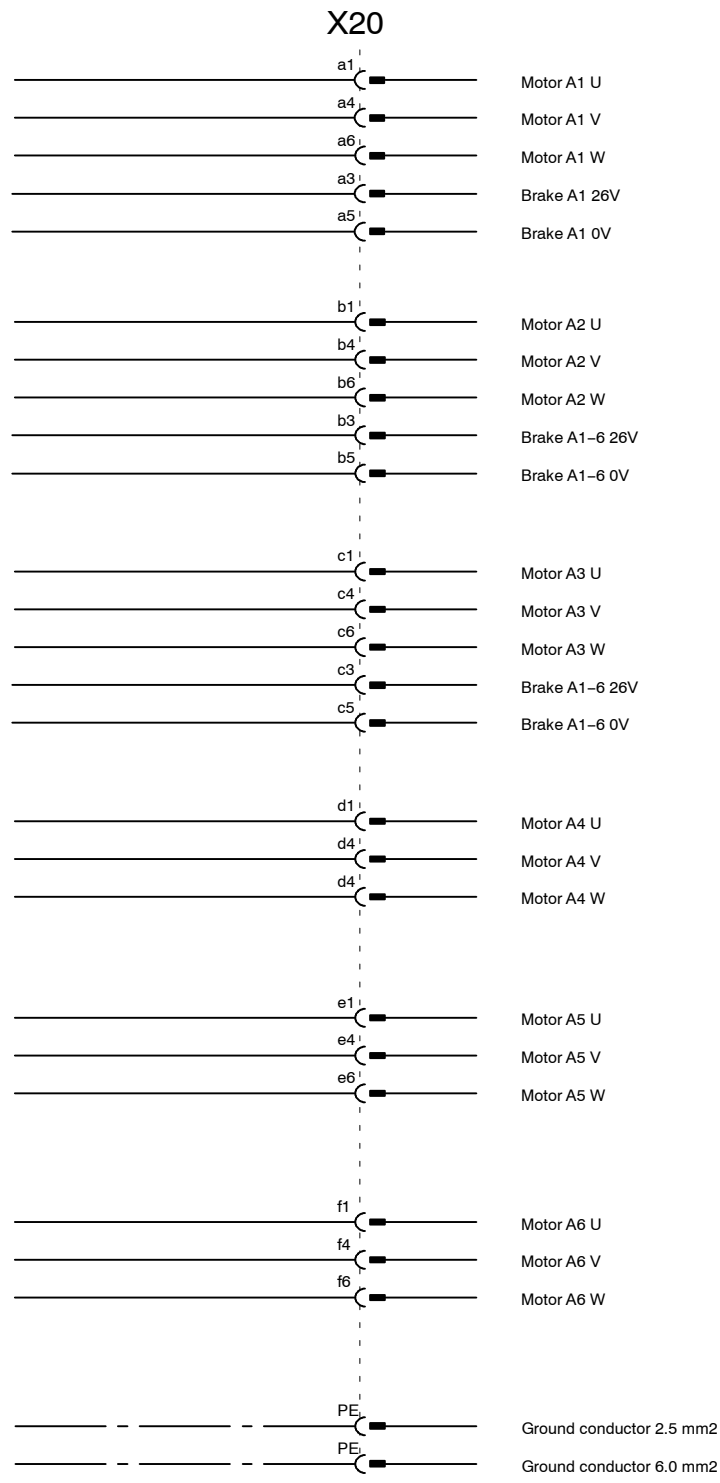


**Fig. 18 Supply connection X1**



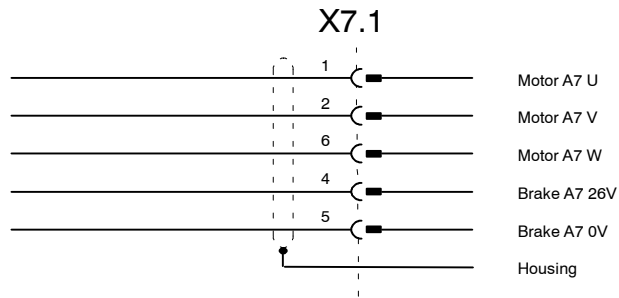
**Fig. 19 Service socket X01 (optional)**

## 5.5 Motor connector X20, axes 1 to 6

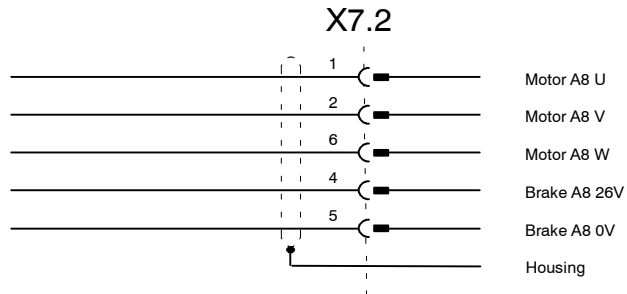


**Fig. 20 Motor connector X20**

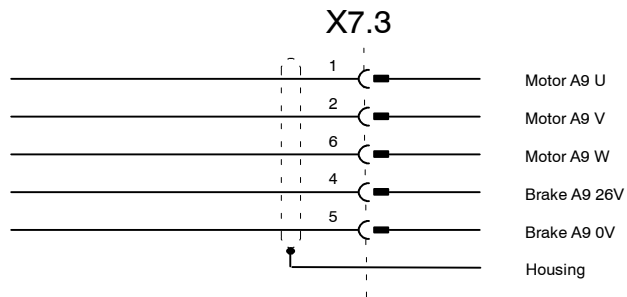
## 5.6 Motor connectors X7.1, X7.2, X7.3 (optional)



**Fig. 21 Motor connector X7.1**



**Fig. 22 Motor connector X7.2**



**Fig. 23 Motor connector X7.3**

## 5.7 Peripheral connector X11

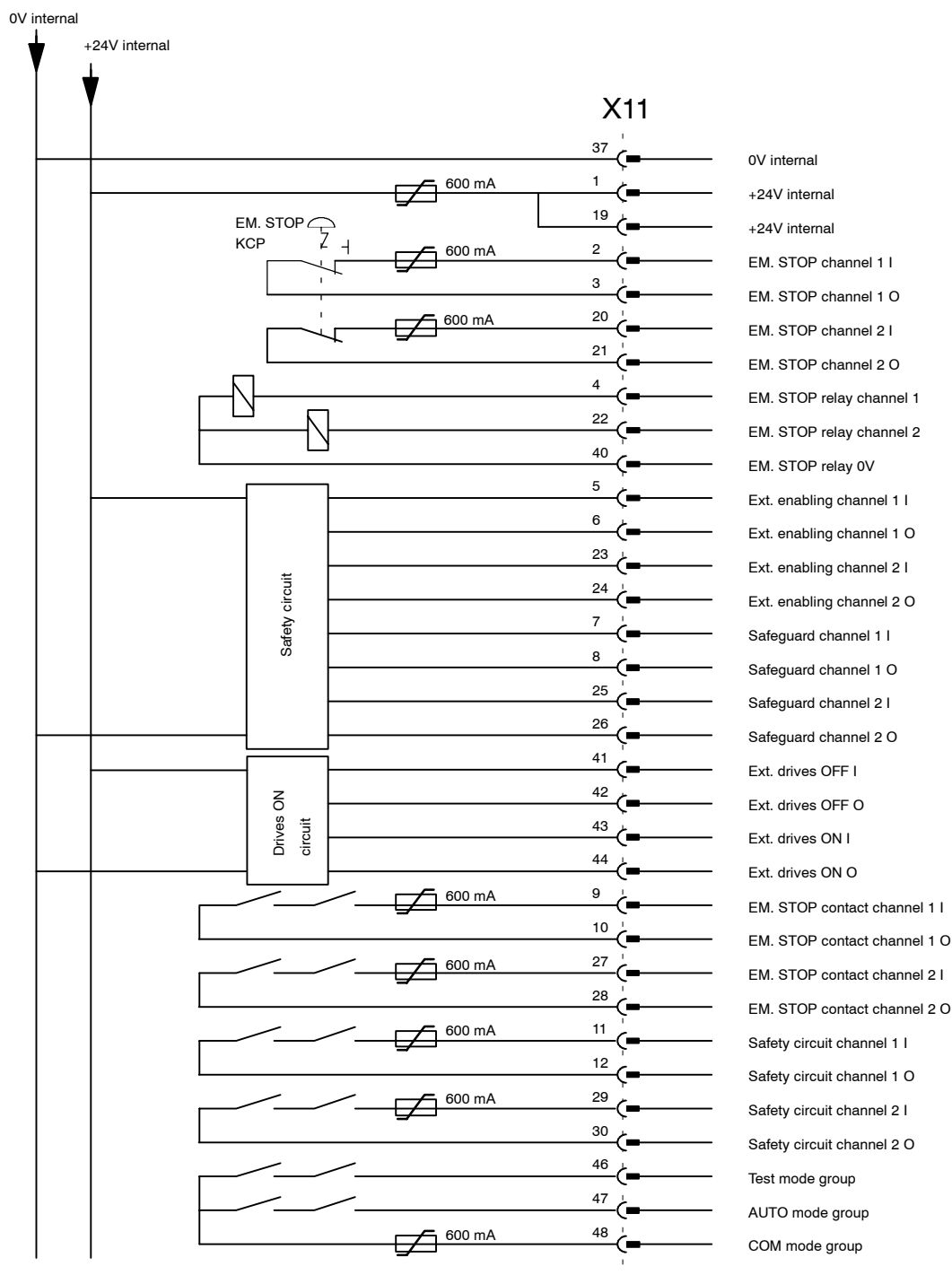
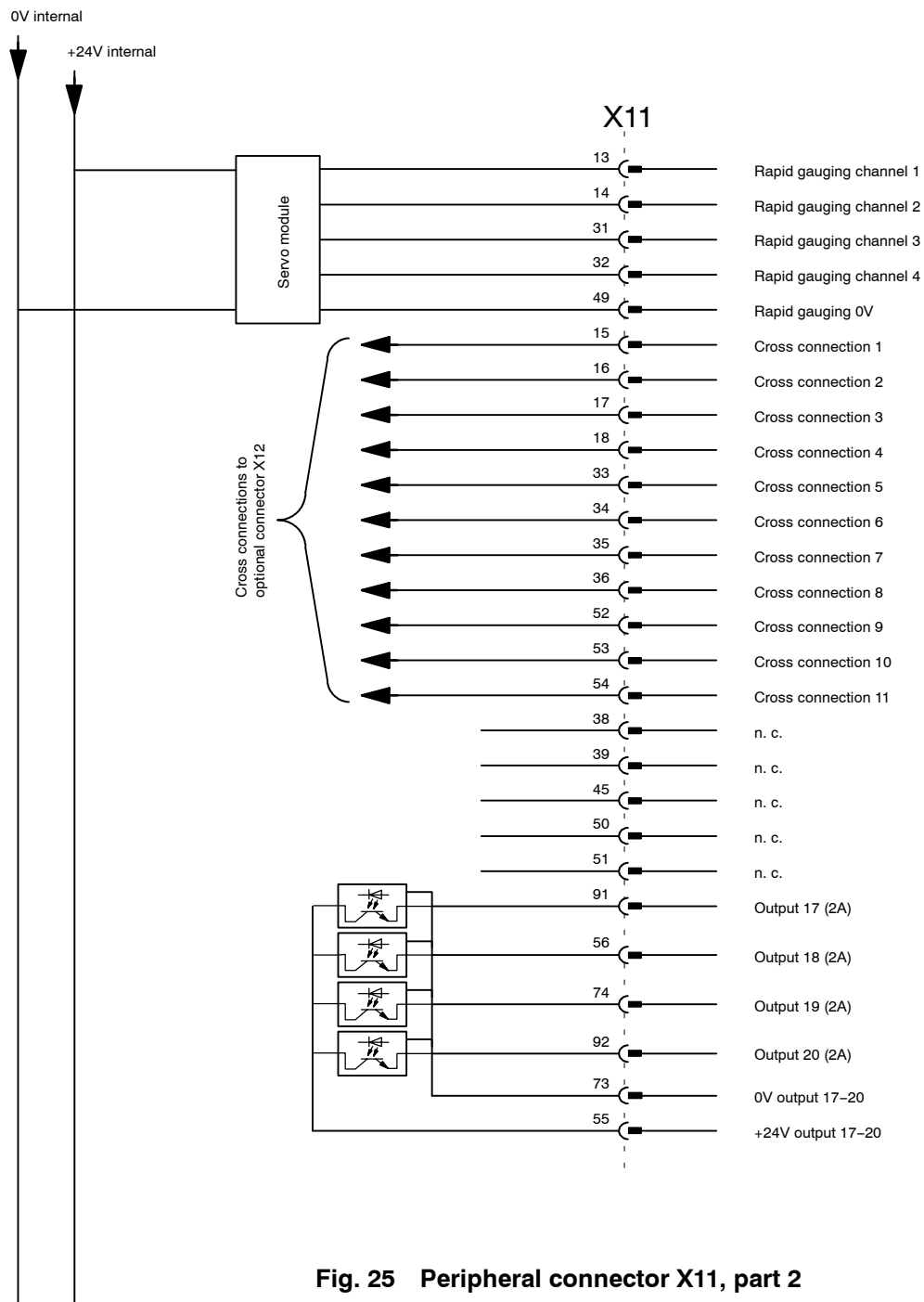
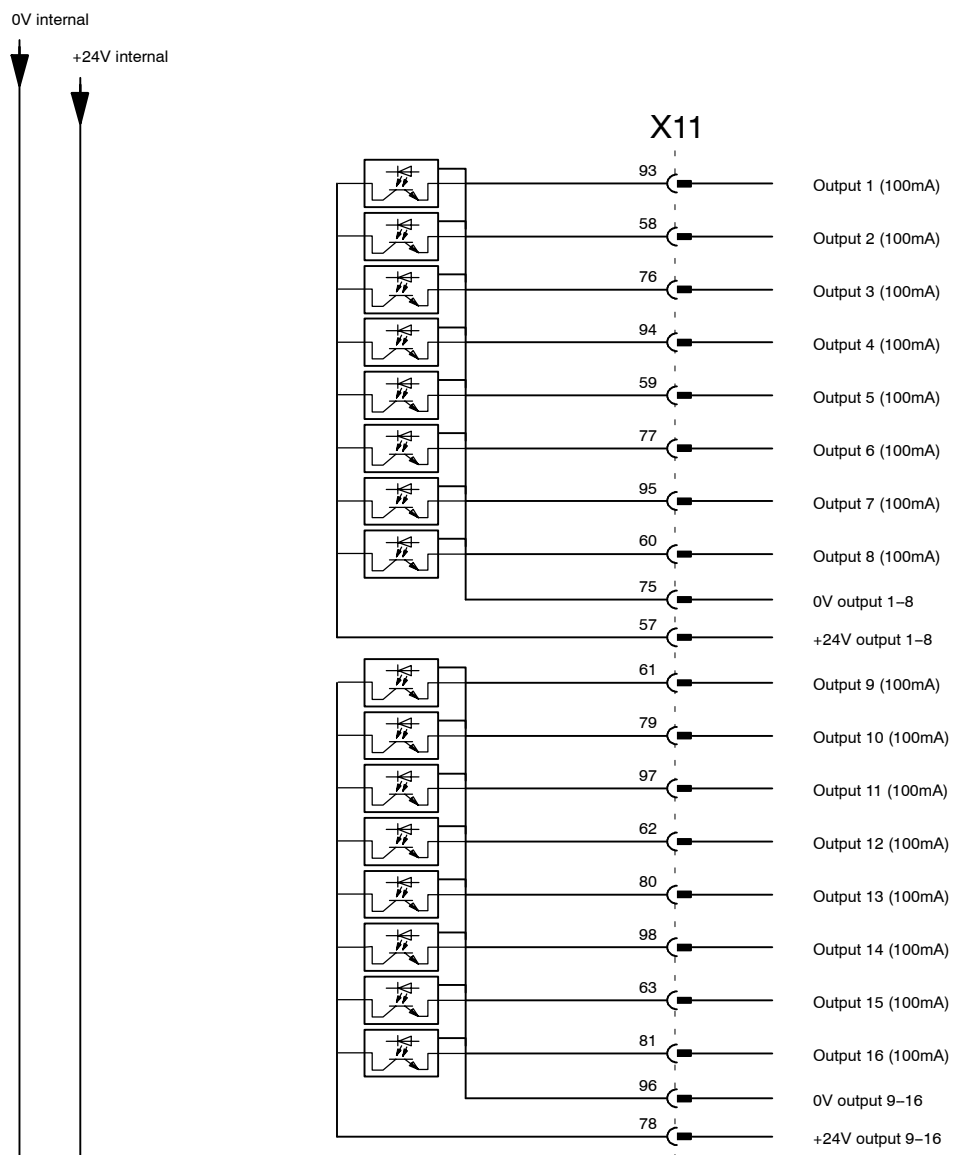


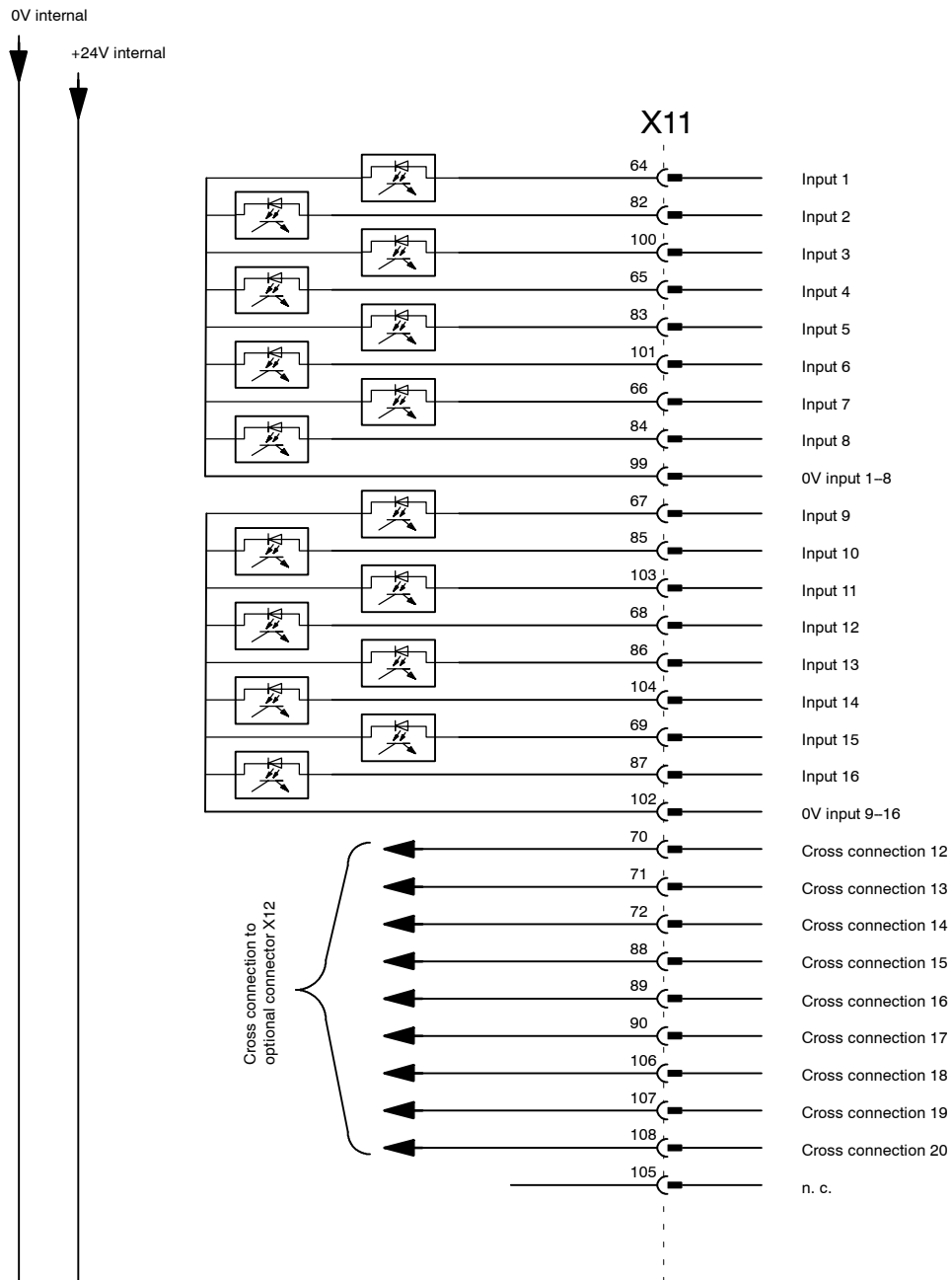
Fig. 24 Peripheral connector X11, part 1



**Fig. 25** Peripheral connector X11, part 2

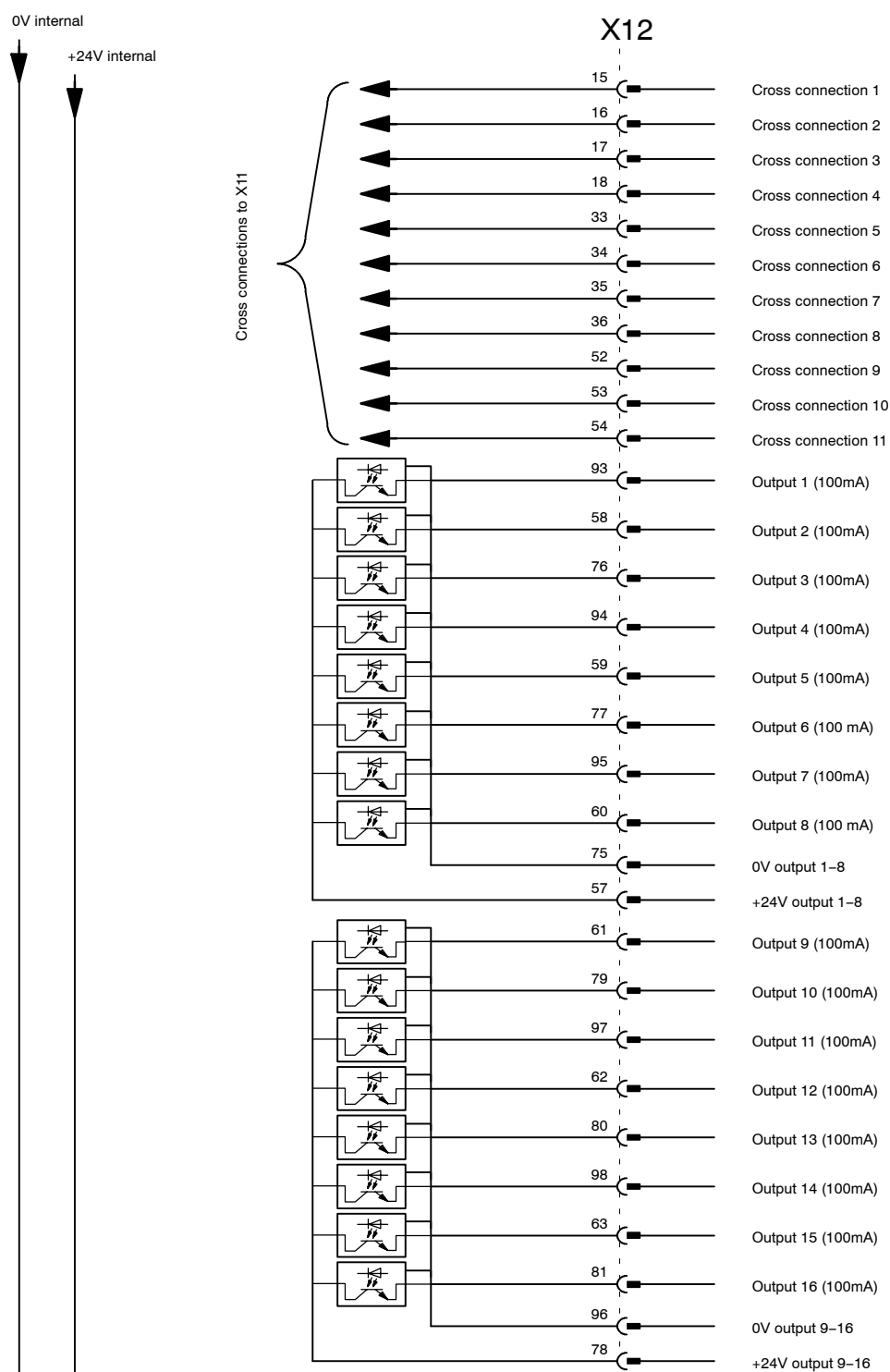


**Fig. 26 Peripheral connector X11, part 3**



**Fig. 27 Peripheral connector X11, part 4**

## 5.8 Peripheral connector X12 (optional)

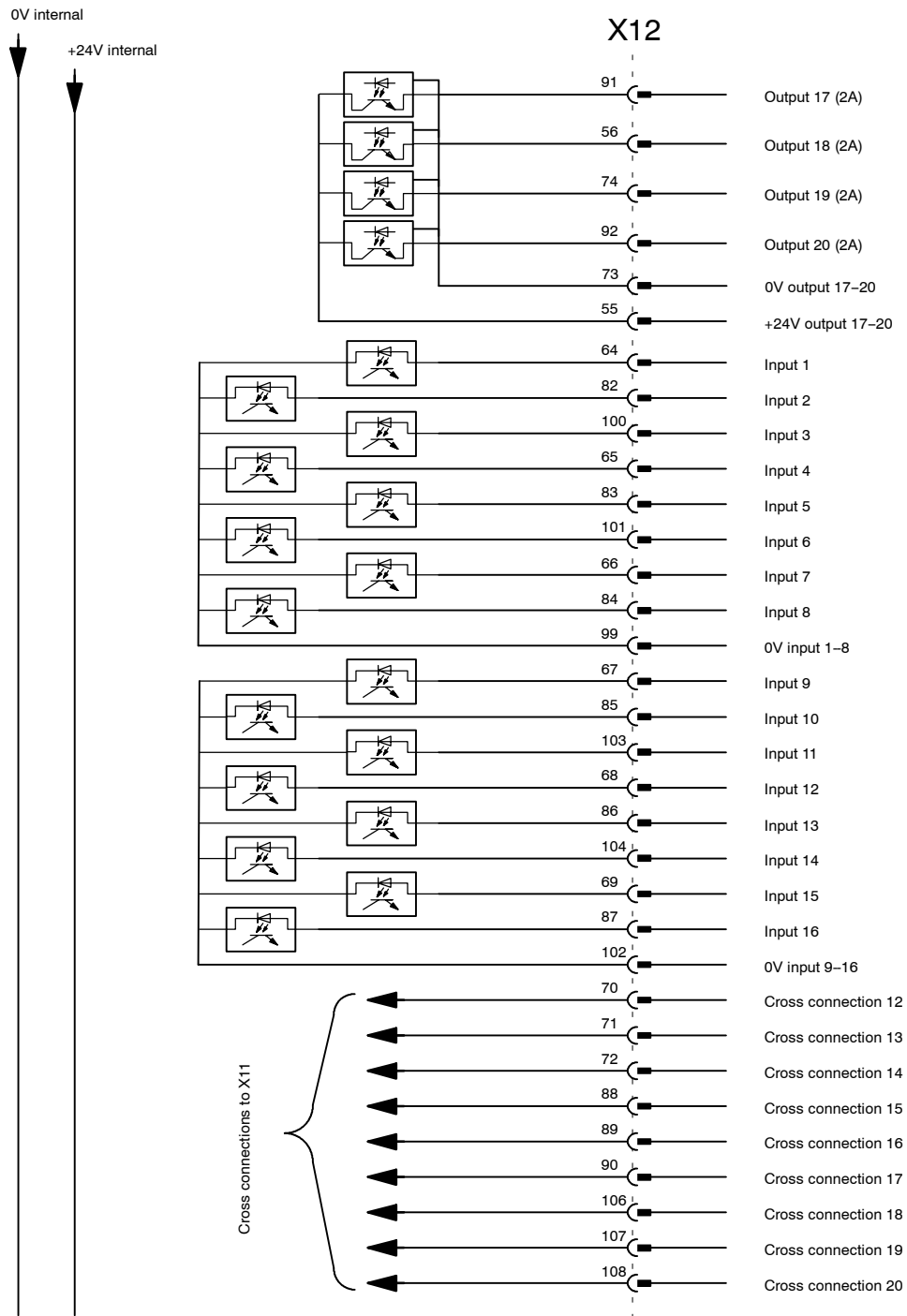


If option X12 is used, the freely-programmable inputs/outputs on connector X11 are omitted.

The cross connections are required for the routing of signals between connectors X11 and X12. They have a maximum load capacity of 1 A per cross connection.

**Fig. 28 Peripheral connector X12, part 1**





**Fig. 29** Peripheral connector X 12, part 2

## 5.9 CAN bus Sub-D connector X801

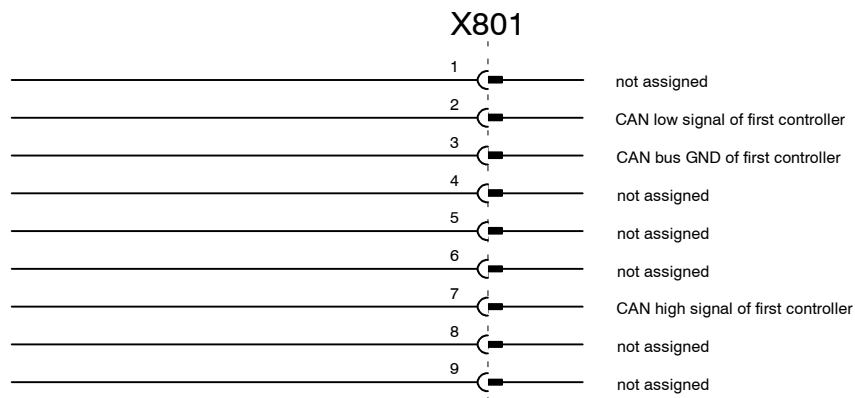


Fig. 30 CAN bus Sub-D connector X801

## 5.10 Ethernet Sub-D connector X802

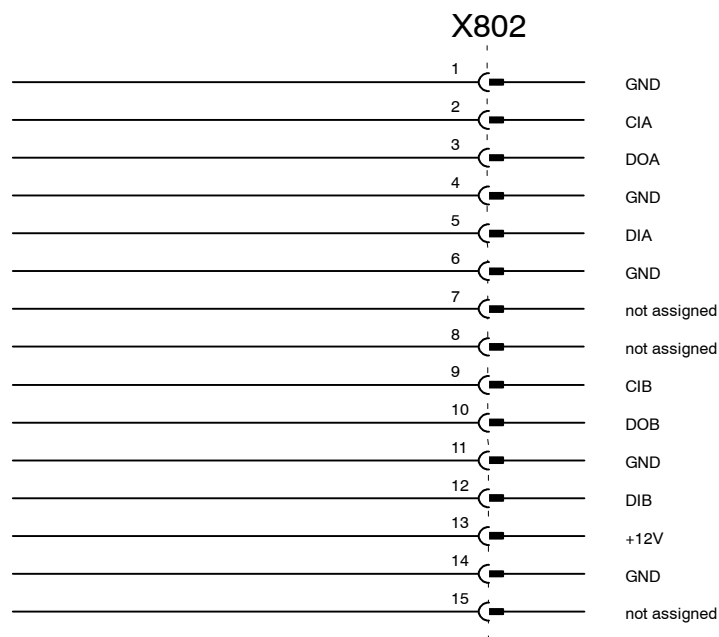
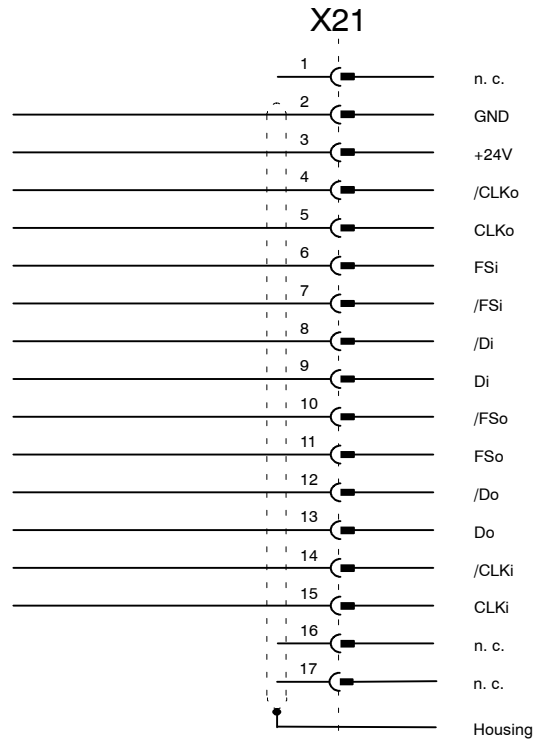
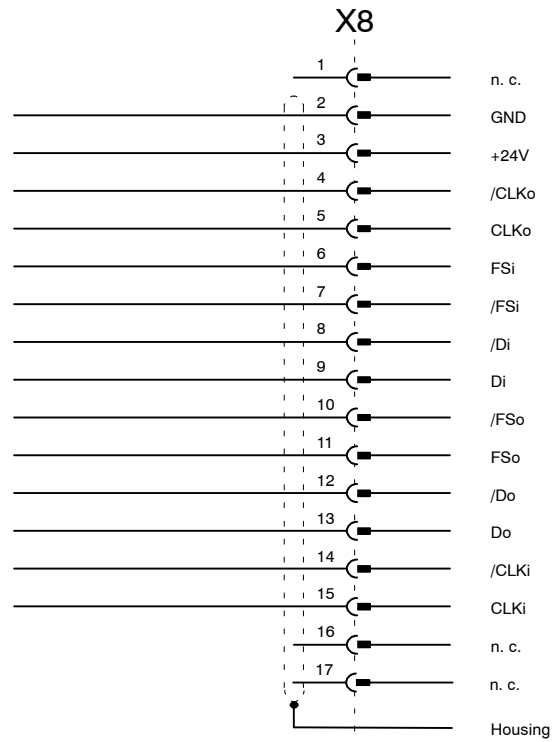


Fig. 31 Ethernet Sub-D connector X802

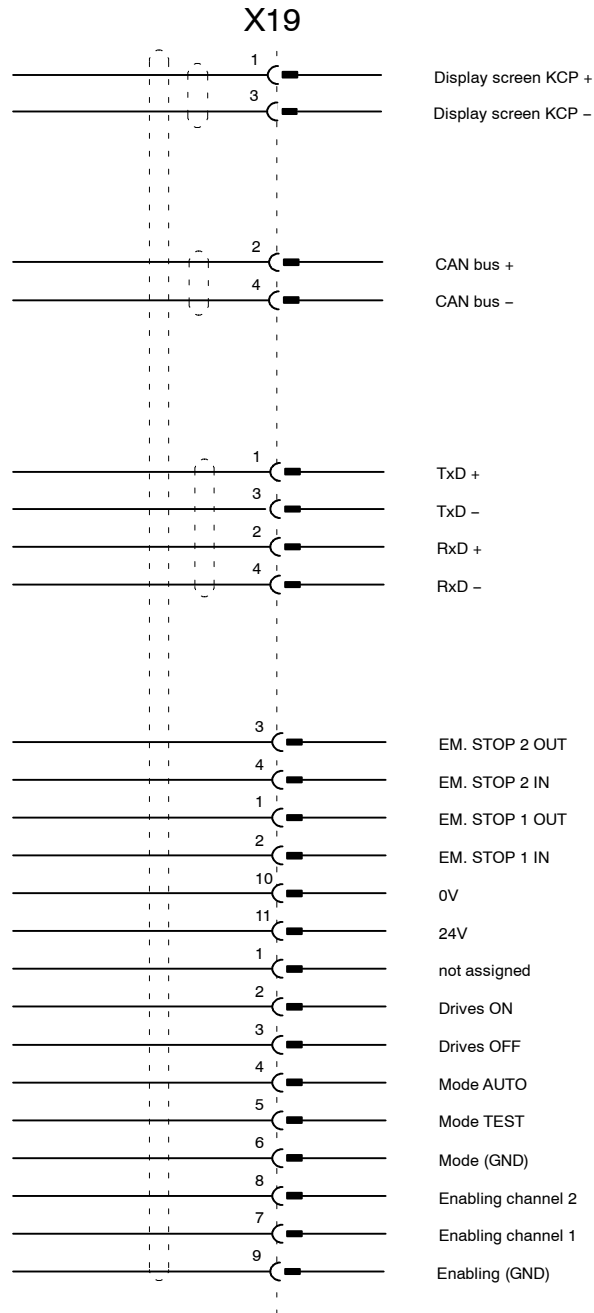
**5.11 Data cable connector X21, axes 1 to 8****Fig. 32 Data cable connector X21**

## 5.12 Data cable connector X8, axes 7 to 12 (optional)



**Fig. 33 Data cable connector X8**

### 5.13 KCP connector X19



**Fig. 34 KCP connector X19**

## 5.14 Jumpers for stand-alone operation X11

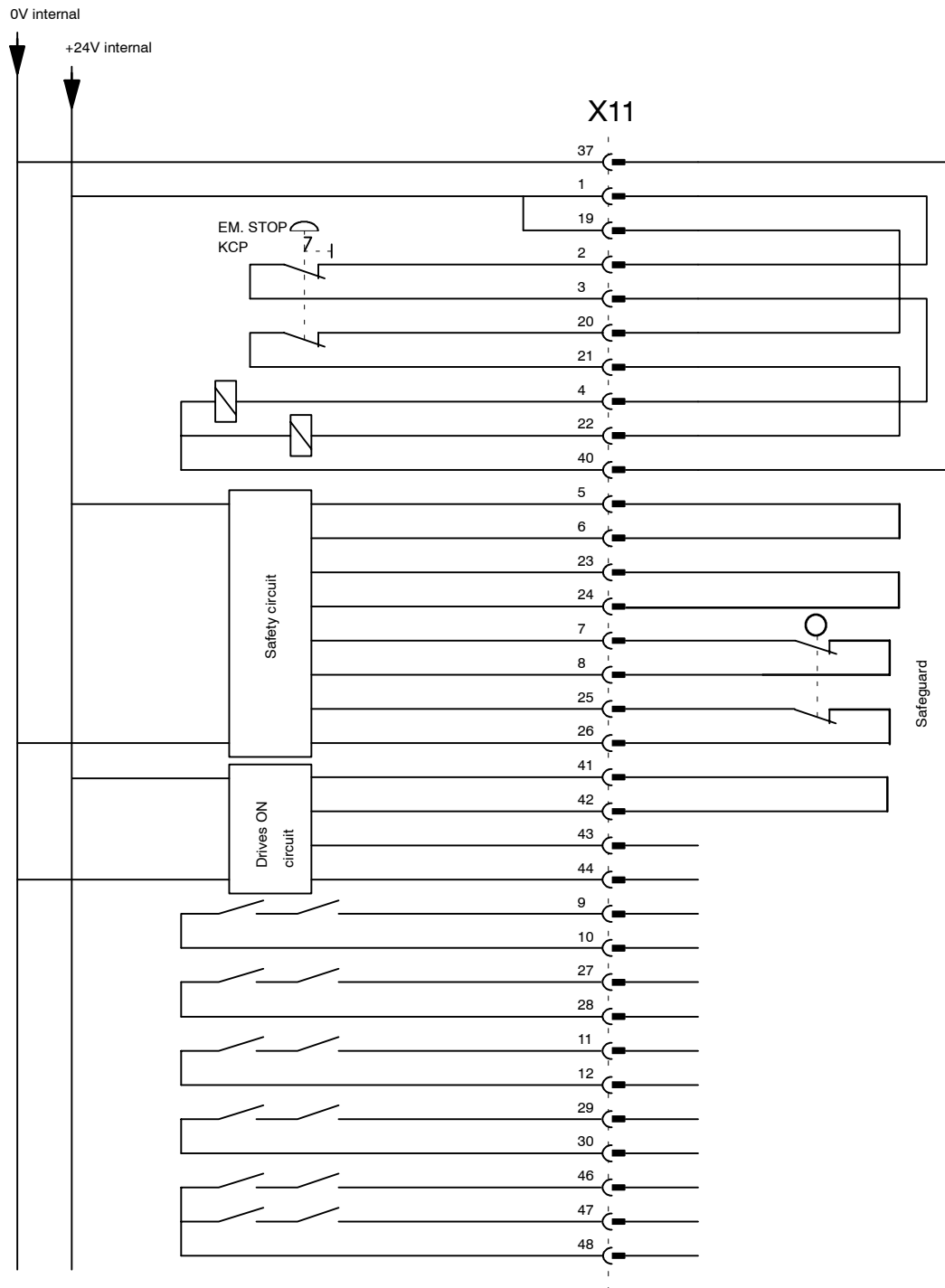


Fig. 35 Jumpers for stand-alone operation X11

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## 6 Digital Servo Electronics (DSEAT)

### 6.1 Description of the DSEAT

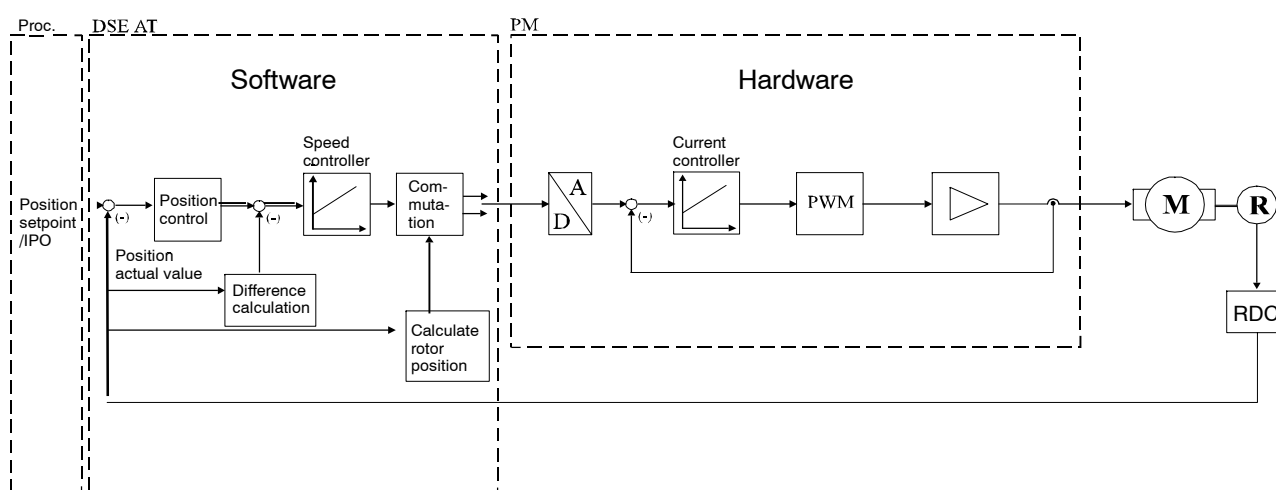
In the KR C1 the main processor is responsible for all controller tasks except the drive control functions, which require very short cycle times that would overload the main processor. Therefore the drive control functions (position controller, speed controller, etc.) are implemented on a separate slot-in card (or possibly two separate cards).

The DSEAT module on the multifunction card (MFC) is responsible for digital closed-loop control of up to 8 axes, for controlling a servo power module by means of phase current setpoints and parameterization data and for processing the error and status messages read by the servo power module. Additionally, the DSEAT communicates with the RDC.

▪ **Advantages of this concept:**

- An optimally adapted processor (RISC, DSP) can be selected for the drive section on the DSEAT.
- The software implementation on the PC processor (CISC Processor, Pentium) is simpler, because no high-priority tasks have to be taken into account.
- Windows conventions and the protected mode of the main processor do not have to be taken into account during software development.
- The two software sections can be developed largely independently of each other.
- DSEAT provides a modular structure for expanding to higher numbers of axes. The requisite computer power is automatically provided by the hardware simply by plugging in an additional DSEAT.

### 6.2 Schematic diagram of the controller architecture

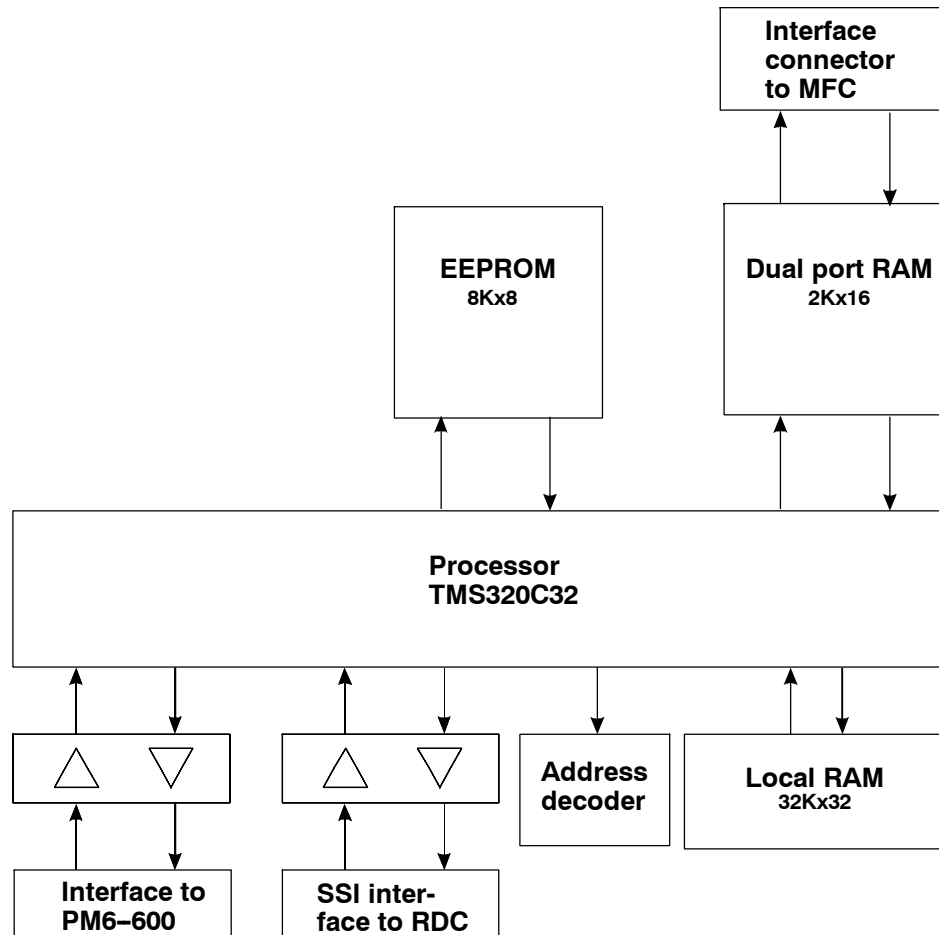


**Fig. 36** Schematic diagram of the controller architecture



### 6.3 Block diagram of the DSEAT

The DSEAT consists of a DSP (Digital Signal Processor), RAM, EEPROM and interfaces to the RDC and to the PM6-600.



SSI: synchronous serial interface (the same data block every 125  $\mu$ s)

**Fig. 37** Block diagram of the DSEAT

## 6.4 DSEAT functions

### **Actual position sensing:**

Resolvers are used as the encoders for position sensing. The encoder signals are conditioned on the RDC module. The DSEAT then receives the actual position values via a serial interface in the form of digital signals transmitted at the rate of the position controller clock (2 ms), i.e. the actual values are delivered as discrete numbers.

Absolute pos. = absolute pos. + partial actual value (refreshed every 2 ms)

### **Position control:**

Closed-loop position control is implemented digitally (i.e. in the software). The difference between the programmed position (signalled by the main processor) and the actual position value (signalled by the RDC) is calculated. This difference is the "following error". Position control is implemented on the DSEAT, in order to relieve the load on the main processor.

### **Speed controller:**

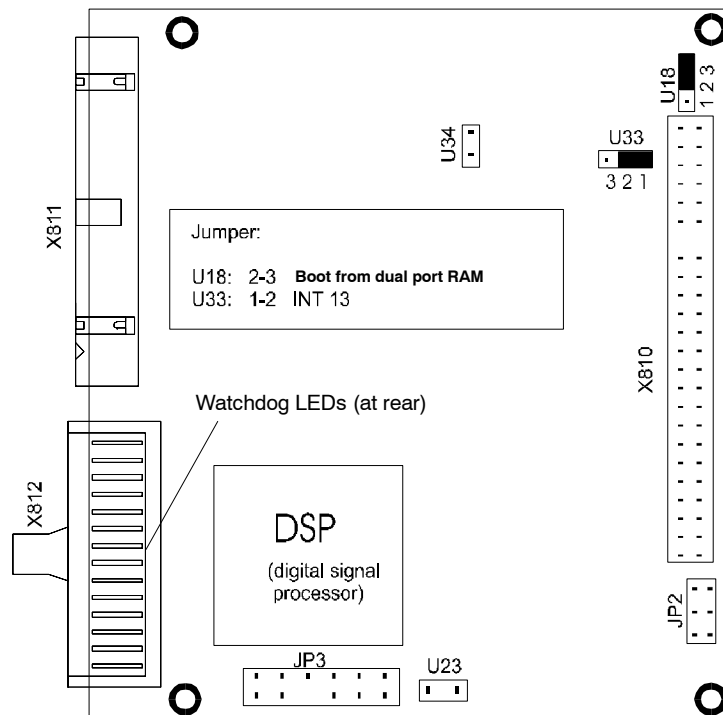
This controller corrects the motor speed. The actual speed (i.e. the instantaneous value of the motor speed) can be calculated from the difference between the last two actual position values (from the RDC). The speed setpoint is calculated from:

Following error  $\times$  position controller gain + speed precontrol.

### **Commutation:**

The output from the speed controller must be multiplied by a sinusoidal function (sine of the motor position) in order to ensure that the output voltage is in correct phase sequence relative to the rotor position. The instantaneous rotor position can also be calculated from the actual position value. This calculation must be performed for 2 phases. The result gives the actual current intensity for phases U and W. These two values (per axis) are transmitted in digital form to the PM6 via a parallel interface.

## 6.5 Configuration of the DSEAT



**Fig. 38** (Rough) View of the DSEAT card

### Connectors

X810	Connection for MFC	50-pin
X811	Connection for PM6-600	40-pin
X812	Connection for RDC	15-pin
JP2:	Connection for test adaptor (only for developers)	6-pin
JP3:	Connection for interface emulator (only for developers)	12-pin

## 6.6 Replacing the DSEAT card

- Switch off the system and wait until the battery-backed shutdown storage procedure is terminated.
- Release the card retainer (butterfly screw)
- Disconnect all lines to the KVGA, MFC and DSEAT and lay them out of the way on one side.
- Release the MFC and remove the card carefully.
- Unscrew the DSEAT card on the MFC and disconnect it carefully.
- Check that the new DSEAT card is correctly configured (jumper), valid (date of manufacture) and mechanically undamaged. Then plug it into the MFC and fix it in place.
- Reinsert the complete card assembly (MFC + DSEAT) in AT slot 1 and fix in position.
- Reconnect all connections.

## 6.7 Function test of the DSEAT card

### 6.7.1 Visual inspection of the LEDs

- Switch on the system.
- After initialization (DSE runup), check that the LED on the DSEAT is flashing (at intervals of 0.5 sec.) and that the watchdog LED on the power module and the LED on the RDC are lit.

### 6.7.2 Function test of the DSEAT with the "DSERDW" diagnostic tool

- Quit the KR C1 user interface by clicking the mouse on the status bar. Confirm the dialog window with the "ICON" entry by clicking "OK".
- Minimize any other running applications.
- Start the "DSERDW.EXE" program (by double-clicking the icon with the label "dserdw.exe" on the WIN95 desktop).
- In the main program (dserdw.exe), check that the DSE controller program is running; the "DSE 125  $\mu$ s Interrupt Counter" is incremented by DSEAT every 125  $\mu$ s and displayed in hexadecimal format. If the counter is stationary, the DSE program is not running correctly.
- Select menu item "7" (Check RDC communication).
  - The 1st word (command sent by DSE to RDC) should always vary from 4000 to 4007 (but the display is too slow to show the individual values).
  - The 2nd to 9th word (axis X) shows the resolver positions of the individual axes. These values will normally vary: if the value of the relevant axes is "000", an encoder fault has occurred.
  - The 10th word (value) is the motor temperature of axes 1–8, requested by the DSE in the command. Normally, this value should vary.
  - The 11th word (error) shows the error bits and EMT signals. Bits 0 to 7 are the error bits of axes 1 to 8. If a bit is "high", a sensor error has been recorded for the axis. In the component test stand (6 axes), this value is normally set to "00C0" (hex), corresponding to "0000 0000 1100 0000" (binary). This value recognizably represents the error bits of axis 7 and axis 8 (because these axes are not connected). Bits 8 and 9 are the EMT signals (see "EMT mastering").
  - The 12th word (Chksum) is the checksum for all the data. Normally, this value should vary.
  - The "Communication error status" indicates whether more than 3 consecutive transmissions have failed. If so, the status value is 1. Under normal conditions, this value is "0000". If the status is 1, DSEAT–RDC communication is disrupted by fault condition(s).
  - The "Communication error counter" counts all faulty transmissions; under normal conditions, this value too should be "0000".

## 7 Resolver-to-Digital Converter (RDC)

### 7.1 Description of the RDC

The RDC card with built-in DSP (Digital Signal Processor) is located in a housing at the base of the robot and performs the following functions:

- Generation of all necessary operating voltages from the 27V supply;
- Resolver power supply for 8 axes;
- Isolated power supply of 8 temperature sensors (KTY 84) in the motor windings;
- R/D conversion for up to 8 axes (approx. 3 x 4096 increments/motor revolution)
- A/D conversion for 8 temperature sensors (12-bit resolution);
- Evaluation of 2 EMT channels (1 EMT);
- Resolver open-circuit monitoring;
- Motor temperature monitoring;
- Communication with the DSEAT via an RS422 serial interface.

The RDC also has an EEPROM that stores the following data even after the controller is switched off:

- Operating hour counter (counts in minutes when the brakes are opened; can be displayed with \$ROBRUNTIME);
- Absolute position (important for maintaining the mastering), in increments;
- Resolver position (this value is compared to the actual resolver position on power-up – tolerance 6 increments), in increments;
- Calibration data (offset, symmetry).

Moreover, this EEPROM also contains a write-protected area with the boot program for the processor.

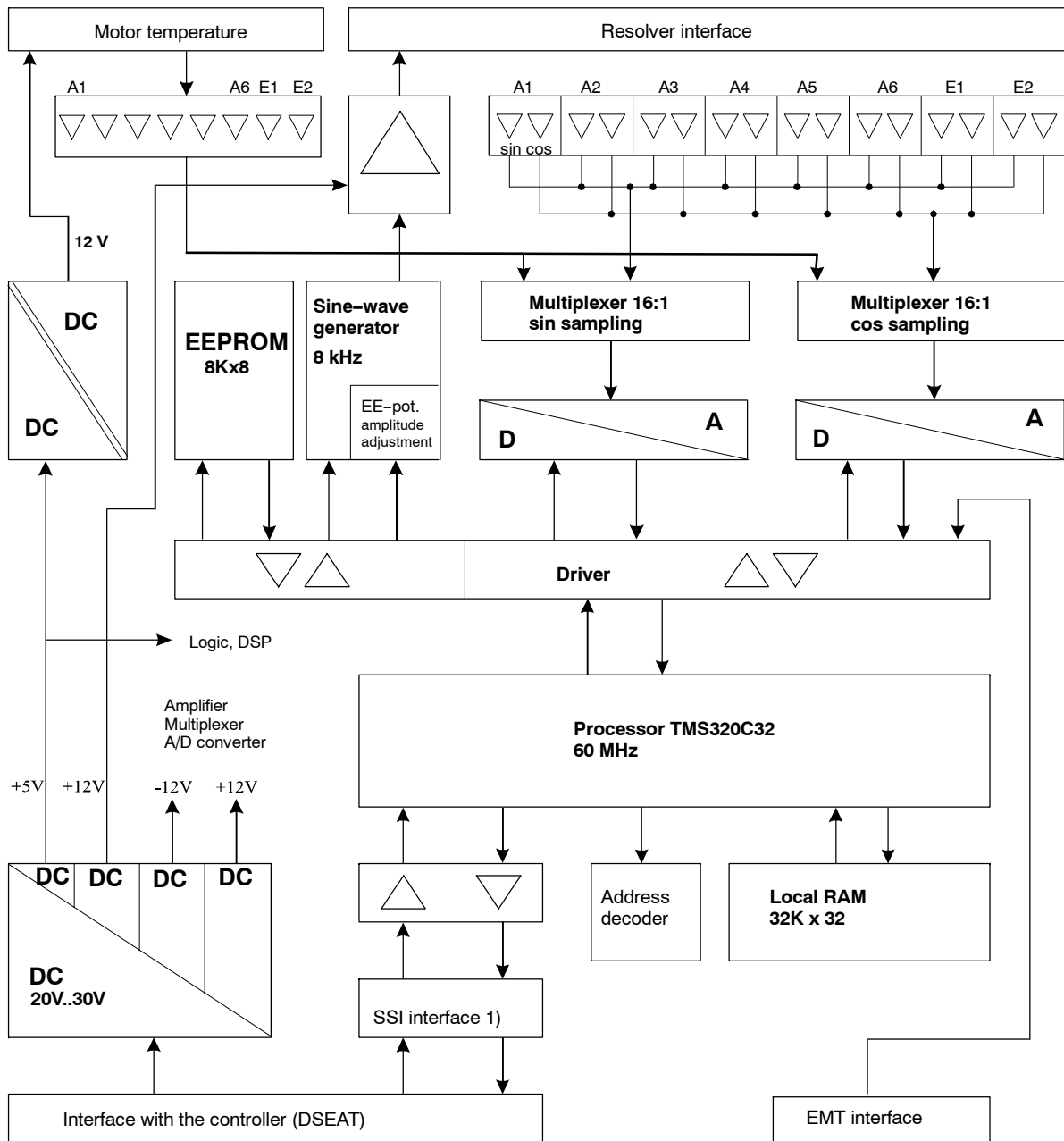
The cable cores of the 6 robot axes are routed into the housing via a special molding and are plugged directly to the circuit board.

The cables of the 2 external axes are passed through a screwed gland and connected to the RDC.

#### **Advantages of this independent module:**

- The DSEAT can be smaller and can therefore be designed as a PC module;
- No functions requiring a +/-12V supply voltage are located on the DSEAT: this configuration would cause problems, because the PC power supply unit cannot supply the necessary voltage, especially in the case of -12V;
- The cables for the resolvers and motor temperature do not have to be routed to the DSEAT:
  - shorter shielded cables (only in the robot),
  - no problems of space requirement, stability and cable routing on the DSEAT;
- The encoder cable contains 6 conductor pairs instead of 20 in the old system:
  - thinner, more flexible and cheaper cable,
  - instead of a Harting connector, another (smaller, cheaper) connector can be used.

## 7.2 Block diagram of the RDC



### 1) Synchronous serial interface

**Fig. 39** RDC block diagram

### 7.3 Operating principle of the RDC

#### **Power supply unit:**

The 27V supply voltage generated in the PM is fed via the encoder cable to the power supply unit, which adapts it to provide all the voltages required by the RDC:

+5 V	Processor, logic components, temperature sensors
+12 V	Output stage of the sine-wave generator
±12 V	Amplifier, multiplexer, A/D converter

#### **Processor:**

The central component of the RDC is a floating-point processor (TMS320C32) with 60 MHz clock frequency.

The processor acts purely as a RAM machine. The program code is not stored on the RDC but is loaded via the serial interface. The necessary boot code and basic software are stored in an 8Kx8 EEPROM.

The RAM size is 32 KByte. Maximum speed is guaranteed by the 32-bit data bus width, 15 ns access time and therefore 0 wait states.

#### **Sine-wave generator:**

The input voltage is a square-wave voltage from the processor. The frequency of 8 kHz is therefore determined by the software.

The amplitude can be set by software in the range from 4.5 V<sub>pp</sub> to 7 V<sub>pp</sub> by means of an EE-potentiometer.

The square-wave voltage is converted to sine-wave voltage by filters.

The maximum output current is 200 mA rms (corresponding to the maximum load with 8 resolvers). The output is thermally protected against short-circuits.

#### **Resolver evaluation:**

The resolver response signals (8 x SIN and 8 x COS) are fed to 2 multiplexers and then converted from analog to digital signals. A/D conversion takes place at every peak value of the carrier frequency (8 kHz).

Synchronization is easily implemented, because the carrier frequency is generated by the processor.

The position of the resolver can now be calculated from the two values for SIN and COS.

#### **Motor temperature:**

Each motor contains a temperature sensor (analog sensor KTY 84) with an essentially linear characteristic. This sensor is supplied with constant current. The voltage is filtered, fed to one of the two multiplexers and then converted from analog to digital, thereby providing the processor with the temperature of each motor in the form of a 12-bit value.

#### **Actual value storage:**

All actual values (including motor temperature) are transmitted to the DSEAT at the commutation frequency (every 125µs).

When the controller is switched OFF, the actual values are stored in the EEPROM. For this purpose, the controller voltage must be briefly maintained by (rechargeable) back-up battery. When the software has completed all its tasks, a "back-up stop" bit is transmitted to the PM6, which then switches off the battery (in the absence of this bit, the battery is switched off by the hardware after 70 seconds).

When the controller is switched ON, it checks whether the manipulator has been moved: the present actual value from the resolver (delivered by the RDC) is compared with the last value stored in the RDC EEPROM before the controller was switched off.

**EMT interface:**

The two channels of the EMT are read as binary inputs and transmitted in serial mode to the DSEAT together with the actual values and motor temperatures.

A Lemosa (5-pin) connector is used for the EMT interface.

**Serial connection from DSE X812 to RDC X31**

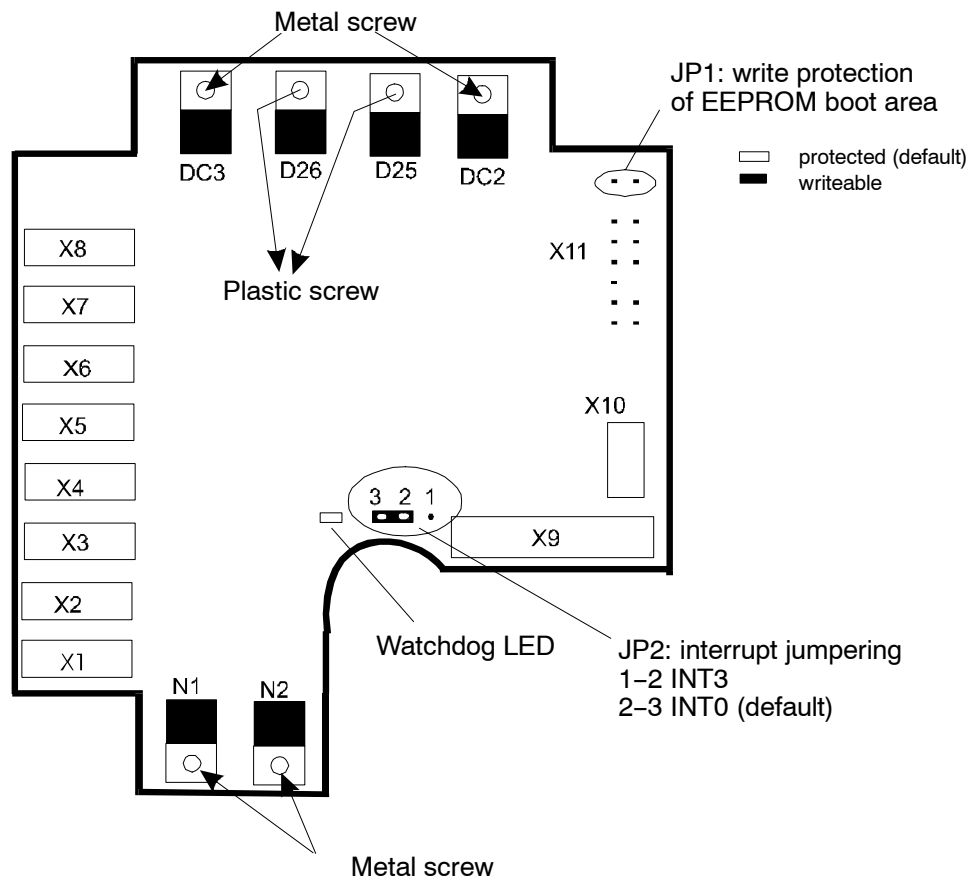
Data communication with the DSEAT is implemented by a synchronous serial interface (SSI interface with RS422/485 drivers).

	DSEAT con- nector	Cabinet connec- tor	Cable con- nector	Connecting cable	Cable con- nector	Connector on robot box	Cable in RDC box	RDC con- nector
	X812	X21	X21		X31	X31		
Frei	1							
GND <sup>7)</sup>	2	2	2	2	2	2	14	14
24V <sup>7)</sup>	3	3	3	3	3	3	15	15
/CLKo <sup>1)</sup>	4	4	4	4	4	4	10	10
CLKo <sup>1)</sup>	5	5	5	5	5	5	11	11
FSi <sup>6)</sup>	6	6	6	6	6	6	7	7
/FSi <sup>6)</sup>	7	7	7	7	7	7	6	6
Di <sup>4)</sup>	8	8	8	8	8	8	9	9
/Di <sup>4)</sup>	9	9	9	9	9	9	8	8
/FSO <sup>5)</sup>	10	10	10	10	10	10	3	3
FSO <sup>5)</sup>	11	11	11	11	11	11	2	2
/Do <sup>3)</sup>	12	12	12	12	12	12	5	5
Do <sup>3)</sup>	13	13	13	13	13	13	4	4
/CLKi <sup>2)</sup>	14	14	14	14	14	14	13	13
CLKi <sup>2)</sup>	15	15	15	15	15	15	12	12
	16	16						

- |    |  |                                |
|----|--|--------------------------------|
| 1) | Clock signal from RDC                  | differential, 1 pair, shielded |
| 2) | Clock signal from DSEAT                | differential, 1 pair, shielded |
| 3) | Transmitted data                       | differential, 1 pair, shielded |
| 4) | Received data                          | differential, 1 pair, shielded |
| 5) | Frame synchronization transmitted data | differential, 1 pair, shielded |
| 6) | Frame synchronization received data    | differential, 1 pair, shielded |
| 7) | Supply voltage                         | 1 pair or 2 single conductors  |



## 7.4 Configuration of the RDC



**Fig. 40** Configuration of the RDC card

## 7.5 RDC interfaces

X1:	Resolver, axis 1	Connector: Lumberg
X2:	Resolver, axis 2	Connector: Lumberg
X3:	Resolver, axis 3	Connector: Lumberg
X4:	Resolver, axis 4	Connector: Lumberg
X5:	Resolver, axis 5	Connector: Lumberg
X6:	Resolver, axis 6	Connector: Lumberg
X7:	Resolver, axis 7	Connector: Lumberg
X8:	Resolver, axis 8	Connector: Lumberg
X9:	Bus to DSEAT	
X10:	To EMT X32 socket on box	
X11:	Connection for emulator (only for development engineers)	

### 7.5.1 Lumberg connectors on RDC per axis for resolver cables X1 to X8

Pin	Assignment		Pin–Pin	R [Ohm]
1	KTY		1 – 2	588 (at 25°C) 1000 (at 100°C)
2	KTY			
3	GND			
4	R2		4 – 5	36 (Type B) otherwise 53
5	R1			
6	S4		6 – 7	48 (Type B) otherwise 147
7	S2			
8	S3		8 – 9	48 (Type B) otherwise 147
9	S1			

## 7.6 Removing/Installing the RDC

- Switch off the system and wait until the battery-backed shutdown storage procedure is complete (if the battery is connected).
- Unscrew the cover from the RDC box.
- Carefully disconnect all connections to the RDC (X1 to X6, X9 and X10) and bend them to one side so that they are out of the way.
- Unscrew and carefully remove the fixings of the RDC.
- Check the configuration of the new RDC, and then install it and secure it in place.



**Make sure that you do not use metal screws but only plastic screws at power diodes D25 and D26 to secure the RDC. Failure to observe this precaution will result in a short-circuit that will damage the circuit board, with the result that it will no longer be recognized by the system (see the above illustration of the RDC configuration).**

- Reconnect all connections (the cables are marked; if there are no external axes, connectors X7 and X8 are not used).

## 7.7 Function test of the RDC

### 7.7.1 Function test: dial gauge mastering

- Switch on the system.
- After the system has run up, the LED on the RDC must be lit and the LEDs on the DSEAT must be flashing.
- In the message window, check whether any error messages have been generated for the RDC.
- Perform dial gauge mastering
  - If the message "Perform mastering" appears but adjustment is not possible → the RDC is probably defective.
- Move all axes manually and follow the rotation of the motors under "Monitor", "Act. position", "Joint".

### 7.7.2 Function test of the RDC with the "DSERDW" tool

- Quit the KR C1 user interface by clicking the mouse on the status bar. Confirm the dialog window with the "ICON" entry by clicking "OK".
- Minimize any other running applications.
- Start the "DSERDW.EXE" program (by double-clicking the icon with the label "dserdw.exe" on the WIN95 desktop).
- In the main program (dserdw.exe), check that the DSE controller program is running; the "DSE 125  $\mu$ s Interrupt Counter" is incremented by DSEAT every 125  $\mu$ s and displayed in hexadecimal format. If the counter is stationary, the DSE program is not running correctly.

#### 7.7.2.1 Displaying the RDC table

- Select menu option [1] "Show RDC table".
  - Items 0 to 7 show the motor temperature of the individual axes. Press the space bar several times to refresh the display at more frequent intervals. Only the connected axes are relevant, and in each case the value should vary between 9000 and 11000 (decimal), or, for the older RDCs (up to version 2) between 6000 and 11000. Values deviating significantly from this range and negative values indicate a faulty RDC.
  - Positions 40 to 47 display the "Signal error counter: axis ..". Here, the value should not exceed "30" (only for relevant axes).
  - Positions 88 to Position 93 show the RDC configuration data. The set frequency must match the processor frequency and processor quartz frequency: if not, sensor errors will occur on every axis. The serial number, year of manufacture, month of manufacture and hardware version of the RDC can also be programmed here (see "DSERDW.EXE" Diagnostic Tool, menu option 5).

#### 7.7.2.2 Checking RDC communication

- Select menu item "7" (Check RDC communication).
  - The 1st word (command sent by DSE to RDC) should always vary from 4000 to 4007 (but the display is too slow to show the individual values).
  - The 2nd to 9th word (axis X) shows the resolver positions of the individual axes. These values will normally vary: if the value of the relevant axes is "000", an encoder fault has occurred.

- The 10th word (value) is the motor temperature of axes 1–8, requested by the DSE in the command. Normally, this value should vary.
- The 11th word (error) shows the error bits and EMT signals. Bits 0 to 7 are the error bits of axes 1 to 8. If a bit is "high", an encoder error has been recorded for the axis. In the component test stand (6 axes), this value is normally set to "00C0" (hex), corresponding to "0000 0000 1100 0000" (binary). This value recognizably represents the error bits of axis 7 and axis 8 (because these axes are not connected). Bits 8 and 9 are the EMT signals (see "EMT mastering").
- The 12th word (Chksum) is the checksum for all the data. Normally, this value should vary.
- The "Communication error status" indicates whether more than 3 consecutive transmissions have failed. If so, the status value is 1. Under normal conditions, this value is "0000". If the status is 1, DSEAT–RDC communication is disrupted by fault condition(s).
- The "Communication error counter" counts all faulty transmissions; under normal conditions, this value too should be "0000".

### 7.7.2.3 Simulating EMT mastering

- As already described above, bits 8 and 9 of the 11th word (errors) represent the EMT signals. There are two possible ways of simulating EMT mastering:
  - Connect the EMT and press in the measuring probe with a screw knob:
 

Press in probe	→	1
Hold probe down	→	3
Release probe	→	2
  - Construction of a test plug (switch) for X32
 

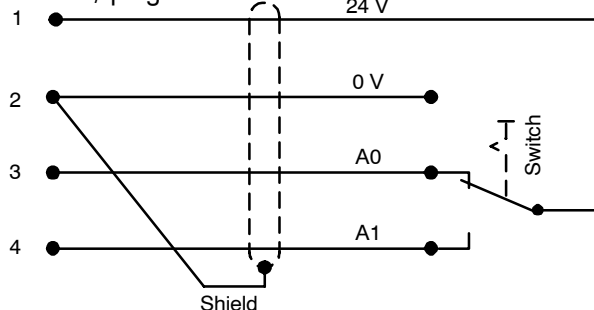
24 V at A0	→	1
24 V at A1	→	2

Deviating values indicate a faulty RDC.

#### EMT simulator test plug

X32 Lemos

socket / plug



The internal connection between the built-in Lemos socket and X10 on the RDC (4-pin Lumberg) must be connected for EMT simulation.

## 7.7.2.4 RDC calibration

RDC calibration is necessary after a motor has been replaced. During calibration, the A/D converter and EEPROM of the RDC can be tested. All RDCs supplied by KUKA, including replacement RDCs, are ready-calibrated.

- Return to the main menu by pressing the "Esc" key.
- Select menu option "A" (Set RDC offset and symmetry to default values); this option automatically sets the RDC sine and cosine offset values to "0" and the sine and cosine calibration to "20000" (default setting).
- Quit "dserdw.exe" by pressing "Esc" and open KR C1 (ICON).
- When the KR C1 controller is running, all axes must travel through at least one motor revolution.
- Exit the KR C1 user interface again, as described above.
- Restart the "dserdw.exe" program.
- Select menu option "3" (Offset compensation); the existing offset compensation values of the individual axes will be calculated and displayed:
  - the displayed values for offset compensation can be between –1500 and +1600 and depend largely on the installed A/D converter and multiplexer;
  - if the values are correct, press key "Y" to accept the values of the RDC and to load them into the EEPROM.
  - if the values are incorrect, press key "N" to refuse the values from the RDC and reset the RDC to its default values. In this case, repeat step 5 (RDC calibration) and try again to calibrate the RDC. If calibration fails again, there is probably a hardware fault.



**Deviating sine and cosine offset values lead to poor quality control response and therefore, on occasion, to rough running noise.**

- With the KR C1 controller running, move all axes through at least one motor revolution.
- Select menu option "4" (Symmetry calibration): the symmetry calibration values of the individual axes will be calculated and displayed:
  - the displayed values for symmetry calibration can be between –18000 and +23000 and depend largely on the installed A/D converter and multiplexer.
  - if the values are correct, press key "Y" to accept the values of the RDC and to load them into the EEPROM.
  - if the values are incorrect, press key "N" to refuse the values from the RDC and reset the RDC to its default values. In this case, repeat step 5 (RDC calibration) and try again to calibrate the RDC. If calibration fails again, there is probably a hardware fault.



**Deviating symmetry calibration values generally lead to the error "Encoder cable failure axis X".**

### 7.7.2.5 Memory test

- Return to the main menu by pressing "Esc".
- Select menu option [1] and note down on paper a few values from items 104 to 135 of the table.
- Make sure that the back-up battery is connected.
- Exit "dserdw.exe" and switch off the system; wait until the battery-backed shutdown storage procedure is terminated.
- About one minute after shutdown, switch the system on again.
- When the system has run up, recheck the LEDs on the RDC (lit) and DSEAT (flashing).
- Check that the shutdown storage procedure was successful ("No axes to master").
- Restart "dserdw.exe".
- Select menu option "1" and compare the displayed values of items 104 to 103 with the values previously noted down.
- Select menu option "7" again, as described in step 4 above (Checking RDC communication) and check each sub-item.

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