Profile : Robot controllers

Profile No. : 91

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Preface

Within the framework of factory automation, increasingly powerful and flexible systems are needed in the field of industrial sensors and actuators. Robot controllers can meet these requirements. However, open and standardized communication capabilities are needed to enable their complete integration into complex production sequences.

The basic concept of open systems is to enable an exchange of information between application functions implemented on hardware from a diversity of manufacturers.

These functions include defined application functions, a standard user interface for communications and a standard transmission medium.

To be able to define the device functions of the robot controllers independent of the communication medium, an internationally recognized and standardized user interface (DIN 19245 Part 2) was used for communications. This created compatibility with MMS.

The InterBus-S system, which meets the requirements of sensors and actuators with regard to real-time response and a standardized user interface, was chosen as the communication medium.

The profile for robot controllers is oriented to the user and manufacturer of robot controllers to be operated on the sensor/actuator bus.

For the user, this profile definition is a useful addition to standardized communication and represents a generally valid convention concerning the contents of data and the response of devices. These function definitions standardize a few essential device parameters of a robot controller. Consequently, hardware from different manufacturers exhibits the same response in the communication medium when these standard parameters are used.

As standardization work is continuing, additions are to be expected.

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(all of the above companies are in Germany)

Introduction

This profile defines application functions of robot controllers. The application functions are subdivided into robot controller functions, communication functions, and control functions. In addition, free areas for the manufacturer-specific functions are defined (see Figure 1).

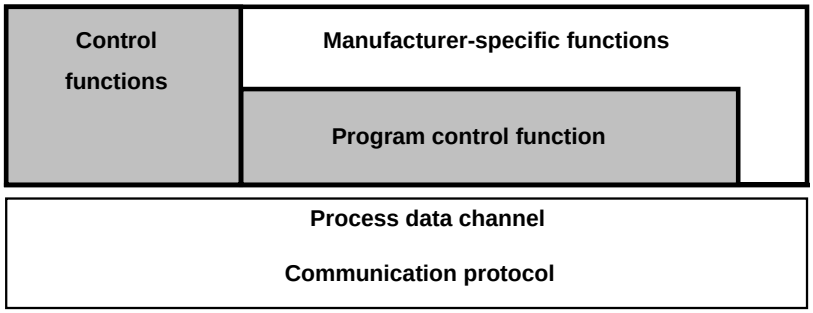


Figure 1: Application functions of robot controllers

Each application function is described with the aid of a function block. The device response is described with the help of a state machine in the control functions. This profile takes the fact into account that there may be separate hardware for communication and for tasks related to communication.

The robot controller functions comprise the standardized robot controller functions, which communicate with the communication medium through the defined communication functions.

The control functions serve to coordinate the function areas; a further subdivision into standardized and manufacturer-specific functions is possible. In this profile, device control (robot operation) is described as a standardized control function.

The freely definable manufacturer-specific functions may utilize the standardized functions of all other function areas.

1. Scope

The definitions in this profile are oriented towards the use of robot controllers in a sensor/actuator network on the sensor/actuator level. The sensor/actuator network used is InterBus-S.

2. Normative References

The definitions for data transfer via the process data channel are based on the draft standard DIN 19258 INTERBUS-S.

3. Definitions

Device Profile

The device profile defines the application functions that are visible through communication. The application functions are mapped to the communication by the following definitions:

- by the communication profile,
- by interaction between the application functions, insofar as they are executed through the communication system, and
- by the communication services used and the communication objects that can be manipulated with them.

The result of this mapping is the visible response of the application. The definitions contained in an application profile enable interoperability in a field of application if permitted by the device characteristics used. Characteristics of devices significant to the user are also defined.

A distinction is made between mandatory functions, optional and manufacturer-specific device functions, and parameters.

If users restrict themselves to the mandatory functions or parameters, interchangeability of devices is possible if this is permitted by the device characteristics and settings used. With respect to communication, and regardless of the function, devices are always interchangeable if use is made of the same parameters.

Communication Profile

In relation to the specific application or hardware group, the communication profile limits or classifies the degrees of freedom contained in the specification of the data transfer medium. The communication profile defines communication services and parameters that are identified in the specification as being optional.

All optional functions and parameters that are not stated in the communication profile remain optional. Mandatory services and parameters are binding, even if not stated in the profile.

The profile also limits or defines value ranges of attributes and parameters.

The communication medium is InterBus-S.

Communication Interface

The communication interface is composed of a channel for services compatible with DIN 19 245, Part 2 (Peripherals Communication Protocol channel, PCP channel), and a channel for process data.

All communication objects can be accessed via the PCP channel. The process data channel serves the purpose of swift transfer of specific communication objects. The PCP services allow acknowledged access to communication objects, i.e. access to a communication object is confirmed by the device.

Below, the data transferred to the process data channel is referred to as process data.

Via the process data channel, data is transferred in unacknowledged and equidistant form. Each byte can be read and written.

The direction specified for the process data is viewed from the bus, i.e.,

- Process output data is data read out of the process data channel by the robot controller.
- Process input data is data written into the process data channel by the robot controller.

State Machine

Some functions are described in this profile with the aid of a state machine. A state represents a specific internal and external response. It can only be terminated by means of defined events. Corresponding state transitions are assigned to events. Actions can be executed at a transition. The response of the state is changed at the transition. When the transition is ended, the current state is followed by the new state.

Definitions Specific to Robot Controllers

Task Program

The task program controls the robot's sequence of movements.

Actuators

Robot actuators

Auto External

Switching the robot controller into the "Auto External" mode is carried out manually (e.g. with a key-operated switch). This mode allows programs to be started.

4. Abbreviations

ID code	identification code
m	mandatory
o	optional
PA channel	parameter channel
PD channel	process data channel
RC	robot controller

5. Device Characterization

The robot controller constitutes the link between the automation equipment (PLC, host computer) and the process. In simple terms: The robot controller converts setpoint values from the task program into physical values for the process. Robot controllers may be active or passive bus devices.

The market of general robot controllers requires a wide range of different devices with regard to functions and prices. Owing to its open structure, the robot controller covers the whole variety of functions.

With regard to communication, the devices are always interchangeable if use is made of the same parameters.

The bus interface includes a process data channel with a length of 3 words.

The assignment of the process data channel is as follows:

Process output data

Control word	Optional	Optional

Process input data

Status word	Optional	Optional

Figure 2: Process data channel

5.1 System Data

A typical system configuration is shown in Figure 3.

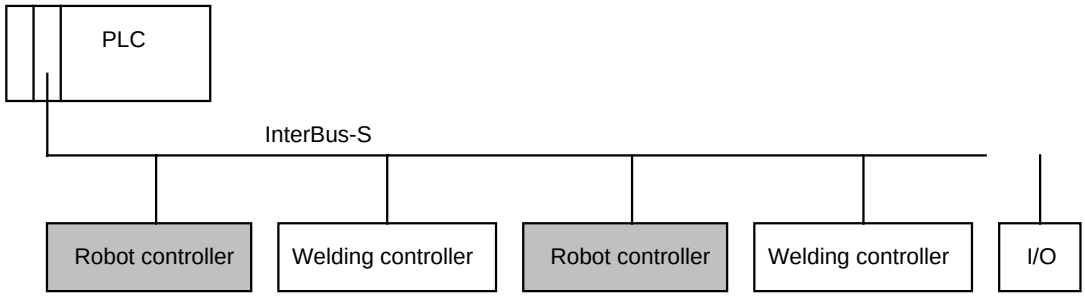


Figure 3: Description of a typical system configuration

Typical Communication Times

Control signals from the PLC to the robot controller in 3ms

Typical Bus Scan Times:

3 ms

Communication Relationships

Higher-level control (PLC) -> RC

RC -> welding controller

6. Application and Device Characteristics

This chapter describes the complete application from the point of view of communication. The application is broken down into the following function blocks, as shown in Figure 4:

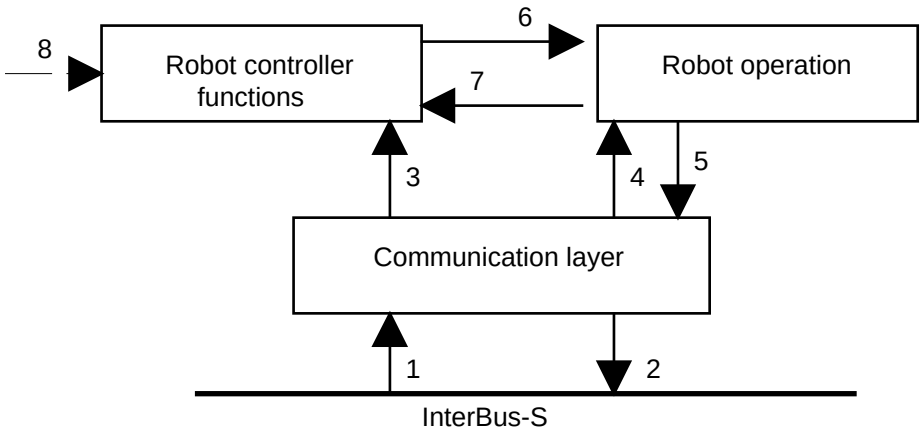


Figure 4: Function blocks of an application

Communication Function

The communication function executes all functions specific to communication.

Device Control (Robot Operation) Function Block

The device control (robot operation) function block controls the complete device function (robot controller function).

RC Functions

The RC controls all robot-specific functions.

Communication Layer

The communication layer contains a layer 7 with process data channel and a layer 2 conforming to the InterBus-S specification.

Interactions between the Function Blocks

1 Data from the bus system
2 Data to the bus system
3 Specification of the program number
4 Instructions to the robot operation (control word)
5 State of the robot operation
6 State of the robot controller function, manual intervention required (malfunction)
7 Control of the robot controller function
8 External signal

6.1 Robot Operation

The device control (robot operation) function block controls the complete device function (see Figure 5). Which mode is active after power on depends on the local setting on the RC (e.g. selection switch). The following modes are possible (according to VDE 2853):

T1 :	Programming, single step (reduced speed)
T2 :	Single step (100% speed)
Auto External:	Remote control by the higher-level control enabled

The control sequence in the "Auto External" mode is described with the help of a state machine.

The device control (robot operation) is influenced by the control word and the control byte, by internal signals, and by malfunctions (manual intervention required). The status word is generated on the basis of the device state and internal signals, and can be read out via the bus.

"Auto External" Mode

In this mode the robot actuators can be switched on by the PLC, with the "Actuators On External" command.

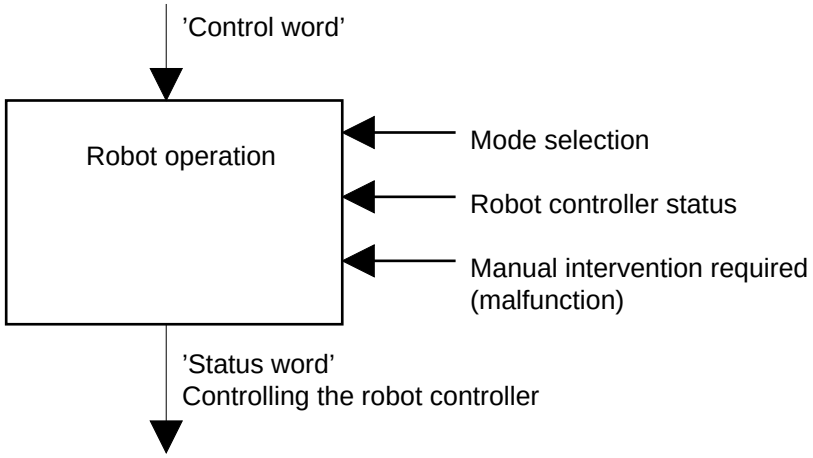


Figure 5: Device control (robot operation) function block

'Control Word'

The robot controller can be controlled by the bits in the 'control word'.

'Status Word'

The 'status word' parameter supplies information on the state and messages of the robot controller.

6.1.1 Robot Operation State Machine

The state machine (see Figure **Fehler! Textmarke nicht definiert.**) describes the device states and the possible control sequence of the robot controller in the "Auto External" mode.

A state represents a particular internal and external response. Using robot operation commands and internal events, the state can be changed to execute a control sequence. The current state can be read out by way of the status word.

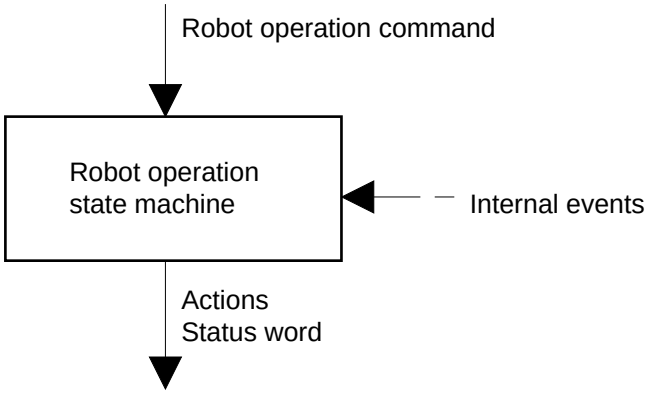


Figure 6: Robot operation state machine function

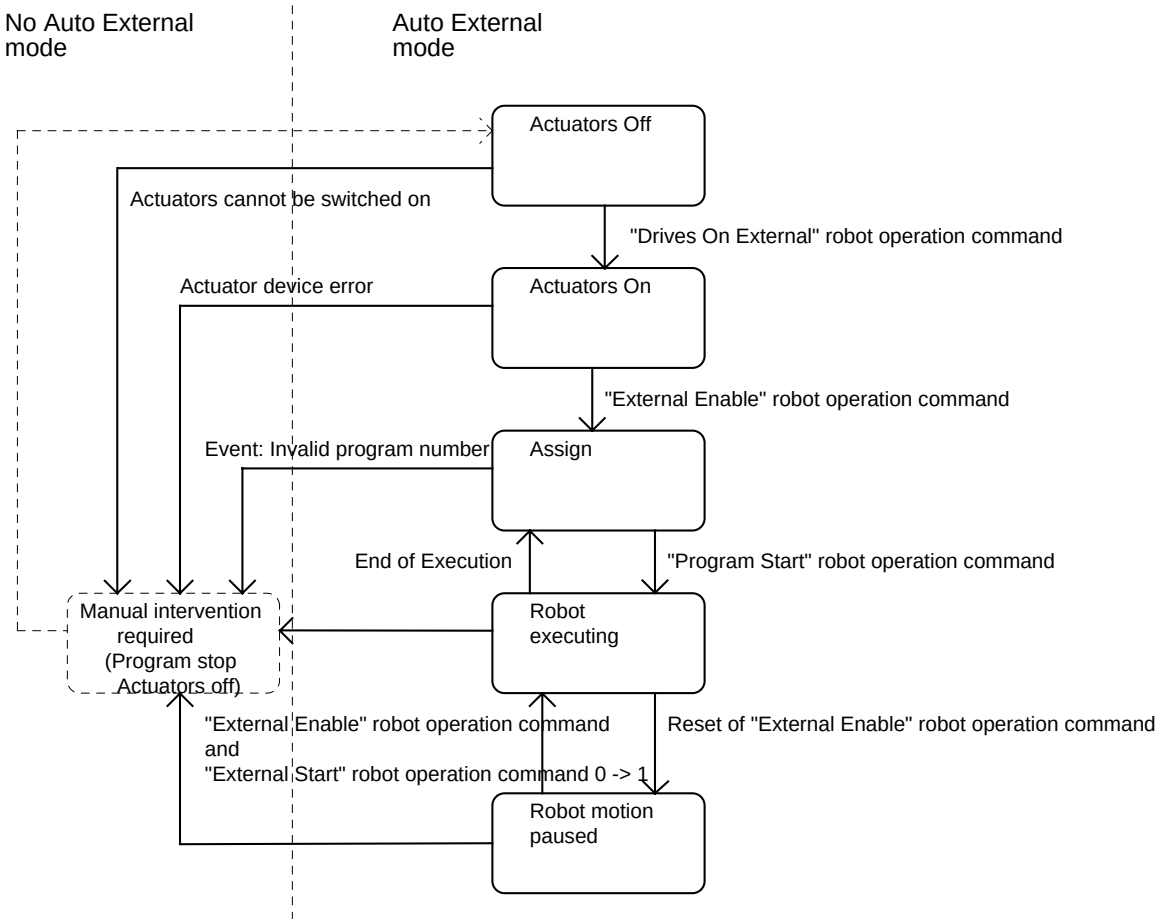


Figure 7: Robot operation state machine

"ACTUATORS OFF" State

This state follows the switching on of the RC if the "Auto External" mode was enabled. In this state the robot actuators are off.

"ACTUATORS ON" State

In this state the robot actuators are on.

"Assign" State

In this state the RC requests a new program number. The PLC sends the program number, then, using the "Program Start" robot operation command, starts from this state the task program selected with the program number. The "Program Start" robot operation command must be set after the program number has been set.

"Robot Executing" State

The task program selected with the program number is running. When the requested program starts, the "Assign" bit in the status word is reset. After the PLC has reset the robot operation command, a change of the program number by the PLC has no effect.

"Robot Motion Paused" State

The task program selected with the program number is stopped. This state follows the reset of the "External Enable" robot operation command (Pause). To continue the program, the "External Enable" robot operation command must be set again.

6.1.2 Control Word

By means of logical operations, the 'control word' and the internal signals generate the robot operation commands which act on the device control state machine. This initiates functions and defines operating states of the device. The control word is composed of 16 bits with the meanings shown in Table 2:

Table 1: Meanings of the control word bits

Bit	Name	Mandatory
0	Actuators Off External	m
1	Actuators On External	m
2	External Enable	m
3	Program Start	m
4	Reserved	m
5	Reserved	m
6	Reserved	m
7	Manufacturer-specific (e.g. parity)	o
8	b0 of program no.	m
9	b1 of program no.	m
10	b2 of program no.	m
11	b3 of program no.	m
12	b4 of program no.	m
13	b5 of program no.	m
14	b6 of program no.	m
15	b7 of program no.	m

Program Start

Setting this bit has three functions:

- According to the situation, start of the executive program in the RC
- Start of the task program with the respective program no. in the RC
- Continuation of the program after program stop

0 ⇨ 1 = Start of a program
1 ⇨ 0 = This bit can be reset following the "Assign" (program no. request) by the RC or when the RC indicates a malfunction (manual intervention required).

Actuators On External

This bit is used to set the actuators of the robot into the "Ready" state.

0 = No change of actuator state
1 = The actuators may go into the "Ready" state. This is only possible when the "Actuators Off" bit is = 1.

Actuators Off External

This bit is used to control the actuators.

1 = The actuators can be switched off. No change of the actuator state.
0 = The actuators are switched off and remain disabled.

External Enable

This bit is only effective when the RC is in the "Actuators On" state. Stop of the task program and stop of the robot motion.

1 = The start of a program is enabled.
0 = The start of a program is disabled and programs started before are stopped.

Program Number

Bits 8 to 15 provide the program number.

6.1.3 Status Word

The status word provides information on the actuator state as well as messages (see Table 3).

Table 2: Meanings of the status word bits

Bit	Name	Mandatory
0	RC Ready	m
1	Auto External Ready	m
2	Actuators are on	m
3	RC Task Program Running (Robot Executing)	m
4	Assign	m
5	Reserved	m
6	Manual intervention required (group of malfunctions)	m
7	Emergency Off Diagnostic Message	o
8	Reserved	m
9	Reserved	m
10	Reserved	m
11	Reserved	m
12	Manufacturer-specific	o
13	Manufacturer-specific	m
14	Manufacturer-specific	m
15	Manufacturer-specific	m

Operating Modes

Table 3: Device states in the "Auto External" mode

Modes	b6	b1	b0
Ready	x	x	1
Auto External	0	1	1
Malfunction (man. intervention req.)	1	0	1

Device States

The device states in the "Auto External" mode are indicated by the following bit combinations in the status word:

Table 4: Device states in the "Auto External" mode

State	b6	b4	b3	b2	b1	b0
ACTUATORS OFF				0		1
ACTUATORS ON				1		1
ASSIGN		1		1		1
ROBOT EXECUTING			1	1		1
ROBOT MOTION PAUSED			0	1		1

RC Ready

This bit defines whether the RC is ready and whether the process input data channel is supported.

1 = The robot controller is ready, and the process input data channel is supported.
0 = The robot controller is not ready, and the process input data channel is not supported.

Auto External Ready

The RC is in the ’Auto External’ mode. Thus, the RC can be remote controlled.

1 = ’Auto External’ mode
0 = Not in ’Auto External’ mode (The RC is in state ’Test1’ or ’Test2’)

RC Task Program Running (Robot Executing)

1 = An RC application program is running
0 = No RC program is running
or
The application program has been stopped.

Assign

The RC requests a new program no. from the higher-level control (e.g. PLC).

The bit remains set until the application program runs.

1 = Request of program no.
1 ⇨0 Application program is running.

Actuators On

The actuators are supplied with power (Ready)

1 = The actuators are ready
0 = The actuators are not ready

Manual Intervention Required (Group of Malfunctions)

The RC is in the ’Manual Intervention Required’ (malfunction) state. E.g. an internal or external Emergency Off has been triggered.

1 = Malfunction
0 = No malfunction

Emergency Off Diagnostic Message

This bit is set when the RC has triggered an Emergency Off. The actuators of the robot are switched off.

1 = Emergency Off was triggered
0 = Emergency Off was not triggered

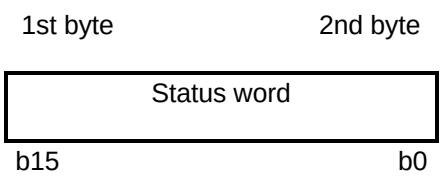
Reserved

These status bits are reserved for profile extensions. The bits must be set to "0" as long as they are not assigned to a defined state.

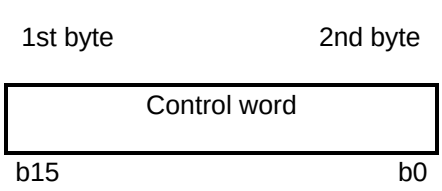
Mapping of the Device Function to the Communication

PD Channel Mapping

Process input data



Process output data



6.2 Robot Controller Functions

The robot controller functions (see Figure 8) consist of functions describing the robot controller.

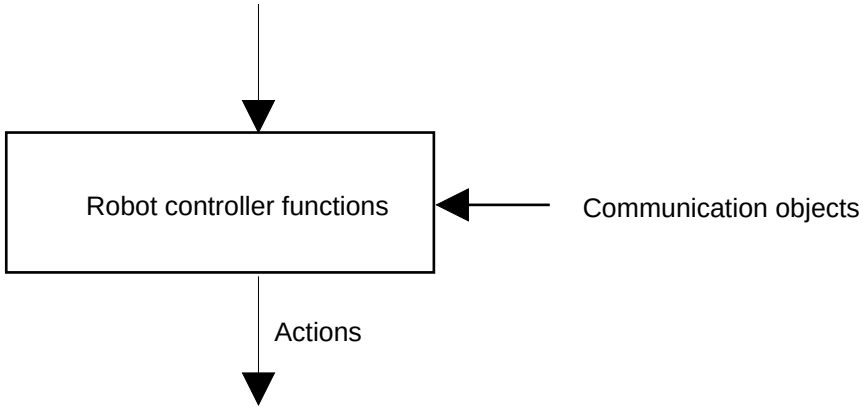


Figure 8: Robot controller functions

The robot controller functions consist of the following subfunctions:

- Application-specific function
- Program control function

6.2.1 Application-Specific Function

The application program may use only the application-specific area of the PD channel freely.

PD Channel Map

Process input data

1st PD channel word	2nd PD channel word	3rd PD channel word
Status word	Application-specific	

Process output data

1st PD channel word	2nd PD channel word	3rd PD channel word
Control word	Application-specific	

6.2.2 Program Control Function

To select a new program, the robot controller must be set to the ASSIGN state. This is achieved with the "External Enable" robot operation command. The robot controller changes into the "ASSIGN" state to request a new program no. from the higher-level control. The higher-level control transfers the program no. and then starts the program with the "Program Start" robot operation command. The RC then changes into the ROBOT EXECUTING" state ("ROBOT EXECUTING" bit is set), starts the application program and resets the Assign bit in the status word. Thereupon, the higher-level control can reset the "Program Start" robot operation command. After the "Program Start" bit has been reset, a program no. change is not effective anymore. In this state of the RC, the task program can be stopped by resetting the "External Enable" robot operation command. A program stopped in this way can only be resumed by the two robot operation commands, "External Enable" and "Program Start". After the end of the program, the RC changes automatically into the "ASSIGN" state.

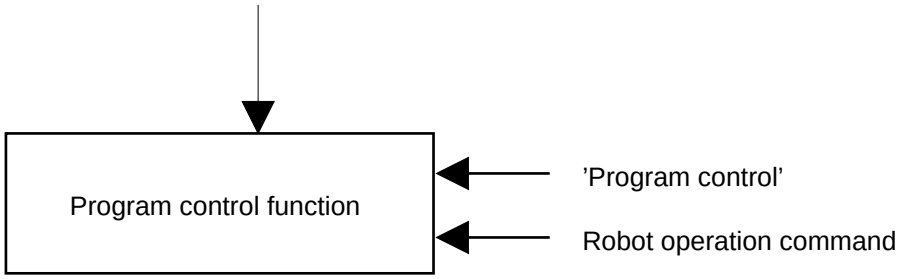


Figure 9: Program control function

'Program No.'

This parameter defines which program is to be executed. Value 0 means no new program no.; the program number transferred before remains valid.

PD Channel Map

Process input data channel

b15 b0

Status bits	Status bits	Application-specific

Process output data channel

b15 b0

Program no.	Control bits	Application-specific

7. Operating Phases of the Application

This chapter describes the possible operating phases of the device. The chapter is divided into

- Start-up/abort;
- Operation;
- Start-up phase and configuring phase.

7.1 Start-up/Abort

Start-up

Power-on of a robot controller or the reset of the actuator is followed by the start-up of the actuator. The following steps are carried out by the actuator:

- Configuration of the process input and output data;
- Initialization of the process data.

The process input and output data default is zero.

Abort

The following actions are carried out:

- Process data reset.

In the case of a decoupling between communication control and robot controller, the process input data are set to zero in the event of a robot controller failure.

7.2 Operation

The following functions are active in the ’Operation’ operating phase:

- Robot operation;
- Robot controller function;

8. Communication Profile

8.1 Layer 1

This chapter contains all definitions concerning layer 1.

InterBus-S coupling

- Installation remote bus interface CONINVERS connector (IP 65) or
- Installation remote bus interface 9-position D-SUB connector (IP 20) (up to 1 A) or
- Remote bus interface
  - D-Sub 9-position (male) to the controller board
  - D-Sub 9-position (female) to the end of the bus
  - 2-wire ring

Diagnostic LEDs

- Remote Bus Control (RC) green
- Remote Bus Disable (Rbd) red
- Bus Active (BA) green
- Transmit (TR) green (only when PCP has been implemented)

8.2 Layer 2

This chapter contains all definitions concerning layer 2.

8.2.1 Configuration of the InterBus-S Registers

Figure 10 defines the arrangement of the data registers of an InterBus-S device and, therefore, the addressing on the I/O level.

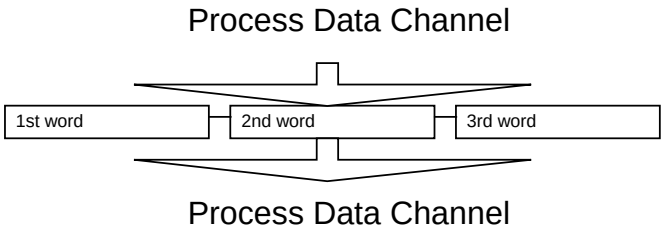


Figure 10: Arrangement of the data registers of an InterBus-S device

Addressing of the process data (see Figure 11):

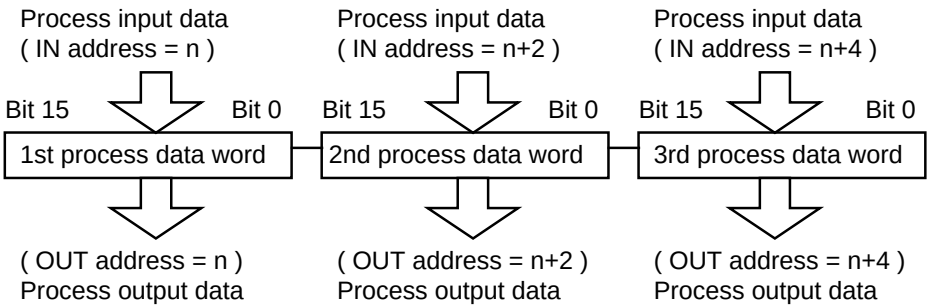


Figure 11: Arrangement of the data registers of an InterBus-S device

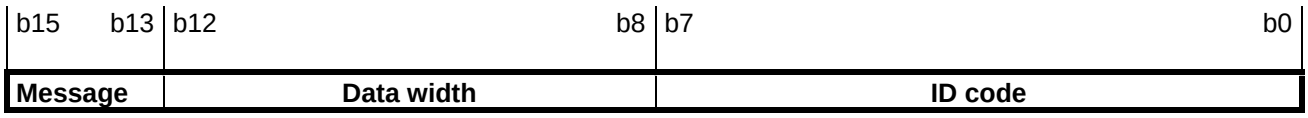
Process Data Direction:

Process input data is transferred from the robot controller to the bus system.

Process output data is transferred from the bus system to the robot controller.

8.2.2. Identification of the InterBus-S Devices

The ID code is composed as follows:



Message

See Sensor/Actuator Profile.

Data Width

The data width specifies how many bits the device uses on the bus. If for example, a device has 16 input bits and 32 output bits, it occupies 32 bits (4 bytes) in the ring (the highest value is decisive). The length of the parameter channel is defined in the ID code. The following data width is defined for robot controllers:

Table 28: Data width

Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Data width
0	0	0	1	1	6 bytes

IDENT Code

Robot controller as:	ID code (binary)	ID code (hex)	ID (dec)	Comment
Local bus device	---0 0011 1011 0111	-3B7	183	PD channel input and output data
Remote bus device	---0 0011 0010 1111	-32F	47	PD channel input and output data

8.3 Layer 7

The parameter channel is not supported.