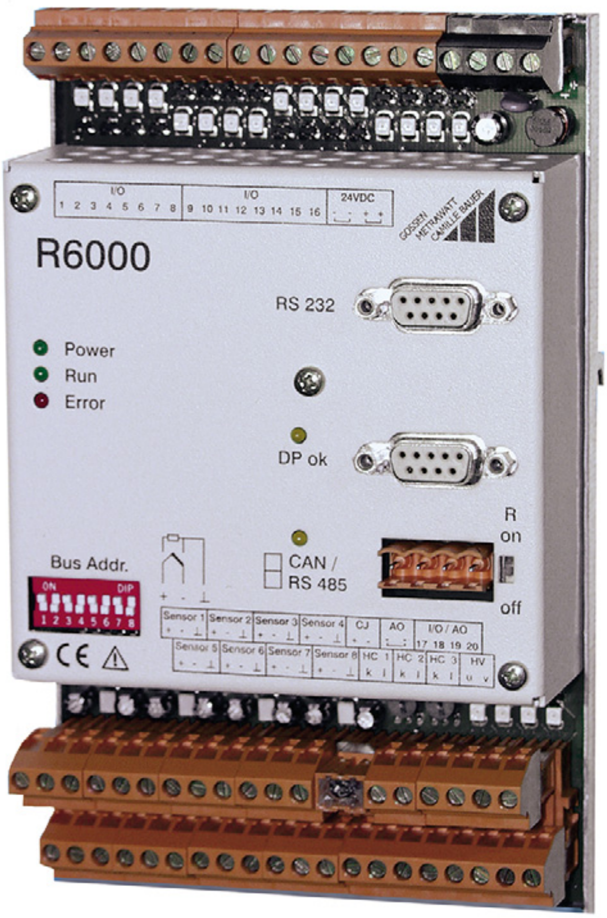
Operating Instructions

GOSSEN METRAWATT

R6000

8-Channel-Controller

Z307B
3/7.02



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1 Initial Start-Up

Read the operating instructions completely and carefully before using the device, and follow all instructions included therein.

Note
Parameter designations are printed in boldface, and *setting values* are printed in cursive typeface in these operating instructions.

The operating instructions should be made available to all users.

1.1 Safety Precautions

The R6000 controller is manufactured and tested in accordance with safety regulations IEC 61010-1 / EN 61010-1 / VDE 0411 part 1. If used for its intended purpose, safety of the user and of the device is assured.

Attention!
Check the specified nominal voltage at the front housing panel before placing the instrument into service.
When wiring the instrument, make sure the connector cables are not damaged, and that they are voltage-free.
If it can be assumed that safe operation is no longer possible, the instrument must be immediately removed from service (disconnect auxiliary voltage!). Safe operation can no longer be relied upon if the instrument demonstrates visible damage.
The device may not be placed back into operation until troubleshooting, repair and subsequent testing have been performed at our factory, or at one of our authorized service centers.
Work on live open instruments may only be carried out by trained personnel who are familiar with the dangers involved.
Capacitors inside the instrument may be dangerously charged, even if it has been disconnected from all power sources.

Requirements set forth in VDE 0100 must be observed during the performance of all work.

1.2 Installing the Controller

The R6000 controller must be installed in accordance with separate installation instructions (3-349-163-29).

Make sure that all relevant criteria have been observed during assembly, preparation, installation, electrical connection and initial start-up by means of identification based upon article number and feature codes.

1.3 Operating the Controller via Interface

Bus interface

Data exchange with the R6000 is accomplished exclusively via the bus interface.

Descriptions regarding functions, interfaces and data transmission are included in the following chapters:

- RS 485 interface, protocol per EN 60870 (see chapter 3 on page 26)
- Profibus DP interface, protocol per EN 50170 (see chapter 4 on page 35)

Service interface

Independent of the bus interface, the R6000 is equipped with an RS 232 service interface with protocol per EN 60870 (see chapter 3 on page 26), which allows for communication with each individual R6000.
R6KONFIG PC software is available for this purpose. It can be downloaded free of charge from the GMC-Instruments Deutschland GmbH website at: http://www.gmc-instruments.com

R6KONFIG PC software

All parameters can be conveniently accessed with R6KONFIG PC software, parameter sets can be saved to memory at the PC, and existing parameter sets can be uploaded to the R6000. Current measured values (cycle data) can be displayed (but not recorded).

Please read chapter 2 on page 8 first, for a thorough understanding of R6KONFIG PC software and the R6000 controller.

System requirements:

IBM PC or compatible with Pentium 300 MHz processor or higher
Windows 95, 98, NT 4.0 or 2000
64 MB RAM for Windows 95 or 98, 128 MB RAM for Windows NT 4.0 or 2000
Approximately 5 MB available hard disk space

2 Controller Settings

After installing the R6000, its parameters must be configured for the desired task. Parameters can be configured with, for example, R6KONFIG configuration software. Upon delivery, the R6000 is configured as an 8-channel *3-step PDPI fixed setpoint controller* with *type J thermocouple* (default setting).

2.1 Basic Configuration as 2 or 3-Step Fixed Setpoint Controller

2.1.1 Configuring the Temperature Measurement Inputs

The 8 temperature measurement inputs included with the R6000 are permanently linked to the 8 control channels.
The sensor type can be freely selected for each input.

- Selecting the sensor type with the DIP switches:

Sensor types are selected during installation of the R6000. They are selected separately for each channel with the DIP switches at the left-hand side of the housing. Unused inputs must be set to thermocouple.

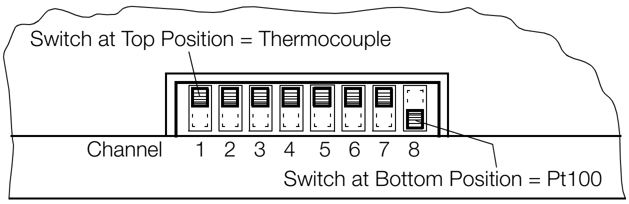


Figure 1 Sensor Type Settings (shown with device in horizontal position)

- Selecting a sensor with **sensor type**:

Sensor Type		Measuring Range Lower Limit		Measuring Range Upper Limit		DIP Switch
No.	Type	°C	°F	°C	°F	
0	J	0	32	900	1652	Top
1	L	0	32	900	1652	
2	K	0	32	1300	2372	
3	B	0	32	1800	3272	
4	S	0	32	1750	3182	
5	R	0	32	1750	3182	
6	N	0	32	1300	2372	
7	E	0	32	700	1292	
8	T	0	32	400	752	
9	U	0	32	600	1112	
10	Linear [1)]	0 mV		50 mV		
11	Pt100	–100	–148	500	932	Bottom
12	Ni100	–50	–58	250	482	

[1)] Scalable temperature, observe instructions in chapter 2.2.13 on page 13!

The factory default setting for all temperature measurement inputs is **sensor type:** *type J thermocouple*.

°C or °F can be selected for the transmission of temperature values via the (bus) interface with the parameter:
controlled variable quantity / device control. All temperature quantities are saved in °C at the controller.
Control parameters which are related to control variables (proportional zone heating and cooling, dead zone and switching hysteresis) are also saved in °C for improved clarity, and are thus independent of the selected sensor type.

2.1.2 Configuring the Control Channels

Upon shipment from the factory, the controller channels are configured with default settings including **controller class:** *fixed setpoint controller*, and **controller type:** *PDPI controller*. Whether the channels are configured as 2 or 3-step controllers, or as step-action or continuous action controllers, is determined by the **initial configuration**.

The **controller type** should be set to *unused* for channels to which no sensor is connected, or for channels which are not required, in order to avoid unnecessary error messages.

Upon shipment from the factory none of the **controller functions** are enabled, which means that the actuating outputs are inactive.

The **controller on** bit must be set at each desired channel in order to enable controller functions.

2.1.3 Configuring the Actuating Outputs

All binary inputs and outputs (and the 4 continuous outputs included with model A2) can be freely assigned to actuating signals and other entry and display functions.

A controller channel can be set up as a 2-step controller by configuring one binary output as a heating output with the corresponding channel number.

A 3-step controller is created when, in addition to the heating output, another binary output is configured as a cooling output with the corresponding channel number.

The 8 bits included in the **initial configuration** have the following significance in the case of a binary actuating output:

Bit Number	Value	Significance
0	0	Configuration as output
1	1	Single channel
2 ... 4	0 ... 7	Channel number
5	0 / 1	Heating / cooling
6	0	Mode
7	0	Actuating signal

The **initial configuration** for unused outputs should be set to *0*.

Upon shipment from the factory, binary outputs 1 through 8 are set up as heating outputs for channels 1 through 8 in their **initial configurations**, and binary outputs 9 through 16 are set up as cooling outputs, which means that all 8 channels are configured as discontinuous-action 3-step controllers.

2.2 Extended Configuration

2.2.1 Actuators, Continuous Action Controllers, Step-Action Controllers

Various actuators for the heating and cooling functions can be freely combined per controller channel with the R6000.

The controller's output function, i.e. 2-step, 3-step, continuous-action, step-action or combinations thereof, is defined by assigning an **output configuration** to the outputs.

Bit Number	Value	Significance for Discontinuous-Action Output	Significance for Continuous-Action Output
0	0	Configuration as output	
1	1	Single channel	
2 ... 4	0 ... 7	Channel number	
5	0 / 1	Heating / cooling	
6	0 / 1	More / less	Dead / live zero
7	0	Actuating signal	

Bits 5 and 6 define the actuator in the **initial configuration**.

Heating Actuator	Configuration of 1st Heating Output		Configuration of 2nd Heating Output	
No heating actuator	—		—	
SSR, contactor for discontinuous control	Binary output	Bit 5 = "heating" = 0 Bit 6 = "more" = 0	—	
(continuous) Proportional actuator	Continuous output	Bit 5 = "heating" = 0	—	
Motor actuator for step-action control	Binary output	Bit 5 = "heating" = 0 Bit 6 = "more" = 0	Binary output	Bit 5 = "heating" = 0 Bit 6 = "less" = 1

Cooling Actuator	Configuration of 1st Cooling Output		Configuration of 2nd Cooling Output	
No cooling actuator	—			
SSR, contactor for discontinuous control	Binary output	Bit 5 = "cooling" = 1 Bit 6 = "more" = 0	—	
(continuous) Proportional actuator	Continuous output	Bit 5 = "cooling" = 1	—	
Motor actuator for step-action control	Binary output	Bit 5 = "cooling" = 1 Bit 6 = "more" = 0	Binary output	Bit 5 = "cooling" = 1 Bit 6 = "less" = 1

- Actuators for heating and cooling are selected independent of each other (this allows for the combination of, for example, step-action control for heating, as well as for cooling.)
- If 2-step control is required, heating and cooling outputs may not be configured simultaneously for the respective channel.
- Several outputs of the same type can be assigned to the same controller output for separate control of several actuators with a single controller output.
- If continuous and discontinuous outputs are configured simultaneously for heating (or cooling), the channel functions as a continuous-action controller, and the step-action outputs are disabled.
- If only a "less" output is inadvertently configured for heating (or cooling), it remains inactive.
- Settings for **controller class** and **controller type** can be freely combined.

2.2.2 Hot Runner Controller

If the **hot runner** bit is set in the **controller configuration**, the heating manipulated variable is read out as a rapidly pulsating signal. This assures that localized overheating is avoided at hygroscopic cartridge heaters during actuation, and prevents temperature fluctuation within the
heaters.

2.2.3 Water Cooling

If the **water cooling** bit is set in the **controller configuration**, the cooling manipulated variable is read out in a modified fashion, in order to account for the disproportionately powerful cooling effect which prevails when water is evaporated.

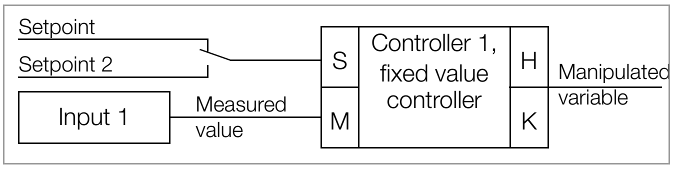
2.2.4 Controller Classes

The **controller class** determines how the controller processes input quantity actual and setpoint values.

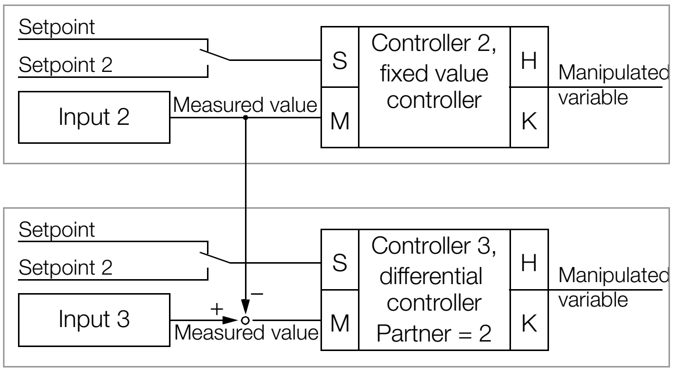
This setting can be combined with all other configurations.

Controller Class	Processing
Fixed setpoint controller (controller class 0)	System deviation equals setpoint value minus actual value
Differential controller (controller class 1)	Actual value difference is controlled, i.e. actual value of the differential controller channel minus the actual value of the partner channel Due to the sampling sequence, it is advisable to position the partner channel upstream from the differential controller channel in high speed circuits. Limit value monitoring is relative to actual value difference, and not the two actual values.
Master controller (controller class 2)	Due to the fact that inputs are not normally assigned to the master controller, it must be configured as such to assure calculation of a suitable manipulated variable for the slave controller. Control dynamics are attenuated to assure that the manipulated variable used as a delta actual value remains steady. Actuating cycle time is used as a time constant for an additional input filter. The manipulated variable is added by the slave controller as a delta setpoint value. 1% manipulated variable is always delta setpoint value 1° C (independent of unit of measurement selection °C or °F).
Slave controller (controller class 3)	The manipulated variable of the partner channel is added to the setpoint value, but only if the partner channel is a master controller. 1% manipulated variable is always delta setpoint value 1° C. Any possible setpoint shifting depends upon control variable limiting at the master controller, and thus has a maximum value of ± 100° C. If switching occurs to the proxy setpoint, the channel becomes a *fixed setpoint controller*, in which case nothing is added to the proxy setpoint value. All functions which effect setpoint values, as well as setpoints ramps, setpoint limiting or actuation, are applied to the setpoint sum.
Switching Controller (controller class 4)	If a control loop has only one actuator and two sensors, and if the sensor to be used depends upon the operating state, switching can be executed by a switching controller in combination with a fixed setpoint controller used as a partner channel. **Configuration:** The channel to which the first sensor and the actuator are connected is configured as a fixed setpoint controller (controller class = 0). The channel to which the second sensor (and no actuator) is connected is configured as a switching controller (controller class = 4), and the channel to which the first sensor is connected is set up as a partner channel. If switching is to be triggered via a binary input, the corresponding input is assigned to the fixed setpoint controller with function selection = 4 (switching controller active). **Function:** As long as the "switching controller active" bit has not been set in the controller function of the fixed setpoint controller, the fixed setpoint controller with the first sensor is active, and the switching controller with the second sensor is inactive. If the "switching controller active" bit at the fixed setpoint controller is set, the fixed setpoint controller is inactive. The switching controller is active in this case and utilizes the setpoint of the fixed setpoint controller (including setpoint limits and the proxy setpoint), as well as its actuator outputs. The internal statuses of the respectively inactive controller are frozen in order to assure bumpless switching in both directions. Limit value monitoring is active for both controllers.

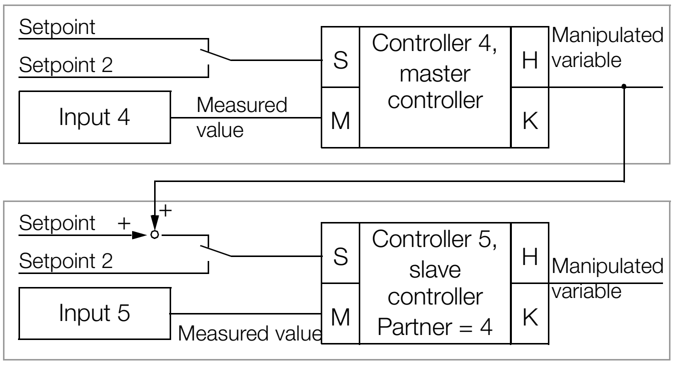
Fixed Value Control



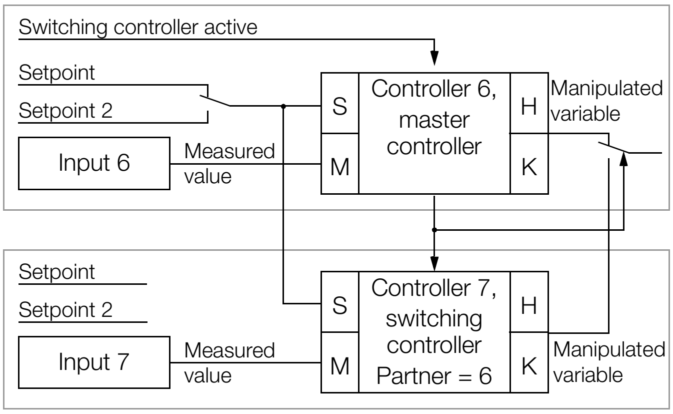
Differential Control



Cascade Control



Switching Control



2.2.5 Controller Type

The **controller type** determines how system deviation is processed.
The type of control variable output, i.e. the utilized actuators, depend upon the controller type.
This setting can be combined with all other configurations.

Controller Type	Processing
Unused (controller type 0)	This configuration is intended for unused channels. The actual value is only measured, without monitoring, error messages etc.
Measuring (controller type 1)	This configuration is intended for temperature monitoring. Limit value monitoring can be configured. System deviation is not used for any other purpose.
Actuator (controller type 2)	Same as **controller type 1** (*measuring*) In addition, the actuator manipulating factor is read out with the actuating cycle.
Limit transducer (controller type 3)	The maximum manipulating factor is read out, if the actual value is less than the momentary setpoint. The minimum manipulating factor is read out, if the actual value is greater than the momentary setpoint plus the dead zone. Switching hysteresis is adjustable, and status changes are possible after each actuating cycle. Actuating cycle time is used as a time constant for an additional input filter.
PDPI controller (controller type 4, 5)	The PDPI control algorithm assures short settling time without overshooting. The actuating cycle is at least as long as the selected value. The dead zone suppresses switching back and forth between heating and cooling if no lasting deviation occurs. The controller selects **controller type** *4* or *5* itself, the user can enter either. *Type 5* is a pure *PDPI step-action controller*, and *type 4* may include any other combination of actuators.
Proportional element (controller type 6)	The manipulated variable is proportional to system deviation, and a statistical dead zone can be adjusted at the cooling side. Actuating cycle time is used as a time constant for an additional input filter. The controller type is not intended for temperature regulation, because it does not demonstrate the dynamics required for control without overshooting.

2.2.6 Setpoint Ramps, Proxy Setpoint, Setpoint Limiting

- The setpoint ramp is activated when:
  – Auxiliary voltage is switched on / after reset
  – When the setpoint is changed / the proxy setpoint is activated
  – Upon switching from the off state or manual operation to automatic operation
- Setpoint ramps are inactive during self-optimization.
- Relative limit values make reference to the targeted setpoint, not the ramp.
- Corresponding bits are set in **controller status** when setpoint ramps are active.

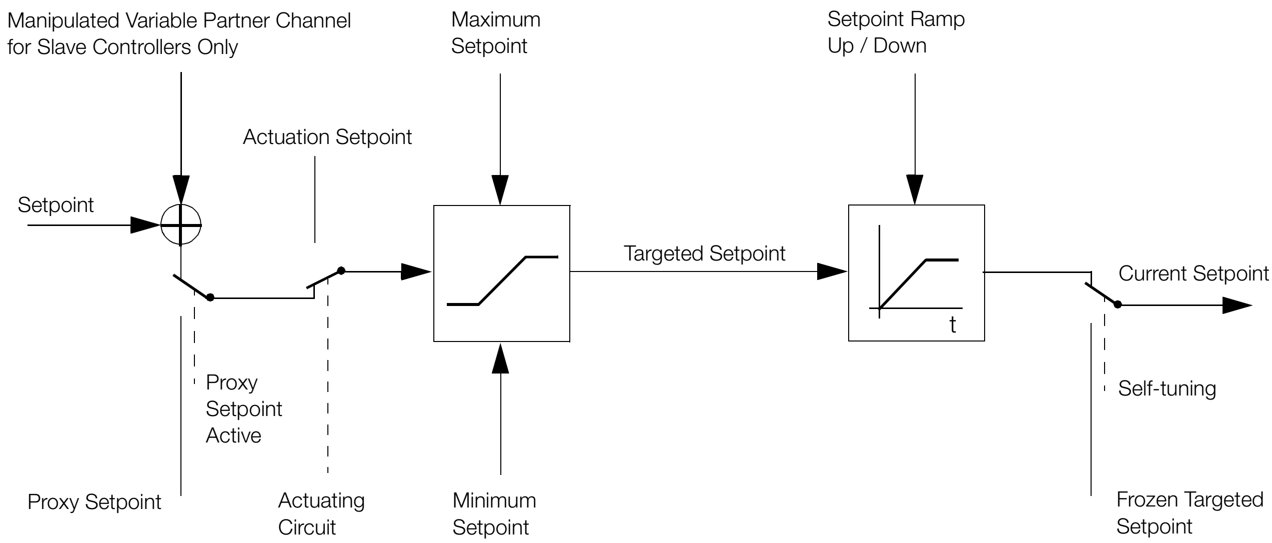


Figure 2 Setpoint Processing Schematic

2.2.7 Actuating Circuit

The actuating circuit is enabled by setting the **actuation** bit in the **controller function**.
The actuating circuit is only enabled for **controller type** *PDPI*. No actuation occurs for other controller types.

If the actuation bit is cleared, any currently active actuation operation is stopped immediately.

The actuation operation is started	if the actual value is more than 2° less than the **actuation setpoint** after auxiliary voltage is turned on (reset), or after the off state has been ended, or if the actual value drops to more than 40° less than the **actuation setpoint** after an actuation operation has been completed or during dwell time.
Actuation continues	until the actual value exceeds the **actuation value** minus 2° C. The manipulated variable is limited to the **actuation set temperature**. If the manipulated variable also needs to be read out as a rapidly pulsating signal, the channel must be configured as a **hot-runner** (**controller configuration**).
Dwell time then begins,	which is adjusted with **dwell time**. The controller regulates temperature to the actuation setpoint.
The actuation operation is ended	as soon as dwell time has expired. The controller then regulates temperature to the valid setpoint.

If the currently valid setpoint is still so far beneath the actuation setpoint that the condition for ending actuation cannot be fulfilled, the actuation operation continues indefinitely. In this case, control variable limiting by means of **maximum manipulating factor** is advisable.

The corresponding bits in **controller status** indicate when actuation and dwell time are active.

2.2.8 Manual Operation

The **controller on** bit in the **controller function** activates the controller channel (automatic operating mode). The controller outputs can then be driven in accordance with the controller's configuration.

If the controller channel has not been activated (**controller on** = *0*), output performance is determined by the **manual instead of off** bit in the **controller configuration**:

"**Manual instead of off**" not set:	Outputs are deactivated (off state). The integral-action component is cleared for PDPI controllers, i.e. the temperature must settle in once again when switched back on.
"**Manual instead of off**" set:	The last active manipulated variable continues to be read out and can be changed with the **manual manipulating factor** (manual operation). The integral-action component is not cleared for PDPI controllers, instead it is preset to the last (possibly changed) manipulated variable so that no jump occurs when switched back on. In this way, for example, the manipulated variable can be temporarily frozen, or another operating point can be approached in a bumpless fashion.

2.2.9 Feed-Forward Control

Control quality can be significantly improved by means of feed-forward control where abrupt load fluctuations prevail when configured as a *PDPI controller*:

When the **feed-forward control** bit is set in **controller function**, the manipulating factor (integral-action component) of the controller is increased by a value equal to the **influencing quantity manipulating factor**, and when the **feed-forward control** bit is cleared, it is reduced by the same value.

Feed-forward control is inactive during self-optimization.

The **feed-forward control** bit is not (no longer) set after a device reset.

Example:
If a machine requires an average of 70% heating power during production operation, but only 10% during idle time, the difference of the influencing quantity manipulating factor is set to 60%, and the **feed-forward control** bit is only activated during production.

2.2.10 Assignment to Groups

Individual controller channels can be assigned to one group by setting **group** in the **controller configuration** to a valid *group number (from 0 to 3)*. In this way, channels assigned to a group can participate mutually in **actual value control**, or selective changes to the **controller function** via binary input (see chapter 2.3 on page 14).

2.2.11 Actual Value Control

If the **actual value control** bit is set and assigned to a **group** (0 to 3) in the **controller configuration**, the channels which belong to the respective group participate in actual value control. **Controller type** must be set to *PDPI controller* for the participating channels to this end.

The objective is to reduce thermoelectromotive forces within the group by minimizing dynamic actual value differences. The slowest control system within the group dictates setpoint rise for all other control systems within the group to this end. Selected setpoint ramps and the actuation circuit are taken into consideration.

2.2.12 Measuring Offset for Temperature Sensors

If a temperature sensor has been directly connected (i.e. if **sensor type** has not been set to *linear*), both the **actual value correction** and the **actual value factor** parameters can be used to compensate for deviations between measured temperature and the temperature value to be displayed.

The **actual value factor** changes temperature in proportion to the measured value. No change takes place with an **actual value factor** of 100.0% (default setting).

The value selected for the **actual value correction** parameter is added to the measured temperature value (and may also be changed by means of the actual value factor). Excessively large measured values obtained from resistance thermometers and with 2-wire connections are thus corrected.

Two measuring points are required for calculating the parameter setting (the measured value corresponds to temperature prior to correction, and the display value corresponds to temperature after correction):

$$\textbf{Actual value factor} = \frac{\text{display value 1} - \text{display value 2}}{\text{meas. value 1} - \text{meas. value 2}} \bullet 100\%$$

$$\textbf{Actual value correction} = \text{display value} - \frac{\text{meas. value} \bullet \text{actual value factor}}{100\%} \qquad \text{where } \textbf{unit of measure} = {}^\circ C$$

$$\textbf{Actual value correction} = (\text{display value} - 32.0^\circ\text{ F}) - \frac{(\text{meas. value} - 32\ {}^\circ\text{F}) \bullet \text{actual val. corr.}}{100\%} \qquad \text{where } \textbf{unit of measure} = {}^\circ F$$

Example:

A temperature drop occurs between a tool heater and the surface of the tool. The measured temperature value (at the heater) is 375° C (measured value 1), and the temperature at the surface of the tool (temperature to be displayed) is 245° C (display value 1). The measured value should not be changed at room temperature (i.e. with tool heater switched off).
(Measured value 2 = display value 2 = 23.0° C.)

Solution:

$$\textbf{Actual value factor} = \frac{245^\circ\text{ C} - 23^\circ\text{ C}}{375^\circ\text{ C} - 23^\circ\text{ C}} \bullet 100\% = 63.1\%$$

$$\textbf{Actual value correction} = 23^\circ\text{ C} - \frac{23^\circ\text{ C} \bullet 63.1\%}{100\%} = 8.5^\circ\text{ C}$$

2.2.13 Linear Input and Scaling

When the linear input has been selected (**sensor type** = *linear*), the thermocouple input is used without taking the reference junction into consideration.

In the case of high impedance sources, the measured value is influenced as a result of broken sensor monitoring:

Shift:	approx. + 1.2 mV / kΩ
Attenuation:	approx. 0.5% / kΩ

The **actual value correction** and **actual value factor** parameters are used to scale the measured value.

The scaled measured value is treated by the R6000 as a temperature value because the units of measure for the various controller parameters (e.g. setpoint or proportional band) are specified in °C or °F. Where control or monitoring of quantities other than temperature are involved, the unit of measure for the controlled variable should thus not be changed after scaling, because scaling is converted for °C / °F.

The **actual value factor** is the display range which corresponds to an input range of 0 to 50 mV.

The 0 mV measuring point is displayed as 0.0° C or 32.0° F, as long as **actual value correction** is set to 0.

The value assigned to the **actual value correction** parameter is added to the display value.

Two measuring points are required for calculating the parameter setting (measured values in mV):

$$\textbf{Actual value factor} = \frac{\text{display value 1} - \text{display value 2}}{\text{measured value 1} - \text{measured value 2}} \bullet 50\text{ mV}$$

$$\textbf{Actual value correction} = \text{display value} - \frac{\text{measured value} \bullet \text{actual value factor}}{50\text{ mV}}$$ where **unit of measure** = *°C*

$$\textbf{Actual value correction} = (\text{display value} - 32.0°\text{ F}) - \frac{\text{measured value} \bullet \text{actual value factor}}{50\text{ mV}}$$ where **unit of measure** = *°F*

Example:

Pressure needs to be monitored in addition to temperature control in °F. 44 mV are applied to the input at a pressure of 100 bar, and 0 bar corresponds to 0 mV. The measured value is to be transmitted via the interface with a resolution of 0.01 bar.

Solution:

The resolution of 0.1° F is replaced with a resolution of 0.01 bar for the interpretation of all temperature values.

$$\textbf{Actual value factor} = \frac{100.00\text{ bar} - 0.00\text{ bar}}{44\text{ mV} - 0\text{ mV}} \bullet 50\text{ mV} = 113.64\text{ bar}$$ corresponds to 1136.4° F

$$\textbf{Actual value correction} = (0.00\text{ bar} - 3.20\text{ bar}) - \frac{113.64\text{ bar} \bullet 0\text{ mV}}{50\text{ mV}} = -3.20\text{ bar}$$ corresponds to 32.0° F

2.2.14 Limiter

If a controller needs to be deactivated in the event of a limit value violation within the control loop, the channel must be configured as a limiter. In this case, the controller responds just as it would if the "**controller on**" bit were not set in the **controller function** (PI = 20h). (Refer to chapter on manual operation 2.2.8)

The limiter can be combined with all **controller types** and **controller classes**.

- The limiter bit is set in the **limit value function** parameter (PI = 36h) in order to activate the **limiter** function.
- The limiter reacts to the **second limit values** (PI = 04h and 05h), which must be accordingly adjusted and configured. (See also chapter 2.5.1)
- As soon as a second limit value is violated, i.e. when either bit 2 or 5 is set in the **channel error status**, the controller is deactivated. If neither of these bits is set, the controller is reactivated.
- If the controller is to remain continuously deactivated after limit value monitoring has been triggered, the "**save alarm 2 active**" bit must be set in the **limit value function** parameter (PI = 36h).
- **Channel error status** bits 2 and 5 must then be cleared in order to reactivate the controller.
- This is also possible with a binary input by means of the **clear error** function (see also chapter 2.3).

2.3 Setting Controller Functions via Binary Input

The bits included in **controller function** which are set via (bus) interface in order to activate individual functions, can also be set with the binary inputs. In this case, the binary input takes precedence over the interface. One input is required per function, and control can be executed per channel, for one group (1 to 3) or for all eight channels.

In the case of control per individual channel, the **output configuration** of the output is as follows:

Bit Number	Value	Significance
0	1	Configuration as input
1	1	Control per individual channel
2 ... 4	0 ... 7	Channel number
5 ... 7	0 ... 7	Function selection

In the case of control per group, the **output configuration** of the output is as follows:

Bit Number	Value	Significance
0	1	Configuration as input
1	0	Group control
2, 3	0 / 1 ... 3	All 8 channels / group number
4 ... 6	0 ... 7	Function selection
7	0	—

Function selection:

Value	Significance	Comment
0	Proxy setpoint active	
1	Actuating circuit	
2	Feed-forward control	
3	Start automatic heating current transfer	can only be stopped via interface
4	Switching controller active	
5	Clear error	
6	Controller on	
7	Start self-tuning	can only be stopped via interface

2.4 Determining Controller Parameters

Proportional zone heating and cooling (XpI / XpII) parameters, **system delay (Tu)** and **actuation cycle time** must be determined in order to obtain optimized controller dynamics.
Appropriate values for controller amplification, derivative-action time, integral-action time and the measured quantity sampling rate are generated based upon this data internally by the controller.

2.4.1 Self-Optimization (self-tuning)

Self-optimization is used to optimize controller dynamics, i.e. the parameters **proportional zone heating and cooling (XpI / XpII), delay (Tu)** and **actuation cycle time** are determined.

Preparation

- Complete configuration must be performed **before** self-optimization is started.
- The setpoint value is adjusted to the value which is required **after** optimization.
- If the self-tuning error bit for the channel error status is set, it must first be cleared.

Start

- Self-optimization is started by setting the **self-tuning on** bit in the **controller function**.
- The start command is accepted if **controller type** is set to *PDPI controller*,
  outputs are assigned to the channel and
  control variable limiting is no less than 10%.

  If the start command is rejected, the **start error** bit is set for the **channel error status** of the corresponding channel (see also **events data**).
- Self-optimization is also started if the channel is in the off state or in the manual operating mode (**controller on** bit cleared).

Sequence

- The setpoint value which was active at the time self-optimization is started remains valid – changes are not effective at first (slave controllers: changing delta setpoints have no effect).
- Activation or deactivation of the proxy setpoint is not effective.
- Selected setpoint ramps are not taken into consideration.
- If started at the operating point (actual value approximates setpoint value), overshooting cannot be avoided.
- In the case of 3-step controllers, cooling is activated if the upper limit value is exceeded in order to prevent overheating. Self-optimization then performs a oscillation test around the setpoint.
- The bottom 4 bits in **controller status** indicate the optimization phase.
- The **self-tuning on** bit is reset after optimization has been completed.
- If self-optimization is started via the binary input, the binary input must be deactivated before self-optimization has been completed, because it would otherwise be restarted upon its completion. Self-optimization cannot be aborted via the binary input.

Abort

- Self-optimization can be aborted at any time by clearing the **self-tuning on** bit (except when started via binary input).
- If an error occurs during self-optimization, the controller no longer reads out an actuating signal and the **self-tuning error** bit is set for the **channel error status** of the corresponding channel (in **events data**). This is the case in the event of a sensor error, or if the parameters configuration for the channel has been changed such that self-optimization is no longer sensible.
- In the event of an error, the **self-tuning error** bit of the channel error status must first be cleared before closed loop control mode operation can be restarted.

2.4.2 Manual Optimization

The parameters **proportional zone heating and cooling, delay** and **cycle time** are determined by means of manual optimization. An actuation test or an oscillation test is performed to this end.

Preparing for the Actuation Test or the Oscillation Test

- Complete configuration must first be performed for use of the controller.
- The actuators are deactivated by setting **controller on** to *0* in **controller function**.
- A recorder must be connected to the sensor and adjusted appropriately for prevailing circuit dynamics and the setpoint.
  If the case of differential controllers, the actual value difference must be recorded.
- On and off-time of the heating output must be recorded for 3-step controllers (e.g. with an additional recorder channel or a stopwatch).
- Set **controller type** to *limit transducer.*
- Set **cycle time** to its minimum setting (*0.1 s*).
- If possible, deactivate any manipulating factor limiting.
- Reduce (or increase) the setpoint so that overshooting and undershooting do not cause any impermissible values.

Performing the Actuation Test

- Set **dead zone** to *MRS (measuring range span)* for 3-step controllers (cooling may not be triggered).
  Set **dead zone** to *0* for step-action controllers ("less output" must be triggered)
- Start the recorder.
- Activate the actuators by setting **controller on** to *1*.
- Record two overshoots and two undershoots. The actuation test is now complete for 2-step controllers.
  Continue as follows for 3-step controllers:
- Set **dead zone** to *0* in order to cause further overshooting with active cooling output. Record two overshoots and two undershoots.
- Record heating output on-time T_I and off-time T_{II} for the last oscillation.

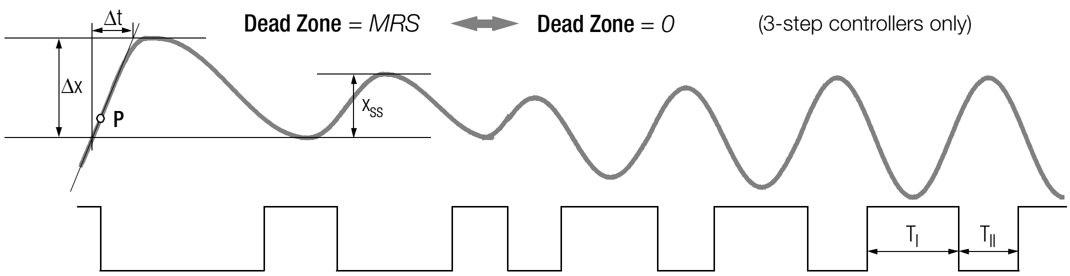


Figure 3 Characteristic Curve during Actuation Test

Evaluating the Actuation Test

- Apply a tangent to the curve at the intersection of the actual value and the setpoint, or the cut-off point of the output.
- Measure time Δt.
- Measure oscillation amplitude x_{SS}, or for step-action controllers overshooting Δx.

Parameter	Parameter Values			
	2-Step Controller	3-Step Controller	Continuous-Action Controller	Step-Action Controller [1]
Delay (Tu)	1.5 • Δt			Δt – (**Ty** / 4)
Cycle time	**Tu** / 12			**Ty** / 100
Proportional zone heating (XpI)	x_{SS}		2 • x_{SS}	0.5 • Δx
Proportional zone cooling (XpII)	–	**XpI** • (T_I / T_{II})	–	–

[1] **Ty = motor actuation time**

If manipulating factor limiting was active, the proportional zone must be corrected:

XpI multiply by 100% / **maximum manipulating factor**
XpII multiply by –100% / **minimum manipulating factor**

Performing the Oscillation Test

If an actuation test is not possible, for example if neighboring control loops influence the actual value too greatly, if cooling must be active in order to maintain the actual value (cooling operating point), or if optimization is required directly to the setpoint for any given reason, control parameters can be determined by means of sustained oscillation. However, calculated values for delay may be too large in this case under certain circumstances.

The test can be performed without a recorder if the actual value is observed and times are measured with a stopwatch.

- Set **dead zone** to *0*.
- Activate the actuators by setting **controller on** to *1*, and start the recorder if one is used. Record several oscillations until they become uniform in size.
- Measure oscillation amplitude x_{SS}.
- Record on-time T_I and off-time T_{II} of the heating output for the oscillations.

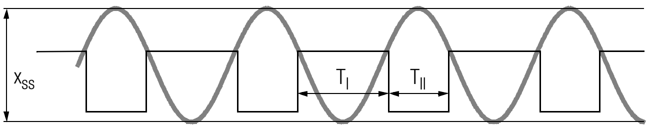


Figure 4 Oscillatory Characteristics

Evaluating the Oscillation Test

Parameter	Parameter Value			
	2-Step Controller	**3-Step Controller**	**Continuous-Action Controller**	**Step-Action Controller** [1]
Delay (Tu) [2]	$0.3 \bullet (T_I + T_{II})$			$0.2 \bullet (T_I + T_{II} - 2\mathbf{Ty})$
Cycle time	**Tu** / 12			**Ty** / 100
Proportional zone heating (XpI)	x_{SS}	$\frac{x_{SS} \bullet T_{II}}{(T_I + T_{II})}$	$2 \bullet x_{SS}$	$0.5 \bullet x_{SS}$
Proportional zone cooling (XpII)	–	**XpI** $\bullet (T_I / T_{II})$	–	–

[1] **Ty = motor actuation time**

2) If either T_I or T_{II} is significantly greater than the other, value Tu is too large.

Correction for manipulating factor limiting:

XpI multiply by 100% / **maximum manipulating factor**
XpII multiply by –100% / **minimum manipulating factor**

Correction for step-action controllers in the event that T_I or T_{II} is smaller than **Ty**:

XpI multiply by $\frac{\mathbf{Ty} \bullet \mathbf{Ty}}{T_I \bullet T_I}$ if T_I is smallest, or by $\frac{\mathbf{Ty} \bullet \mathbf{Ty}}{T_{II} \bullet T_{II}}$, if T_{II} is smallest.

The value for **Tu** is very inaccurate in this case. It should be optimized in closed loop control mode.

Closed Loop Control Mode

The closed loop control mode is started after manual optimization has been completed:

- Set **controller type** to *PDPI*.
  - Adjust the setpoint to the required value.
  - The dead zone can be increased from **dead zone** = *0* for 3-step and step-action controllers, if control of the heating and cooling outputs, or more and less outputs, changes too rapidly due to an unsteady actual value.

2.5 Monitoring Functions

The results of individual monitoring functions are written to the **events data** bits, which can be queried via the (bus) interface, or read out selectively at the binary outputs.

2.5.1 Limit Value Monitoring

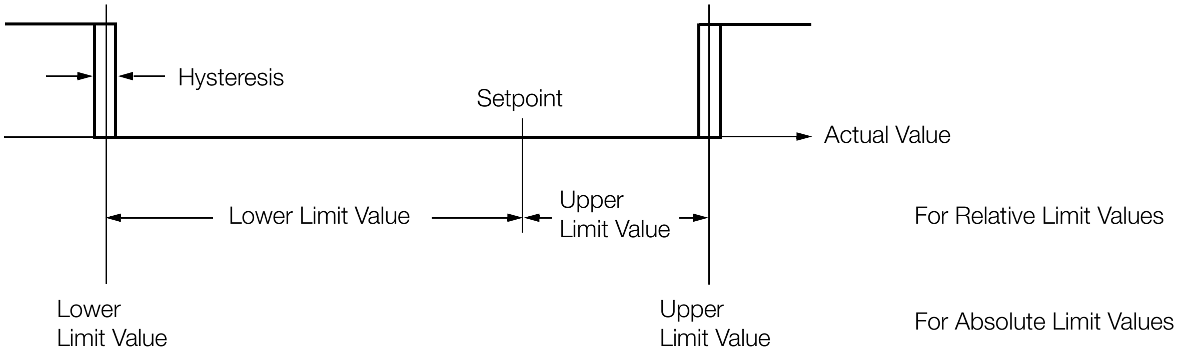


Figure 5 Schematic Representation of Limit Value Monitoring

Actuation Suppression

Alarm suppression is active during actuation (**actuation suppression** bit set in **limit value configuration**) until temperature has exceeded the lower limit value for the first time. During cooling, suppression is active until temperature has fallen below the upper limit value for the first time.
Suppression is active when auxiliary power is activated, if the current setpoint is changed or the proxy setpoint is activated, or if switching takes place from controller off to controller on.

Alarm Memory

If alarm memory is active (**alarm memory** bit set in **limit value configuration**), any bit which has been set in the **channel error status** remains set until it is cleared.

2.5.2 Heating Circuit Monitoring

- Heating circuit monitoring is activated with the **heating circuit monitoring** bit in the **limit value configuration**.
- The controller must be configured as **controller type** *PDPI*, discontinuous or continuous heating with a **maximum manipulating range of** greater than or equal to *20%*.
- No monitoring takes place during self-optimization.
- The monitoring function utilizes the **delay Tu** and **proportional zone heating Xpl** control parameters, which must be correctly optimized for this reason. In the event of manual optimization or subsequent adaptation of control parameters, a lower limit for **Tu** must be maintained. The lower limit is:
  min. Tu = 2 • Xpl / (Δx / Δt) Δx / Δt = maximum temperature rise during actuation with 100% on-time.
  The limit is cut in half with continuous heating.
- An error message occurs at approximately 2 times Tu, if heating is discontinuous and the measured temperature increase is too small, or immediately if temperature plunges rapidly, as would not normally be possible.
  This may be caused by:
  – Polarity is reversed at the sensor, or the sensor is short-circuited.
  – No sensor is installed, the sensor has slipped out of place or has been installed at an incorrect position.
  – The heating current circuit is interrupted or has not been switched on.
  – The actuator is defective.
- In the event of error, the outputs are deactivated and the **heating circuit error** bit is set for **channel error status** (see also **events data**).
- The controller channel remains off until the **heating circuit error** bit is cleared.

2.5.3 Heating Current Monitoring

Connection

- 1 to 3 identical external summation current transformers can be connected (for all 8 channels simultaneously).
  The current value which results in a secondary value of 1 A must be entered to the **summation current transformation ratio** parameter.
- A voltage transformer can be connected in order to compensate for heating voltage fluctuation.
- All channels are monitored whose current is fed through the transformer.

Parameters Configuration

- The current values (sum of phases 1 through 3) to be monitored must be entered to the **heating current nominal value** parameter for each monitored channel. Channels which are not monitored must be set to 0.0 A.
- The open-circuit voltage value which prevails at nominal primary heating voltage must be entered to the heating voltage transformer secondary voltage parameter in order to activate compensation. Compensation is deactivated if a value of less than 10.0 V is entered.
- Automatic adjustment of **nominal heating current values** and **secondary heating voltage** can be activated by setting the **automatic heating current transfer** bits in **controller function**.
  Nominal heating current values are thus determined and monitoring is thereby activated.
  If a value of 10.0 V or less is measured for secondary heating voltage, the value remains at 0.0 V and compensation is inactive. If a value of at least 10.0 V has already been selected for secondary heating voltage, no new value is determined for compensation.

Function

- If heating current monitoring has been activated for at least one channel, the R6000 runs through a cycle of operating states (depending upon the **delay** Tu parameter) such that heating is only activated at one of the channels to be monitored (all other heaters are off), and all heaters are off. In this way, heating current can be measured at the individual channels with the summation current transformers.
- If a secondary heating voltage value within a range of 10.0 V and 50.0 V has been selected, measured current values are compensated:

$$\text{monitored current} = \frac{\text{measured current} \bullet \text{secondary heating voltage}}{\text{measured voltage}}$$

  This allows for more accurate monitoring, for example in the case of parallel connected heaters.
- Monitoring and possible error messages take place with reference to two states:
  Heat off and current is present → Error: **Heating current not off**
  Heat on and too little current → Error: **Too little heating current**
- **Too little heating current** is indicated if the nominal heating current value is fallen short of by more than 20% with inactive heating voltage compensation, or if the nominal heating current value is fallen short of by more than 5% with active heating voltage compensation.

2.5.4 Performance in the Event of Sensor Error

In the event of a broken sensor, thermocouple polarity reversal or short-circuiting of the Pt100, the **broken sensor** bit or the **reversed polarity** bit is set for **channel error status**.

The controller outputs respond as follows:

- No response occurs if **controller type** is set to *off*, *measure* or *actuator*.
- If **controller type** is set to *limit transducer*, *PDPI step-action controller* (controller type 5) or *proportional element*, the **sensor error manipulating factor** is read out in the automatic mode.
- If **controller type** is set to *PDPI controller* (=4) performance depends upon the selected **sensor error manipulating factor**:
  – Where **sensor error manipulating factor** = 0%, or minimum or maximum manipulating factor:
  The sensor error manipulating factor is read out.
  – Where **sensor error manipulating factor** = any other value:
  After the control system settles in, a “plausible” manipulating factor is read out
  which keeps the temperature as close as possible to the setpoint.
  The sensor error manipulating factor is read out until the control system settles in.

2.5.5 Monitoring the Binary Outputs

All binary outputs which have not been configured as inputs are monitored for short-circuiting and incorrect triggering.
2 times 20 bits are included in **output error**, which are set if the output is active although no signal is present at the terminal (short-circuit), or if the output is inactive and a signal is present at the terminal, i.e. the output is triggered due to a wiring error etc.

2.5.6 Device Errors

Appropriate bits are set in **device error status** if:

- Measured value acquirement is defective
- A characteristic error has been detected
- An error in the parameters memory has been discovered
- An output monitoring error has occurred

If one of these bits is set, the **error LED** at the front of the housing lights up as well.

Appropriate bits are also set if:

- Overload occurs at the heating current monitoring inputs
- The reference junction is interrupted or short-circuited

2.5.7 Read-Out of Channel-Specific Alarms

Each channel has its own **channel error mask**, by means of which the errors to be read out via a binary output are selected from the **channel error status** (see chapter 6.4.6 on page 51 for details regarding error bits).

The **output configuration** of the selected output is set as follows for read-out:

Bit Number	Value	Significance
0	0	Configuration as output
1	1	Single channel
2 ... 4	0 ... 7	Channel number
5	0	—
6	0 / 1	Operating current / closed-circuit current
7	1	Configuration as alarm output

2.5.8 Read-Out of Group Alarms or Self-Optimization Active Status

Eight **group error masks** can be programmed, by means of which the group errors are selected which are to be read out via a binary output (see chapter 6.4.7 on page 51 for details regarding error bits).

The **output configuration** of the selected output is set as follows for the read-out of group alarms or the status indicating that self-optimization is still active or defective at some channel:

Bit Number	Value	Significance
0	0	Configuration as output
1	0	Group error
2 ... 6	1 ... 8 9	Group error 0 ... 7, Self-tuning in progress or self-tuning error
7	0 / 1	Operating current / closed-circuit current

2.5.9 Clearing Error Bits

Several of the error bits in the **channel error status** and the **device error status** must be acknowledged because they are not cleared by the R6000 (except after a reset). This can be accomplished by overwriting the error status words via the interface as described in chapter 6.4.3.

The following bits in the **channel error status** can also be cleared via a binary input by adjusting the controller function selection setting to *clear errors* (see also chapter 2.3):

- Limit value error for alarm memory
- Heating circuit error
- Self-tuning start-up error
- Self-tuning error

Newly occurring errors are not suppressed.

The signal at the binary input must be applied for at least 100 ms.

2.6 Alarm Overview

Refer to the specified chapter for a complete description, and see chapter 6.4.3 for a description of the interface.

2.6.1 Channel-Specific Alarms

These alarms are summarized for each channel in the channel error status word.

Bit no.	Meaning	Causes	Remedy	Comment
0	Broken sensor	Interrupted cable	Inspect wiring and sensor	See chapter 2.5.4.
1	Reversed polarity	Polarity reversed at thermocouple or incorrectly connected Pt100		
2	2nd upper limit value exceeded	Temperature too high	Inspect the actuators Acknowledge alarm in event of alarm memory	See chapter 2.5.1.
3	1st upper limit value exceeded			
4	1st lower limit value fallen short of	Temperature too low		
5	2nd lower limit value fallen short of			
6	Impermissible parameter	Transmitted parameter value out of limits Value has been rejected	Transmit plausible parameter value Acknowledge alarm	
7	Heating current not off with deactivated actuating signal	Short-circuited actuator	Inspect actuator and heating current circuit	See chapter 2.5.3.
8	Too little heating current with active actuating signal	Actuator interrupted / fuse blown		
9	Heating circuit error	Sensor does not measure correctly Heating current circuit interrupted	Inspect sensor, actuator and heating current circuit Acknowledge alarm	See chapter 2.5.2.
10	Self-tuning start-up error	Controller is configured incorrectly Controller cannot be self-tuned	Configure controller correctly Acknowledge alarm	See chapter 2.4.1.
11	Self-tuning error and abort	Sensor error has occurred Configuration has been changed during self-tuning		

2.6.2 Device-Specific Alarms

These alarms are summarized in the device error status word.

Bit no.	Meaning	Causes	Remedy	Comment
0	Analog error	Device is defective	Repair	Error LED lights up
1	Overload, heating current 1	Secondary heating current greater than 1.2 A Interference voltage	Use a different transformer Transformer secondary must be potential-free	
2	Overload, heating current 2			
3	Overload, heating current 3			
4	Heating voltage overload	Secondary heating voltage greater than 60 V Interference voltage	Use a different transformer Transformer secondary must be potential-free	
5	Invalid features combination	Device is defective	Repair	Error LED lights up
6	Reference junction error	Wiring to the remote cold junction is interrupted or short-circuited	Inspect wiring	
		Defective reference junction	Replace reference junction	
7	EEPROM error	Implausible parameter values in memory	Restore default settings and reenter parameter values Acknowledge alarm	Error LED lights up See chapter 2.9.1.
		Defective parameters memory	Repair	
8	Group output error	Inactive output has high level signal (> 14 V), or active output has low level signal (< 7 V)	Correct wiring error or short-circuit	Error LED lights up
		Output defective	Repair	
9	Mapping error	Sensor and heater assigned to different channels	Correct wiring or configuration Acknowledge alarm	See chapter 2.8.1.

2.7 Reading In Freely Available Binary Inputs

Binary inputs and outputs which are not required for control and monitoring functions can be configured as message inputs so that the master controller can acquire up to eight statuses per R6000. Sampling takes place once every 10 ms for all inputs.

The **output configuration** of the desired output is set as follows:

Bit Number	Value	Meaning
0	1	Configuration as input
1	0	Group control
2, 3	0	Message input
4 ... 7	8 ... 15	Bit no. 0 to 7 in the **message word**

The **message word** can be queried as a **controller status** (PI = 24h) from channel 9.

2.8 Device Control

Processes are initialized by the "controlled variable quantity / device control parameter" which influence the entire R6000 (see also chapter 2.9.1, loading and storing parameter sets).

Bit Number	Value	Meaning
0 - 7	AAh	Check sensor and heater assignments (mapping)

2.8.1 Checking Sensor and Heater Assignments

Currently in preparation

2.9 Parameters Configuration

2.9.1 Parameter Sets

There are three parameter sets stored to non-volatile memory in the R6000.
The device works with the current parameter sets, and only this set is effected by changes to individual parameters.

The two background parameter sets can be overwritten with the current parameter set, or loaded as the current parameter set. This allows for easy switching back and forth between two applications, and intermediate statuses can be saved during testing.

The default parameter set is stored to the firmware, and the R6000 can thus be reset to its default parameters at any time by overwriting the current parameter set.

Copying is controlled by means of the **controlled variable quantity / device control** parameter, and all parameters and configurations included in the table on page 23 are effected, except for the interface configuration.

Bit Number	Value	Significance
0 ... 7	0Fh 1Eh 1Fh 2Eh 2Fh	Load default settings to current parameter set Save current parameters to parameter set 1 Load parameter set 1 as current parameters Save current parameters to parameter set 2 Load parameter set 2 as current parameters

2.9.2 Overview of all Parameters and Configuration

PI	Parameter Designation	U/M	Format	Setting Range	Default	Comment
Temperature Parameters						
00h	Setpoint	0.1°	± 15 bit	Minimum ... maximum setpoint	0.0° C	
01h	First upper limit value	0.1°	± 15 Bit	0.0 ° = off, –MRS ... +MRS *)	0,0°	For Relative Limit Value
				0.0 ° = off, –MRS ... +MRS		For absolute LV and diff. controller
				0.0 °C / 32.0 °F = off, MRL ... MRU		For abs. LV and abs. value controller
02h	First lower limit value	0.1°	± 15 bit	Same as first upper limit value	0.0°	
03h	Proxy setpoint	0.1°	± 15 bit	Same as setpoint	0.0° C	
04h	Second upper limit value	0.1°	± 15 bit	Same as first upper limit value	0.0°	
05h	Second lower limit value	0.1°	± 15 bit	Same as first upper limit value	0.0°	
06h	Minimum setpoint	0.1°	± 15 bit	MRL ... maximum setpoint *)	0.0° C	For absolute value controller
				–MRS ... maximum setpoint		For differential controller
07h	Maximum setpoint	0.1°	± 15 bit	minimum setpoint ... MRU *)	900.0° C	For absolute value controller
				minimum setpoint ... MRS		For differential controller
0Ah	Actuation setpoint	0.1°	± 15 bit	Same as setpoint	0.0° C	See chapter 2.2.7 on page 11
0Bh	Dwell time	0.1 s	± 15 bit	0.0 ... 3000.0 s	0.0 s	
0Ch	Actual value correction	0.1°	± 15 bit	–MRS ... +MRS *)	0.0°	See chapter 2.2.11 on page 12
0Dh	Actual value factor	‰ / 0.1°	± 15 bits	10.0 ... 1800.0 ‰ / °C	100.0 %	See chapter 2.2.12 on page 12
0Eh	Setpoint ramp, up	0.1° / min.	± 15 bit	0.0 ° = off, 0.1 ° ... MRS *)	0.0	See chapter 2.2.6 on page 10
0Fh	Setpoint ramp, down	0.1° / min.	± 15 bit	0.0 ° = off, 0.1 ° ... MRS *)	0.0	
Control Parameters						
10h	Proportional zone heating	0.1°	± 15 bit	0.0 ° ... MRS *)	50.0 °	See chapter 2.4 on page 15
11h	Proportional zone cooling	0.1°	± 15 bit	0.0 ° ... MRS *)	50.0 °	
12h	Dead zone	0.1°	± 15 bit	0.0 ° ... MRS *)	0.0 °	Not for 2-step controllers
14h	System delay	0.1 s	± 15 bit	0.0 ... 3000.0 s	50.0 s	See chapter 2.4 on page 15
15h	Actuation cycle time	0.1 s	± 15 bit	0.1 ... 300.0 s	1.0 s	
16h	Actuator manipulating factor	%	± 7 bit	Min. ... max. manipulating factor	0%	
17h	Actuation manipulating factor	%	± 7 bit	Min. ... max. manipulating factor	100%	See chapter 2.2.7 on page 11
18h	Motor operating time	0.1 s	± 15 bit	1.0 ...600.0 s	60.0 s	With step-action controllers
19h	Influencing quantity manipulating factor	%	± 7 bit	Min. ... max. manipulating factor	0%	See chapter 2.2.9 on page 11
1Ch	Minimum manipulating factor	%	± 7 bit	–100 ... 0%	–100%	Not with step-action controllers
1Dh	Maximum manipulating factor	%	± 7 bit	0 ... +100%	100%	Not with step-action controllers
1Eh	Sensor error manipulating factor	%	± 7 bit	Min. ... max. manipulating factor	0%	See chapter 2.5.4 on page 19
1Fh	Switching hysteresis	0.1°	± 15 bit	0.0 ° ... MRS *)	4.0 °	For limit value monitoring and limit transducers
Control Commands						
20h	Controller function	Bit	8 bit	See chapter 6.4.2 on page 48	0 = off	
22h	Controller configuration	Bit	16 bit	See chapter 6.4.4 on page 50	1 = PDPI	
28h	Manual manipulating factor	%	± 7 bit	Min. ... max. manipulating factor	0%	In manual mode only
29h	Channel error mask	Bit	16 bit	See chapter 6.4.6 on page 51	0 = none	See chapter 2.5.7 on page 20
2Ah	Group error mask	Bit	16 bit	See chapter 6.4.7 on page 51	0 = none	See chapter 2.5.8 on page 20
Device Specification						
32h	Controlled variable quantity Device control	Bit	8 bit	°C / °F See chapter 6.5.3 on page 52	0 =° C	See chapter 2.9.1 on page 22
33h	Sensor type	–	8 bit	See chapter 6.5.3 on page 52	0 = type J	See chapter 2.1.1 on page 6
36h	Limit value configuration	Bit	8 bit	See chapter 6.5.4 on page 52	0 = none	See chapter 2.5.1 on page 18
37h	Output configuration	Bit	8 bit	See chapter 6.5.5 on page 53	8-chan. 3-step	
Heating Current Monitoring						
60h	Nominal heating current	0.1 A	± 15 bit	0.0 = off, 0.1 ... 3000.0 A	0 = off	See chapter 2.5.3 on page 19
64h	Summation current transformation ratio	0.1 A	± 15 bit	0.0 ... 1000.0 A	100.0 A	
69h	Secondary heating voltage	0.1 V	± 15 bit	0.0 = off, 10.0 ... 50.0 V	0 = off	
Interface						
A0h	Interface configuration	Bit	8 bit	See chapter 6.7.2 on page 54	2 = 19.2 kB, even	One-time only

*) MRL = measuring range lower limit, MRU = measuring range upper limit, MRS = measuring range span

3 RS 232 / RS 485-Interface with Protocol per EN 60870

3.1 General

Interface connection is described in a separate set of installation instructions (3-349-163-29).

3.1.1 Interface Configuration

The controller is equipped with a serial interface with the following configuration:

- Modes RS 232 and RS 485 (2-wire)
- Baud rates 4800, 9600 and 19,200 (adjustable via interface)
- Format 8 data bit, 1 parity bit, 1 stop bit
- Parity even, odd, space or none (adjustable via interface)

Selection of a user address (0 ... 254) for RS 485 bus operation is accomplished with a DIP switch at the front panel. User address changes do not become effective until the device has been switched off, and then back on again.

3.1.2 Communication Protocol

The data transmission protocol per EN 60870 is used for communication between the field control level and the device level.
Only a sub-group of the functions defined by this protocol is utilized by the R6000.

3.1.3 Primary Function

A master-slave protocol is used with a permanently assigned master (master computer) and up to 255 slaves (devices).
Communication takes place in the half-duplex operating mode, i.e. a device connected to the master computer only becomes active (responds):

- If it receives a valid frame addressed to itself
- If the specified maximum response delay time (t rd) has expired, allowing the master computer enough time to become ready to receive

The master computer may not become active again until:

- It receives a valid response frame from the addressed device and the specified waiting period after completion of the response frame (t rw) has expired
- The specified maximum response delay time (t rd) has expired
- The specified character delay time has expired (t cdt = pause between 2 character transmissions). This waiting time also applies for the receipt of invalid and incomplete responses!

3.1.4 Time Response

Ready to transmit/receive after power-up	t rdy	approx. 5 s
Character delay time (R6000 transmitter)	t cdt	< 3 ms
Character delay time (master)	t cdm	< 100 ms
Response delay time (R6000 transmitter)	t rd	< 10 ... 100 ms
Query waiting time after R6000 response (master)	t rw	> 10 ms

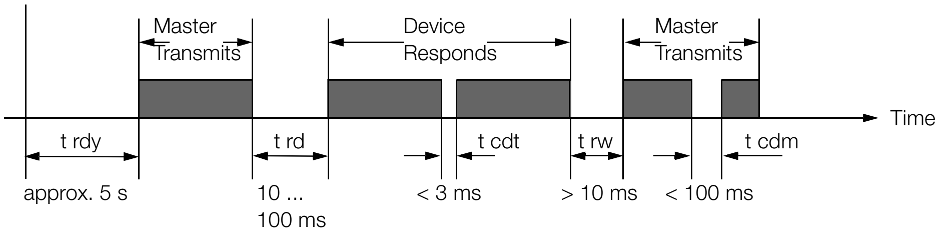


Figure 6 Basic Time Response

3.2 Frame Types and Layout

In both the query and the response direction, all frames consist of one of three string types which differ in their basic structure. Their use is required for all interface functions made available by the R6000, and they are described as follows.

3.2.1 Short Strings

Short strings are used

by the querying device:

- For the transmission of short commands to devices (e.g. “reset” etc.)
- For abbreviated querying of important data from the devices (e.g. events data etc.)

by the responding device:

- To acknowledge queries which do not require response

Basic Short String Layout

Character No.	Content	Significance		Comment
1	10h	Start message character	(SMC)	
2		Function field	(FF)	See chapter 3.2.4 on page 26
3		Device address	(DA)	DIP switch at housing front
4		Checksum	(CS)	See chapter 3.2.4 on page 26
5	16h	End message character	(EC)	

3.2.2 Control Strings

Control strings are only used by the querying device with the R6000. They are used to query all devices which cannot be queried with short strings, because they require a complete specification.

Basic Control String Layout

Character No.	Content	Significance		Comment
1	68h	Start message character	(SC1)	
2		Length	(L1)	Number of characters from function field up to but not including the checksum
3		Length (repetition)	(L2)	
4	68h	Start message character (repetition)	(SC2)	
5		Function field	(FF)	See chapter 3.2.4 on page 26
6		Device address	(DA)	DIP switch at housing front
7		Parameters index	(PI)	See chapter 3.2.4 on page 26
8		From channel	(fC)	See chapter 3.2.4 on page 26 These characters are not included in some parameters indices from main group 3.
9		To channel	(tC)	
10	00h	Recipe number	(RN)	
8 or 11		Checksum	(CS)	See chapter 3.2.4 on page 26
9 or 12	16h	End message character	(EC)	

3.2.3 Long String

Long strings are used with the R6000:

- To transmit commands and parameters to a device
- To receive data and parameters from a device

Basic Long String Layout

Character No.	Content	Significance		Comment	
1	68h	Start message character	(SC1)		
2		Length without SC1, L1, L2, SC2, CS, EC	(L1)	Number of characters from function field up to but not including the checksum	
3		Length (repetition)	(L2)		
4	68h	Start message character (repetition)	(SC2)		
5		Function field	(FF)	See chapter 3.2.4 on page 26	
6		Device address	(DA)	DIP switch at housing front	
7		Parameters index	(PI)	See chapter 3.2.4 on page 26	Not included in response cycle data and events data
8		From channel	(fC)	See chapter 3.2.4 on page 26 These characters are not included in some parameters indices from main group 3.	
9		To channel	(tC)		
10	00h	Recipe number	(RN)		
		n characters of user data		See chapter 3.2.4 on page 26	
L1 + 5		Checksum	(CS)		
L1 + 6	16h	End message character	(EC)		

3.2.4 Format Character Function and Value Range

Device Address (DA)

- 0 ... 254 Range of individual device addresses, set by means of DIP switches at the front of the housing.
- 255 This address can be used to contact all devices connected to the bus simultaneously. Data and commands transmitted to this address are accepted by all devices, and no acknowledgement is transmitted to the master.

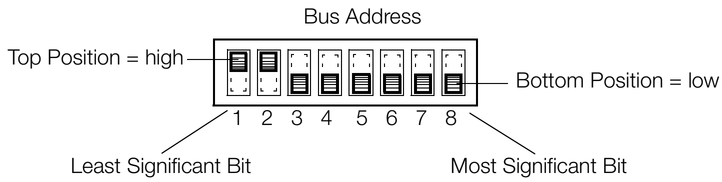


Figure 7 Example: Bus Address = 3

Length (L1, L2)

Length entries L1 = L2 make reference to the number of characters from the function field (FF) up to but not including the checksum (CS), and are used in control strings and long strings. L1 and L2 are independent of the utilization of fC, tC and RN, and the number (n) of user data characters.

Correspondingly, L1 and L2 have a

- value of 3 or six in control strings and
- a value of n + 3 or n + 6 in long strings.

Function Field (FF)

The function field includes

- actual user information in short strings – its function is predefined bit by bit, and is different in the query and response directions,
- direction and control information for transmitted user data in control strings and long strings.

Function Coding for the Function Field in the Query Direction

Query Control	Code	String	Comment
Standardize data layer link	40h	Short string	Only the indicated codes are evaluated by the R6000, invalid codes are responded to with an error acknowledgement.
Reset device	44h		
Query: “device OK?”	49h		
Request events data	7Ah		
Request cycle data	7Bh		
Transmit data to R6000	73h	Long string	
Request data from R6000	7Bh		

Function Coding for the Function Field in the Response Direction

Bit no.	Function	Value	Significance	
0 ... 3	Response	0 1 B	ACK: positive acknowledgement NACK: negative acknowledgement; message not accepted Response to: “device OK?”	Short string
		8	Transmit data	Long string
4	Job acknowledgement	0 1	Job executed, device ready Device not ready for this job, repeat job if required	
5	Service request	0 1	No error Error occurred (query events data)	
6	Direction bit	0		
7	—	0		

Parameters Index (PI)

The type of data to be transmitted is determined with the parameters index. The “PI” character is interpreted as follows:

Bits 7 ... 4	Bits 3 ... 0
0 ... Fh	0 ... Fh
Selection number for main parameters group	Selection number for special parameters

Functionally related data and setting parameters for a given device are included in the main parameters groups. Only those parameters indices which are documented in chapter 6 on page 46 can be accessed in the R6000, all others are acknowledged with an error message.

Channel and Recipe Selection (fC, tC, RN)

Due to the fact that the R6000 is a multi-channel device, the entries

“from channel” fC

“to channel” tC

are used to determine which channels will transmit the requested data. The entry fC = 0 and tC = 0 indicates that all channels will be used.

Data can be requested from various parameter sets with the recipe number (RN). The R6000 includes only one recipe (RN = 0).

Checksum (CS)

The checksum consists of a byte-by-byte summation (without overflow summation) including all characters from the function field (FF), up to but not including the checksum (CS) for all string types.

Example: short string: CS = FF + DA

Length and Structure of User Data Blocks

Length and structure are variable, and depend upon PI, fC and tC.

Transmitted values may be structured according to bytes or words. the following formats are used:

±7 bit	Representation as 2 part compliment	Number with plus or minus sign
±15 bit	LS byte first, representation as 2 part compliment	Number with plus or minus sign
8 bit	LS byte first	Bit field

3.2.5 Criteria for the Validity of a Query Frame

If criteria are fulfilled, the R6000 responds with the requested data:

- No parity error in the query frame or in the response frames of other bus users.
- For short strings:

Character	Content	Significance	Comment
1	10h	SMC	
2	 40h 44h 49h 7Ah 7Bh	FF	Valid function coding: Standardize data layer link Reset Device OK? Event Cycle
3	0 ... 255	DA	
4	(DA) + (FF)	CS	
5	16h	EC	

- For control strings and long strings:

Character	Content	Significance	Comment
1	68h	SC1	
2		L1	
3	L1	L2	
4	68h	SC2	
5	73h 7Bh	FF	Write Read
6	0 ... 255	DA	Interface address
7		PI	Valid value
...		Data	
L1 + 5th character		CS	Sum of FF up to and including data
L1 + 6th character	16h	EC	

Exceptions, no response in the event of:

- Reset short string
- DA = 255 (broadcast address)

If incorrect FF, PI or CS data are received by the master computer, the R6000 responds with a short string with negative acknowledgement NACK.

If an error occurs at the R6000 (any bit set for device error or channel error), the R6000 responds with a short string in which the service request bit is set.

3.3 Frame Contents

3.3.1 Reset Device

The addressed device performs a hardware reset (same as for brief interruption of auxiliary power).

Example: device address = 2

Command (short string):

Character No.	Content	Significance
1	10h	SMC
2	44h	FF (reset device)
3	02h	DA
4	46h	CS
5	16h	EC

Response:

None, because reset is executed

3.3.2 Query: Device OK?

The addressed device transmits the function field only.

Example: device address = 3

Command (short string):

Character No.	Content	Significance
1	10h	SMC
2	49h	FF (device OK?)
3	03h	DA
4	4Ch	CS
5	16h	EC

Response (short string):

Character No.	Content	Significance
1	10h	SMC
2	0Bh	FF (e.g. no error occurred)
3	03h	DA
4	0Eh	CS
5	16h	EC

3.3.3 Cycle Data

The most important controller measurement and evaluation data are contained in a single data packet. Cyclical queries for these values are thus possible in compact form (short string command query).

Example: device address 2

Command (short string):

Character No.	Content	Significance
1	10h	SC
2	7Bh	FF
3	02h	DA
4	7Dh	CS
5	16h	EC

Response (long string):

Character No.	Content	Significance	U/M	Format	Comment
1	69h	SC1			
2	2Ch	L1			Number of characters from character 5 ... 48
3	2Ch	L2			
4	68h	SC2			
5	08h	FF			(e.g. no error)
6	02h	DA			
7, 8			0.1 °	± 15 bit	Momentary controlled variable, channel 1
...			0.1 °	...	...
21, 22			0.1 °	± 15 bit	Momentary controlled variable, channel 8
23			%	± 7 bit	Momentary manipulated variable, channel 1
...			%	...	...
30			%	± 7 bit	Momentary manipulated variable, channel 8
31, 32			0.1 A	± 15 bit	Momentary heating current, channel 1
...			0.1 A	...	...
45, 46			0.1 A	± 15 bit	Momentary heating current, channel 8
47, 48			0.1 V	± 15 bit	Momentary heating voltage
49		CS			
50	16h	EC			

3.3.4 Events Data

Events data include all error messages and alarms generated by the device. They can be queried by means of a short string for the identification of a specific error alarm, for example if the BA bit (group error) was previously set in the function field (FF) of any given response frame.

Example: device address 5:

Command (short string):

Character No.	Content	Significance
1	10h	SC
2	7Ah	FF
3	05h	DA
4	7Fh	CS
5	16h	EC

Response (long string):

Character No.	Content	Significance	U/M	Format	Comment
1	68h	SC1			
2	1Ah	L1			Number of characters from character 5 ... 30
3	1Ah	L2			
4	68h	SC2			
5	28h	FF			(e.g. bit 6 = 1, one or several errors)
6	05h	DA			
7, 8			Bit	16 bit	Error status, channel 1
...			Bit	...	...
21. 22			Bit	16 bit	Error status, channel 8
23, 24			Bit	16 bit	Device error status
25			Bit	8 bit	Output error 1
...			Bit	...	...
30			Bit	8 bit	Output error 6
31		CS			
32	16h	EC			

Bit assignments for the error status word and the output error are described in chapter 6.4.3 on page 48.

3.3.5 Requesting Data from the R6000

All values, parameters, configurations, statuses, device IDs etc. can be queried with this type of communication.
Data are queried individually per parameters index. A complete list of all parameters indices is included in chapter 6 on page 46.

Querying a Device Specification

The parameters index is in main group 3. The characters “from / to channel” and “recipe number” are thus omitted for some parameters indices in control strings and long strings.

Example: Read device ID from device no. 33

Query (control string without fC, tC, RN):

Character No.	Content	Significance
1	68h	SC1
2	03h	L1
3	03h	L2
4	68h	SC2
5	7Bh	FF (e.g. = 7Bh: read data from R6000)
6	21h	DA (e.g. = 33)
7	30h	PI (e.g. = 30h: device ID)
8	CCh	CS
9	16h	EC

Response (long string without fC, tC, RN):

Character No.	Content	Significance
1	68h	SC1
2	04h	L1
3	04h	L2
4	68h	SC2
5	08h	FF (e.g. = 08h: no error)
6	21h	DA (e.g. = 33)
7	30h	PI (e.g. = 30h: device ID)
8	60h	Device ID = 60h = R6000
9	B9h	CS
10	16h	EC

Requesting, for Example, a Control Parameter

The parameters index is not part of main group 3, and the characters “from / to channel” and “recipe number” are thus included in control strings and long strings.

Example: Read sensor error manipulating factor from device no. 33, channel 1, value = 20%

Command (control string):

Character No.	Content	Significance
1	68h	SC1
2	06h	L1
3	06h	L2
4	68h	SC2
5	7Bh	FF (e.g. = 7Bh: read R6000)
6	21h	DA (e.g. = 33)
7	1Eh	PI (e.g. = 1Eh: sensor error manipulating factor)
8	01h	fC
9	01h	tC
10	00h	RN
11	BCh	CS
12	16h	EC

Response (long string):

Character No.	Content	Significance
1	68h	SC1
2	07h	L1
3	07h	L2
4	68h	SC2
5	08h	FF (e.g. = 08h: = no error)
6	21h	DA (e.g. = 33)
7	1Eh	PI (e.g. = 1Eh: sensor error manipulating factor)
8	01h	fC
9	01h	tC
10	00h	RN
11	14h	Information field where n = 1 character
12	5Dh	CS
13	16h	EC

3.3.6 Transmitting Data to the R6000

All parameters, configurations and operating states can be set with this type of communication. Data are queried individually per parameters index.

A complete list of all parameters indices is included in chapter 6 on page 46.

The setting range of the transmitted value is checked by the R6000. If the value is not within the allowable range, it is not saved to memory. In the event of an error, the “parameter error” bit is set, and the “service request” bit is set in the function field of the acknowledgement short string.

Complete configuration must be performed before parameters are set, because the configuration effects usage and the setting ranges of individual “temperature parameters”.

Transmitting a Device Specification

The parameters index is in main group 3. The characters “from / to channel” and “recipe number” are thus omitted for some parameters indices in control strings and long strings.

Example: Set controlled variable quantity at device no. 33 to °F

Command (long string):

Character No.	Content	Significance
1	68h	SC1
2	04h	L1
3	04h	L2
4	68h	SC2
5	73h	FF (read data from R6000)
6	21h	DA (= 33)
7	32h	PI
8	01h	Value
9	C7h	CS
10	16h	EC

Response (short string):

Character No.	Content	Significance
1	10h	SMC
2	00h	FF (no error)
3	21h	DA (= 33)
4	21h	CS
5	16h	EC

Transmitting, for Example, a Temperature Parameter

The parameters index (PI) is not part of main group 3, and the characters “from / to channel” and “recipe number” are thus included in long strings.

Example: Transmit setpoint = 25.0° to device no. 33, channel 3

Command (long string):

Character No.	Content	Significance
1	68h	SC1
2	08h	L1
3	08h	L2
4	68h	SC2
5	73h	FF (e.g. = 73h: transmit data to R6000)
6	21h	DA (e.g. = 33)
7	00h	PI (e.g. = 00h: setpoint)
8	03h	fC
9	03h	tC
10	00h	RN
11, 12	FAh, 00h	Information field where n = 2 characters, format: ± 15 bit, LSB first
13	94h	CS
14	16h	EC

Response (short string):

Character No.	Content	Significance
1	10h	SC
2	10h	FF (e.g. device not ready for job)
3	21h	DA
4	31h	CS
5	16h	EC

4 Profibus DP interface with Protocol per EN 50170

4.1 General

Interface connection is described in a separate set of installation instructions (3-349-163-29).

4.1.1 Interface Configuration

The R6000 is equipped with an RS 485 serial interface per EN 50170 (Profibus DP) for communication with a master computer, an SPC etc. Baud rates of up to 12 Mbit per second are supported.

The user address for Profibus operation is selected with the DIP switches at the front of the housing. User address changes do not become effective until the device has been switched off, and then back on again.

Address selection via the Profibus “SetSlaveAdress” function is not supported.

4.1.2 Communication Protocol

The data transmission protocol per EN 50170 is used for communication between the field control level and the device level.

4.1.3 Device Database File: GMC_059D.gsd

The file required for configuring the Profibus DP (DDBF multi-channel Profibus DP) can be downloaded free of charge from the GMC-Instruments Deutschland GmbH website (http://www.gmc-instruments.com).

4.2 Frame Formats

Basic Layout of Output Data in the Data_Exchange Send Frame (Profibus master → R6000)

Byte Number	Function	Significance
0	FF	Function field
1	PI	Parameters index
2		Security code 55 for FF = 1 and 3, otherwise 00
3		Security code AA for FF = 1 and 3, otherwise 00
4 ... 27		Data block

Basic Layout of Input Data in the Data_Exchange Response Frame (R6000 → Profibus master)

Byte Number	Function	Significance
0	FF	Function field
1	PI	Parameters index
2, 3		Group error
4 ... 27		Data block

4.2.1 The Function Field

The function field contains directional and control information for transmitted user data.

Function Coding for the Function Field (FF) in the Send Frame (Profibus master → R6000)

Bit Number	Function	Significance	
0 ... 3	Function code (FC)	**Value**	**Function**
		1	Read cyclical data / events data
		2	Read parameter with parameters index (PI)
		3	Write parameter with parameters index (PI)
		Otherwise	Idle, is responded to with empty frame (see chapter 4.2.4 on page 34)
4, 5		not used	
6	W toggle	The Profibus DP master can use this bit in combination with the corresponding acknowledgement bit in the FF of the response frame in order to monitor processing of a parameter read or write operation which has been requested by the slave. The master sets this bit to the inverse value of the momentary value of the W toggle acknowledgement bit in its request to this end, and waits until the slave indicates processing of the request by adapting the status of the acknowledgement bit in the response frame to the status of the W toggle bit in the request frame. Use of the W toggle bit function is only absolutely essential for parameter write requests because the R6000 only executes internal write operations after the status of the W toggle bit has changed!	
7		not used	

Function Coding for the Function Field (FF) in the Response Frame (R6000 → Profibus master)

Bit Number	Function	Significance	
0 ... 3	Function code (FC)	**Value**	**Function**
		1	Read cyclical data / events data
		2	Read parameter with parameters index (PI)
		3	Write parameter with parameters index (PI)
		Otherwise	Idle, is responded to with empty frame (see chapter 4.2.4 on page 34)
4	Equal	Only where FC = 1, PI = 0 and FC = 1, PI = 1 This bit indicates that the parameters in the send frame and the parameters in the R6000 are identical.	
5	Busy	This bit indicates that no further write access is momentarily possible to the parameters EEPROM.	
6	W toggle acknowledgement	The R6000 Profibus DP slave adapts the status of this bit to the status of the W toggle bit in the request frame after processing the frame.	
7	R toggle	This bit is always inverted after the R6000 has processed a Data_Exchange send frame. With the help of the R toggle bit, the master is able to determine whether or not the requested values have been updated. The master must always remember the last status of these bits to this end. If the received value is not identical to the last value, the values have been updated.	

4.2.2 Parameters Index (PI)

The type of data to be transmitted is determined with the parameters index.

Selection is made from individual cyclical data or events data for function code 1.

Value	Function
0	Cyclical temperature values and on-time
1	Cyclical current and voltage values
2	Events data

The PI character is interpreted as follows for function codes 2 and 3 (read and write parameters):

Bits 7 ... 4	Bits 3 ... 0
0 ... Fh	0 ... Fh
Selection number for main parameters group	Selection number for special parameters from the main group

Functionally related data and setting parameters are included in the main parameters groups.

Only those parameters indices which are documented in chapter 6 starting on page 46, except for the **interface configuration** (PI = A0h), can be accessed in the R6000, all others are responded to with an empty frame (see chapter 4.2.4 on page 34).

4.2.3 Data Block Length and Format

The data block is always 24 bytes long. User data length and format are variable, and are dependent upon PI or FF. One or several individual values with the following formats can be transmitted:

Format	Interpretation		
8 bit	Bit field		
± 7 bit	Number	–128 ... +127	
16 bit	Bit field		LS byte first
± 15 bit	Number	–32768 ... +32767	LS byte first

4.2.4 Empty Frames

If the R6000 receives an invalid request frame, it responds with an empty frame which basically only contains the group error:

Character No.	Function	Content
0	FF	Impermissible combination
1	PI	
2, 3		Group error
4 ... 27	Data	0

4.2.5 Group Errors

All errors from the individual channels, as well as errors which effect the device as a whole, are summed up in the group error word.

The group error is always transmitted in the response frame from the R6000, so that any errors which may have occurred can be recognized in every frame.

Bit Number	Significance
0	Broken sensor
1	Polarity reversal
2	Second upper limit value fallen short of
3	First upper limit value fallen short of
4	First lower limit value exceeded
5	Second lower limit value exceeded
6	Impermissible parameter
7	Heating current monitoring error
8	Heating circuit error
9	Adaptation error
10	Analog error
11	Overload, heating current monitoring
12	Invalid characteristics combination
13	Reference junction error
14	EEPROM error
15	Group output error

4.3 Individual Functions

4.3.1 Cycle and Events Data (function code 1)

The R6000 responds to function code 1 with cycle or events data.
These include the most important controller measurement and evaluation data, as well as any errors which may have occurred.
The parameters index is used ins this case as a sub-distributor for cycle and events data.

Parameters index (PI):

Value	Function
0	Cyclical temperature values and on-time
1	Cyclical current and voltage values
2	Events data

The most important parameters are transmitted to the R6000 simultaneously along with cycle data. These parameters (the 8 setpoints and the 8 control function entries) can be written by the user. The parameter is set to the desired value in the Data_Exchange send frame to this end.

In order to start a write operation, the W toggle bit must be set to the inverse value of the momentary W toggle acknowledgement bit of the response frame. The desired parameters are then written, if no errors occur. In the process, the W toggle acknowledgement bit is set to the value of the W toggle bit, thus indicating that the write request has been registered.

The R6000 then writes the changed values to the EEPROM. The busy bit in the function field indicates that the R6000 is incapable of executing further write cycles. As long as this bit is set, no additional write access may be requested.

Characters 2 and 3 in the security code prevent undesired parameters writing operations. If the values 55h (character 2) and AAh (character 3) are assigned to these characters, parameters can be written. All other combinations of values prevent parameters writing in the R6000.

Cyclical Temperature Values and On-Time (FC = 1, PI = 0)

Cyclical data for temperature and on-time contain the momentary actual value and the manipulated variable for each channel.

Cyclical Temperature and On-Time Data, Request Frame

Character No.	Function	Content	U/M	Format	Comment
0	FF	01h, 41h	Bit	8 bit	Function field
1	PI	0	Bit	8 bit	Parameters index for cyclical temperature data
2		55h	Bit	8 bit	Security code
3		AAh	Bit	8 bit	Security code
4, 5			0.1 °	± 15 bit	Setpoint, channel 1
...			0.1 °	± 15 bit	...
18, 19			0.1 °	± 15 bit	Setpoint, channel 8
20			Bit	8 bit	Controller function, channel 1
...			Bit	8 bit	...
27			Bit	8 bit	Controller function, channel 8

Cyclical Temperature and On-Time Data, Response Frame

Character No.	Function	Content	U/M	Format	Comment
0	FF	X1h	Bit	8 bit	Function field
1	PI	0	Bit	8 bit	Parameters index for cyclical temperature data
2, 3			Bit	16 bit	Group error
4, 5			0.1 °	± 15 bit	Current controlled variable, channel 1
...			0.1 °	± 15 bit	...
18, 19			0.1 °	± 15 bit	Current controlled variable, channel 8
20			%	± 7 bit	Current manipulated variable, channel 1
...			%	± 7 bit	...
27			%	± 7 bit	Current manipulated variable, channel 8

Cyclical Current and Voltage Values (FC = 1, PI = 1)

Cyclical current and voltage data include the actual current value from the heating current monitoring function, as well as heating voltage.

Cyclical Current and Voltage Data, Request Frame

Character No.	Function	Content	U/M	Format	Comment
0	FF	01h, 41h	Bit	8 bit	Function field
1	PI	1	Bit	8 bit	Parameters index for cyclical current data
2		55h	Bit	8 bit	Security code
3		AAh	Bit	8 bit	Security code
4, 5			0.1 A	± 15 bit	Nominal heating current, channel 1
...			0.1 A	± 15 bit	...
18, 19			0.1 A	± 15 bit	Nominal heating current, channel 8
20			Bit	8 bit	Controller function, channel 1
...			Bit	8 bit	...
27			Bit	8 bit	Controller function, channel 8

Cyclical Current and Voltage Data, Response Frame

Character No.	Function	Content	U/M	Format	Comment
0	FF	X1h	Bit	8 bit	Function field
1	PI	1	Bit	8 bit	Parameters index for cyclical current data
2, 3			Bit	16 bit	Group error
4, 5			0.1 A	± 15 bit	Momentary heating current, channel 1
...			0.1 A	± 15 bit	...
18, 19			0.1 A	± 15 bit	Momentary heating current, channel 8
20			0.1 V	± 15 bit	Momentary heating voltage
21 ... 27					not used

Events Data (FC = 1, PI = 2)

Events data include all error messages and alarms generated by the device. They can be queried in order to identify a specific error or alarm. Error messages and alarms can be simultaneously reset. This is accomplished by linking the errors and alarms to the transmitted values, so that individual errors can be selectively acknowledged.

Events Data Request Frame

Character No.	Function	Content	U/M	Format	Comment
0	FF	01h, 41h	Bit	8 bit	Function field
1	PI	2	Bit	8 bit	Parameters index for events data
2		55h	Bit	8 bit	Security code
3		AAh	Bit	8 bit	Security code
4, 5			Bit	16 bit	Error status, channel 1
...			Bit	16 bit	...
18, 19			Bit	16 bit	Error status, channel 8
20, 21			Bit	16 bit	Device error status
22			Bit	8 bit	Output error 1
...			Bit	8 bit	...
27			Bit	8 bit	Output error 6

Events Data Response Frame

Character No.	Function	Content	U/M	Format	Comment
0	FF	X1h	Bit	8 bit	Function field
1	PI	2	Bit	8 bit	Parameters index for events data
2, 3			Bit	16 bit	Group error
4, 5			Bit	16 bit	Error status, channel 1
...			Bit	16 bit	...
18, 19			Bit	16 bit	Error status, channel 8
20, 21			Bit	16 bit	Device error status
22			Bit	8 bit	Output error 1
...			Bit	8 bit	...
27			Bit	8 bit	Output error 6

Bit assignments for the error status word and the output error are described in chapter 6.4.3 on page 48.

4.3.2 Reading Parameters (function code 2)

Parameters can be read with function code 2. The desired parameters index (PI) is entered to the Data_Exchange send frame to this end. The desired parameters are then transmitted with the Data_Exchange response frame after slave response time has expired.

With the help of the R toggle bit, the master is able to determine whether or not the requested values have been updated. The master must always remember the last status of these bits to this end. If the received value is not identical to the last value, the values have been updated.

All parameters indices are supported as described in chapter 6 starting on page 46, except for the **interface configuration** (PI = A0h). The number of transmitted data depends upon the parameters index and can be determined based upon the “format” and the “number”.

Read

Request

Character No.	Function	Content	U/M	Format	Comment
0	FF	02h, 42h	Bit	8 bit	Function field
1	PI		Bit	8 bit	Parameters index
2		00	Bit	8 bit	Security code
3		00	Bit	8 bit	Security code
4 ... 27					not used

Response

Character No.	Function	Content	U/M	Format	Comment
0	FF	X2h	Bit	8 bit	Function field
1	PI		Bit	8 bit	Parameters index
2, 3			Bit	16 bit	Group error
4 ... n	Data				Requested data
n + 1 ... 27					not used

4.3.3 Writing Parameters (function code 3)

Parameters can be written with function code 3. The desired parameters group (PI) is entered to the Data_Exchange send frame to this end, and the corresponding parameters are written with the desired value.
In order to start a write operation, the W toggle bit must be set to the inverse value of the momentary W toggle acknowledgement bit of the response frame. The desired parameters are then written if no errors occur, and changed parameters are transmitted with the Data_Exchange response frame after slave response time has expired. In the process, the W toggle acknowledgement bit is set to the value of the W toggle bit, thus indicating that the write request has been registered. The R6000 then writes the changed values to the EEPROM. The busy bit in the function field indicates that the R6000 is incapable of executing further write cycles. As long as this bit is set, no additional write access may be requested.

All parameters groups are supported as described in chapter 6 starting on page 46, except for the **interface configuration** (PI = A0h). The number of transmitted data depends upon the parameters index and can be determined based upon the “format” and the “number”.

If only the parameters of certain individual channels or outputs need to be changed, parameters must nevertheless be transmitted for all channels or outputs, because writing always takes place for all parameters.

Write

Request

Character No.	Function	Content	U/M	Format	Comment
0	FF	03h, 43h	Bit	8 bit	Function field
1	PI		Bit	8 bit	Parameters index for events data
2		55h	Bit	8 bit	Security code
3		AAh	Bit	8 bit	Security code
4 ... n	Data				Data to be written
n + 1 ... 27					not used

Response

Character No.	Function	Content	U/M	Format	Comment
0	FF	X3h	Bit	8 bit	Function field
1	PI		Bit	8 bit	Parameters index for events data
2, 3			Bit	16 bit	Group error
4 ... n	Data				Written data
n + 1 ... 27					not used

5 Modbus Protocol

5.1 General

Interface connection is described in a separate set of installation instructions (3-349-163-29).

5.1.1 Interface Configuration

The controller is equipped with a serial interface with the following configuration:

- Modes RS 232 and RS 485 (2-wire)
- Baud rates 4800, 9600 and 19,200 (adjustable via interface)
- Format 8 data bits, 1 parity bit, 1 stop bit
- Parity even, odd, space or none (adjustable via interface)

5.1.2 Communication Protocol

The Modbus protocol is used for communication between the field control level and the device level.
The RTU mode and conformity class 0 (read and write words) are utilized by the R6000.

5.1.3 Primary Function

A master-slave protocol is used with a permanently assigned master (master computer) and up to 255 slaves (devices).
Communication takes place in the half-duplex operating mode, i.e. a device connected to the master computer only becomes active (i.e. responds):

- If it receives a valid frame addressed to itself
- If the specified maximum response delay time (t rd) has expired, allowing the master computer enough time to become ready to receive

The master computer may not become active again until:

- It receives a valid response frame from the addressed device and the specified waiting period after completion of the response frame (t rw) has expired
- The specified maximum response delay time (t rd) has expired
- The specified character delay time has expired (t cdt = pause between 2 character transmissions). This waiting time also applies for the receipt of invalid and incomplete responses!

5.1.4 Time Response

Ready to transmit / receive after power-up	t rdy	approx. 5 s	
Character delay time (R6000 transmitter)	t cdt	< 3.5 t ch	(2 ms at 19.2 kbd)
Character delay time (master)	t cdm	< 3.5 t ch	(2 ms at 19.2 kbd)
Response delay time (R6000 transmitter)	t rd	< 10 ... 100 ms	
Query waiting time after R6000 response (master)	t rw	> 10 ms	

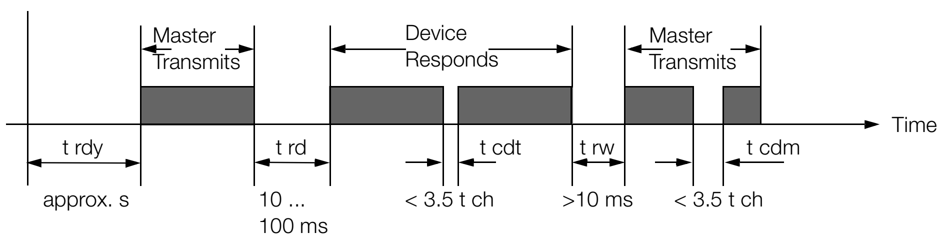


Figure 8 Basic Time Response

Character time = time for transmitting one character t ch 0.57 ms at 19.2 kbd

5.2 Frame Types and Layout

5.2.1 Basic Layout

Number of Characters	Meaning	Comment
1	Slave address (0 to 255)	DIP switch at housing front (not 0) 0 = to all (only where function code = 5, 16)
1	Function Code	See chapter 5.2.3 on page 40
n	Data	See chapter 5.2.4 on page 40 and chapter 5.2.6 on page 41
1	Error check (CRC-16) low byte	See chapter 5.2.5 on page 40
1	Error check (CRC-16) high byte	
(4)	Waiting time, no characters are transmitted	See chapter 5.2.2 on page 40

5.2.2 Waiting Time

- Waiting time is equal to the time it would take to transmit 4 characters.
- Waiting time serves to delineate the beginning and the end of the frame, because no explicit length specification is included in the frame.
- A frame is considered finished when waiting time has expired.
- If, for any reason, transmission of a frame is interrupted for a period which exceeds waiting time, the frame is considered finished. The first character after the interruption is interpreted as the first character of a new frame (both parts of the frame are rejected due to error check failures for this reason).

5.2.3 Function Code

The following function codes (FC) are supported:

Function Code	Meaning	Application
3	Read words	For reading values and parameters
5	Write single bit	Only for resetting the R6000
7	Read status	Query: “R6000 OK?”
16	Write words	For writing parameters

5.2.4 Data

Refer to chapter 5.2.6 on page 41 and chapter 5.3 on page 44 for details concerning the data field in the frame.

- Data used with Modbus are always 16 bit words.
  The high byte is transmitted first.
- Numeric values are represented as compliments of 2.
- Quantities with a ±7 bit format are expanded to ±15 bit.
- Bit fields in 8 bit format are expanded with a high byte = 0.

5.2.5 Error Check

Correct transmission of the frame is assured by means of the CRC-16 cyclical redundancy check. Both CRC-16 characters are generated as follows, based upon all of the characters included in the frame (slave address to last data byte):

1. Presetting of a 16 bit register (CRC-16 register) with FFFFh
2. Exclusive OR linking of the low bytes in the CRC-16 register to the frame’s character,
   results to CRC-16 register
3. Shift the CRC-16 register one bit to the right,
   A0 is added and the displaced, least significant bit (LSB) is saved
4. Where LSB = 0, continue as of step 5.
   Where LSB = 1, establish exclusive OR linking of the CRC-16 registers to A001h.
5. Repeat steps 3 and 4 until a total of 8 shifts to the right have occurred.
   At this point, one of the frame’s characters has been processed.
6. Execute steps 2 through 5 for each of the frame’s remaining characters.
7. The content of the CRC-16 register, preceded by the low byte, is added to the frame after all of the frame’s characters have been processed.

For example, programming in C would result in the following code:

```
/* --------------------------------------------------------------
crc_16()                      calculate the crc_16 error check field
Input parameters:    buffer:   string to calculate CRC
                     length:   bytes number of the string
Return value:                  CRC value.
-------------------------------------------------------------- */
unsigned int crc_16 (unsigned char *buffer, unsigned int length) {
   unsigned int i, j, lsb, tmp, crc = 0xFFFF;
   for ( i = 0; i < length; i++ ) {
      tmp = (unsigned char) *buffer++;
      crc ^= tmp;
      for ( j = 0; j < 8; j++ ) {
         lsb = crc & 0x0001;
         crc >>= 1;
         if ( lsb != 0 ) crc ^= 0xA001;
      }
   }
   return (crc);
}
```

5.2.6 Support Frames

Read Words (FC = 3)

Query from Master:

Character No.	Meaning
1	Slave address (1 to 255)
2	FC = 3
3	Word address (high byte)
4	Word address (low byte)
5	Number of words (high byte)
6	Number of words (low byte)
7	CRC-16 (low byte)
8	CRC-16 (high byte)

Response from Slave:

Character No.	Meaning
1	Slave address (1 to 255)
2	FC = 3
3	Number of characters (n)
4	Word data (n/2 words)
...	Respective high byte first
...	...
4 + n	CRC-16 (low byte)
5 + n	CRC-16 (high byte)

If the word address does not exist in the R6000, or if the number of words is too great, the R6000 transmits an "error response" with corresponding error code (see also chapter 5.2.7 on page 43).

Reset (FC = 5)

Query from Master:

Character No.	Meaning
1	Slave address (0 to 255)
2	FC = 5
3	Bit address (high byte) = 0
4	Bit address (low byte) = 0
5	Bit data (high byte) = 0
6	Bit data (low byte) = 0
7	CRC-16 (low byte)
8	CRC-16 (high byte)

Response from Slave:

	Not possible

Transmission of a request to all slaves is possible (slave address = 0).

The “write single bit function” is used exclusively for restarting the R6000.

If the bit address is not 0, or if it is not deleted, the R6000 transmits an “error response” with corresponding error code (see also chapter 5.2.7 on page 43).

Query: “R6000 OK?” (FC = 7)

Query from Master:

Character No.	Meaning
1	Slave address (1 to 255)
2	FC = 7
3	CRC-16 (low byte)
4	CRC-16 (high byte)

Response from Slave:

Character No.	Meaning
1	Slave address (1 to 255)
2	FC = 7
3	Status
4	CRC-16 (low byte)
5	CRC-16 (high byte)

Bit 4 is set in the status if no write tasks (FC = 16) are currently possible.

Bit 5 is set if an error has occurred (operator prompt, read error status).

Other bits are set to 0.

Write Words (FC = 16)

Request from Master:

Character No.	Meaning
1	Slave address (0 to 255)
2	FC = 16
3	Word address (high byte)
4	Word address (low byte)
5	Number of words (high byte)
6	Number of words (low byte)
7	Number of characters (n)
8	Word data (n/2 words)
...	Respective high byte first
...	...
8 + n	CRC-16 (low byte)
9 + n	CRC-16 (high byte)

Response from Slave:

Character No.	Meaning
1	Slave address (1 to 255)
2	FC = 16
3	Word address (high byte)
4	Word address (low byte)
5	Number of words (high byte)
6	Number of words (low byte)
7	CRC-16 (low byte)
8	CRC-16 (high byte)

Transmission of a request to all slaves is possible (slave address = 0), in which case no response ensues from the slaves.
If the word address does not exist in the R6000, if the number of words is too great or if the contained data is invalid, the R6000 transmits an “error response” with corresponding error code (see also chapter 5.2.7 on page 43).

5.2.7 Error Handling

If the slave address does not exist, if a parity error has occurred, if the error check fails (CRC-16 false) or if the function code is not supported, the slave does not send a response.

If the R6000 is incapable of executing the request although the frame is formally correct, it generates an error response in whose error code (character 3) the reason for non-execution is specified.
The error response is recognized by the fact that the most significant bit is set in the returned function code.

Error Response

Character No.	Meaning
1	Slave address (1 to 255)
2	FC + 80h
3	Error code
4	CRC-16 (low byte)
5	CRC-16 (high byte)

Error Code

Value	Meaning
2	Impermissible address
3	Impermissible data content
6	Currently no write tasks possible
9	Number of words is too great
10	Writing impermissible

5.3 Reading and Writing Data

5.3.1 Addressing

All R6000 setting parameters and data are assigned to parameters groups according to functional relationships. Together with cycle data (measured values) and events data (errors and alarms), the R6000 can thus be operated entirely via the bus interface.

The parameters groups are addressed via a parameters index, which is used as the high byte of the word address. A complete list of all parameters indices is included in the chapter entitled “Device Parameters” on page 46.
Several quantities are usually included in each parameters index (as a rule those assigned to each of the 8 channels). Selection is made with the low byte of the word address.

5.3.2 Writing Parameters

Example:

Adjust the actuation set temperatures to 20% for the first 3 channels of the R6000 with address 5.

Request from Master (±7 bit quantities are expanded to ±15 bit):

Character No.	Value	Meaning
1	05h	Device address = DIP switch
2	10h	Function code = write words
3	17h	Word address (high byte) = parameters index
4	00h	Word address (low byte) = 1st channel
5	00h	
6	03h	Number of words = 3
7	06h	Number of characters = 2 times 3
8	00h	
9	14h	Actuation set temperature, channel 1
10	00h	
11	14h	Actuation set temperature, channel 2
12	00h	
13	14h	Actuation set temperature, channel 3
16	D6h	
17	B8h	CRC-16

Response from Slave (if no error has occurred):

Character No.	Value	Meaning
1	05h	Device address = DIP switch
2	10h	Function code = write words
3	17h	Word address (high byte) = parameters index
4	00h	Word address (low byte) = 1st channel
5	00h	
6	03h	Number of words = 3
7	84h	
8	38h	CRC-16

5.3.3 Reading Parameters

Example:

Read in initial configuration of the R6000's four continuous outputs with address 37.

Query from Master:

Character No.	Value	Meaning
1	25h	Device address = DIP switch
2	03h	Function code = read words
3	37h	Word address (high byte) = parameters index
4	10h	Word address (low byte) = AO no. 17
5	00h	
6	04h	Number of words = 4
7	4Dh	
8	5Ch	CRC-16

Response from Slave (if no error has occurred):

Character No.	Value	Meaning
1	25h	Device address = DIP switch
2	03h	Function code = read words
3	08h	Number of characters = 2 times 4
4	00h	
5	42h	Output configuration AO no. 17 = heat channel 1 live zero
6	00h	
7	46h	Output configuration AO no. 18 = heat channel 2 live zero
8	00h	
9	4Ah	Output configuration AO no. 19 = heat channel 3 live zero
10	00h	
11	4Eh	Output configuration AO no. 20 = heat channel 4 live zero
12	61h	
13	0Eh	CRC-16

5.3.4 Cycle Data

The most important controller measurement and evaluation data are contained in a single data packet. Cyclical querying of these values is thus possible by means of continuous addressing in compact form. These values can only be read.

Address	Unit	Comment
0008h	0.1°	Current controlled variable, channel 1
...	...	...
000Fh	0.1°	Current controlled variable, channel 8
0010h	%	Current manipulated variable, channel 1
...	...	...
0017h	%	Current manipulated variable, channel 8
0018h	0.1 A	Momentary heating current, channel 1
...	...	...
001Fh	0.1 A	Momentary heating current, channel 8
0020h	0.1 V	Momentary heating voltage

6 Device Parameters

All R6000 setting parameters and data are assigned to parameters groups according to functional relationships.
Together with cycle data and events data, the R6000 can thus be operated entirely via the bus interface.

The Profibus DP interface always transmits all parameters of any given parameters index, whereas parameters can be selected from individual channels with the EN 60870 interface.

6.1 Overview

Main Group	PI	Value	Format	fC, tC, PN	Number	Comment
0		**Temperature Parameters**				
	00	Setpoint	± 15 bit	✓	8	
	01	First upper limit value	± 15 bit	✓	8	
	02	First lower limit value	± 15 bit	✓	8	
	03	Proxy setpoint	± 15 bit	✓	8	
	04	Second upper limit value	± 15 bit	✓	8	
	05	Second lower limit value	± 15 bit	✓	8	
	06	Minimum setpoint	± 15 bit	✓	8	
	07	Maximum setpoint	± 15 bit	✓	8	
	0a	Actuation setpoint	± 15 bit	✓	8	
	0b	Dwell time (during actuation)	± 15 bit	✓	8	
	0c	Actual value correction	± 15 bit	✓	8	
	0d	Actual value factor	± 15 Bit	✓	8	
	0e	Setpoint ramp, up	± 15 bit	✓	8	
	0f	Setpoint ramp, down	± 15 bit	✓	8	
1		**Control Parameters**				
	10	Proportional zone heating (Xpl)	± 15 bit	✓	8	
	11	Proportional zone cooling (Xpll)	± 15 bit	✓	8	
	12	Dead zone	± 15 bit	✓	8	
	14	System delay (Tu)	± 15 bit	✓	8	
	15	Cycle time	± 15 bit	✓	8	
	16	Actuator manipulating factor	± 7 bit	✓	8	
	17	Actuation manipulating factor	± 7 bit	✓	8	
	18	Motor actuation time	± 15 bit	✓	8	
	19	Influencing quantity manipulating factor	± 7 bit	✓	8	
	1c	Minimum manipulating factor	± 7 bit	✓	8	
	1d	Maximum manipulating factor	± 7 bit	✓	8	
	1e	Sensor error manipulating factor	± 7 bit	✓	8	
	1f	Switching hysteresis	± 15 bit	✓	8	
2		**Control Commands**				
	20	Controller function	8 bit	✓	8	
	21	Error status	16 Bit	✓	12	
	22	Controller configuration	16 bit	✓	8	
	24	Controller status, message word	16 bit	✓	9	Read only
	28	Manual manipulating factor	± 7 bit	✓	8	
	29	Channel error mask	16 bit	✓	8	
	2a	Group error mask	16 bit	✓	8	
3		**Device Specifications**				
	30	Device ID	8 bit		1	Read only
	31	Device characteristic	8 bit		1	Read only
	32	Controlled variable quantity / device control	8 bit		1	
	33	Sensor type	8 bit	✓	8	
	35	Software version	8 bit		1	Read only
	36	Limit value configuration	8 bit	✓	8	
	37	Output configuration	8 bit	✓	20	
6		**Heating Current Monitoring**				
	60	Nominal heating current	± 15 bit	✓	8	
	64	Summation current transformation ratio	± 15 bit	✓	1	
	69	Heating voltage transformer secondary voltage	± 15 bit	✓	1	
A		**Interface**				
	A0	Interface configuration	8 bit		1	
B		**Temporary Values**				
	B0	Current setpoint	± 15 bit	✓	8	Read-only

6.2 Main Group 0: Temperature Parameters

6.2.1 Table of Parameter Indices

PI	Parameter Designation	U/M	Format	Number	Setting Range	Comment
00h	Setpoint	0.1°	± 15 bit	8	Minimum ... maximum setpoint	
01h	First upper limit value	0.1°	± 15 bit	8	0° = off, –MRS ... +MRS *)	For Relative Limit Value
					0° = off, –MRS ... +MRS	For abs. LV and differential controller
					0° C / 32° F = off, MRL ... MRU	For abs. LV and abs. value controller
02h	First lower limit value	0.1°	± 15 bit	8	Same as PI = 01h	Same as PI = 01h
03h	Proxy setpoint	0.1°	± 15 bit	8	Same as PI = 00h	Same as PI = 00h
04h	Second upper limit value	0.1°	± 15 bit	8	Same as PI = 01h	Same as PI = 01h
05h	Second lower limit value	0.1°	± 15 bit	8	Same as PI = 01h	Same as PI = 01h
06h	Minimum setpoint	0.1°	± 15 bit	8	MRL ... maximum setpoint *)	For absolute value controller
					–MRS ... maximum setpoint	For differential controller
07h	Maximum setpoint	0.1°	± 15 bit	8	Minimum setpoint ... MRU *)	For absolute value controller
					Minimum setpoint ... MRS	For differential controller
0Ah	Actuation setpoint	0.1°	± 15 bit	8	Same as PI = 00h	Same as PI = 00h
0Bh	Dwell time (during actuation)	0.1 s	± 15 bit	8	0 ... 30000	
0Ch	Actual value correction	0.1°		8	–MRS ... +MRS *)	
0Dh	Actual value factor	‰ / 0.1°	± 15 bit	8	10.0 ... 1800.0 ‰ / °C	
0Eh	Setpoint ramp, up	0.1° / min.	± 15 bit	8	0 = off, 1 ... MRS *)	
0Fh	Setpoint ramp, down	0.1° / min.	± 15 bit	8	0 = off, 1 ... MRS *)	

*) MRL = measuring range lower limit, MRU = measuring range upper limit, MRS = measuring range span

6.2.2 Unit of Measure and Setting Range

Units of measure and setting ranges for temperature parameters are dependent upon:

- The configured **quantity** for the controlled variable (PI = 32h)
- The configured **sensor type** (PI = 33h)

Sensor Type		Measuring Range Lower Limit		Measuring Range Upper Limit		Polarity Reversal / Short-Circuit		Broken Sensor	
Value	Type	°C	°F	°C	°F	°C	°F	°C	°F
0	J	0	32	900	1652	–20	–4	942.3	1728.1
1	L	0	32	900	1652	–20	–4	900	1652
2	K	0	32	1300	2372	–20	–4	1366.7	2492.1
3	B	0	32	1800	3272	–20	–4	1802.3	3276.1
4	S	0	32	1750	3182	–20	–4	1768.1	3214.6
5	R	0	32	1750	3182	–20	–4	1768.1	3214.6
6	N	0	32	1300	2372	–20	–4	1300	2372
7	E	0	32	700	1292	–20	–4	715.3	1319.5
8	T	0	32	400	752	–20	–4	400	752
9	U	0	32	600	1112	–20	–4	600	1112
10	Linear 1)	0 mV		50 mV		–5 mV		60 mV	
11	Pt100	–100	–148	500	932	–120	–184	approx. 650 2)	approx. 1200 2)
12	Ni100	–50	–58	250	482	–60	–76	250	482

1) Scalable temperature, observe instructions in chapter 2.2.13 on page 13!
2) Depends upon cable resistance

Units of measure depend upon the quantity °C per minute or °F per minute where setpoint ramps are concerned.

6.3 Main Group 1: Control Parameters

6.3.1 Table of Parameter Indices

PI	Parameter Designation	U/M	Format	Number	Setting Range	Comment
10h	Proportional zone heating	0.1°	± 15 bit	8	0 ... MRS *)	
11h	Proportional zone cooling	0.1°	± 15 bit	8	0 ... MRS *)	
12h	Dead zone	0.1°	± 15 bit	8	0 ... MRS *)	
14h	System delay	0.1 s	± 15 bit	8	0 ... 30000	
15h	Cycle time	0.1 s	± 15 bit	8	1 ... 3000	
16h	Actuator manipulating factor	%	± 7 bit	8	Min. ... max. manipulating factor	
17h	Actuation manipulating factor	%	± 7 bit	8	Min. ... max. manipulating factor	
18h	Motor actuation time	0.1 s	± 15 bit	8	10 ... 6000	
19h	Influencing quantity manipulating factor	%	± 7 bit	8	Min. ... max. manipulating factor	
1Ch	Minimum manipulating factor	%	± 7 bit	8	–100 ... 0	
1Dh	Maximum manipulating factor	%	± 7 bit	8	0 ... +100	
1Eh	Sensor error manipulating factor	%	± 7 bit	8	Min. ... max. manipulating factor	
1Fh	Switching hysteresis	0.1°	± 15 bit	8	0 ... MRS *)	

*) MRS = measuring range span

6.4 Main Group 2: Control Commands

6.4.1 Table of Parameter Indices

PI	Parameter Designation	U/M	Format	Number	Setting Range	Comment
20h	Controller function	Bit	8 bit	8	See chapter 6.4.2 on page 48	
21h	Channel error status Device error status Output error	Bit	16 bit 16 bit 8 bit	8 1 6	See chapter 6.4.3 on page 48	See events data
22h	Controller configuration	Bit	16 bit	8	See chapter 6.4.4 on page 50	
24h	Controller status, message word	Bit	16 bit	9	See chapter 6.4.5 on page 50	Read only
28h	Manual manipulating factor	%	± 7 bit	8	Min. ... max. manipulating factor	In manual mode only
29h	Channel error mask	Bit	16 bit	8	See chapter 6.4.6 on page 51	
2Ah	Group error mask	Bit	16 bit	8	See chapter 6.4.7 on page 51	

6.4.2 Controller Function

PI = 20h or function selection for control via binary input

Bit Number	Significance	Comment
0	Proxy setpoint active	
1	Actuator circuit	
2	Feed-forward control	1)
3	Automatic heating current transfer	Can only be stopped via interface 1)
4	Switching controller active	1)
5	Clear error	1)
6	Controller on	
7	Start self-tuning	Can only be stopped via interface

1) Device set deletes

6.4.3 Error Status

PI = 21h   Data are assigned just like events data in accordance with EN 60870 and the Profibus DP protocol.

The entry “from channel to channel” makes reference to 16 bit words, i.e.

Channel 1 ... 8 ≙ channel error status 1 ... 8
Channel 9 ≙ device error status
Channel 10 ... 12 ≙ output error

The following errors must be acknowledged:

Heating circuit error

Adaptation error

EEPROM error

This is accomplished by setting the corresponding error bits to 0. Transferred error status words (control loop, device) are linked to error status words in the controller, bit by bit, by means of AND logic, so that individual bits can be cleared in the error status word when errors are eliminated sequentially. Errors which occur during frame transmission are not cleared.

Bit Assignments for Channel Error Status

Bit Number	Significance	Comment
0	Broken Sensor	
1	Polarity reversal	
2	Second upper limit value exceeded	1) 3)
3	First upper limit value exceeded	1) 3)
4	First lower limit value fallen short of	1) 3)
5	Second lower limit value fallen short of	1) 3)
6	Impermissible parameter	2)
7	Heating current not off with deactivated actuating signal	
8	Too little heating current with active actuating signal	
9	Heating circuit error	2) 3)
10	Error starting adaptation	2) 3)
11	Adaptation error and abort	2) 3)
12 ... 15	—	

1) Must be acknowledged in case of alarm memory
2) Must be acknowledged
3) Can be acknowledged via binary input

Bit Assignment for Device Error Status

Bit Number	Significance	Comment
0	Analog error	Error LED lights up
1	Overload, heating current 1	
2	Overload, heating current 2	
3	Overload, heating current 3	
4	Heating voltage overload	
5	Invalid characteristics combination	2) / error LED lights up
6	Reference junction error	
7	EEPROM error	2) / error LED lights up
8	Group output error	Error LED lights up
9	Mapping error	2)
9 ... 15	—	

2) Must be acknowledged

Bit Assignment Output Error 1 ... 3

Bits are set although the output is short-circuited, i.e. when the output is active but no signal is present at the terminal.

Output Error 1	
Bit Number	Output
0 ... 7	1 ... 8

Output Error 2	
Bit Number	Output
0 ... 7	9 ... 16

Output Error 3	
Bit Number	Output
0 ... 3	17 ... 20
4 ... 7	—

Bit Assignment Output Error 4 ... 6

Bits are set when the output is inactive, but a signal is present at the terminal.

Output Error 4	
Bit Number	Output
0 ... 7	1 ... 8

Output Error 5	
Bit Number	Output
0 ... 7	9 ... 16

Output Error 6	
Bit Number	Output
0 ... 3	17 ... 20
4 ... 7	—

6.4.4 Controller Configuration

PI = 22h

Bit Number	Value	Significance	Comment
0 ... 2		**Controller Type**	
	0	Channel not in use	
	1	Measuring	
	2	Actuator	
	3	Limit transducer	
	4, 5	PDPI controller	
	6	Proportional actuator	
	7	Reserved	
3 ... 5		**Controller Class**	
	0	Fixed setpoint controller	
	1	Differential controller	
	2	Master controller	
	3	Slave controller	
	4	Switching controller	
	5 ... 7	Reserved	
6 ... 8	0 ... 7	Partner channel	For differential, slave and switching controllers
9, 10		**Group**	
	0	No group	
	1 ... 3	Group number	
11	0 / 1	Actual value control off / on	
12	0 / 1	Hot-runner off / on	
13	0 / 1	Water cooling off / on	
14	0		not used
15	0 / 1	Manual instead of off off / on	

6.4.5 Controller Status, Message Word

PI = 24h

Bit Number	Value	Significance		Comment
0 ... 3	1 ... 15	Optimization phase		Controller status (channels 1 ... 8)
4, 5	0, 1, 2	Ramp active	0: no ramp 1: up 2: down	
6, 7	0, 1, 2	Actuation inactive	0: no actuation 1: actuation manipulating factor active 2: dwell time active	
8	0/1	—		
9	0/1	—		
10, 11	0	not used		
12 ... 14	0 ... 7	—		
15	0/1	—		
0 ... 7	0 / 1 ... 0 / 1	Status of the message inputs		Message word (channel 9)
8 ... 15	0	not used		

6.4.6 Channel Error Mask

PI = 29h

Bit Number	Significance
0	Broken sensor
1	Polarity reversal
2	Second upper limit value exceeded
3	First upper limit value exceeded
4	First lower limit value fallen short of
5	Second lower limit value fallen short of
6	Impermissible parameter
7	Heating current not off with deactivated actuating signal
8	Too little heating current with active actuating signal
9	Heating circuit error
10	Error starting adaptation
11	Adaptation error and abort
12 ... 15	—

6.4.7 Group Error Mask

PI = 2Ah

Bit Number	Significance
0	Broken sensor
1	Polarity reversal
2	Second upper limit value exceeded
3	First upper limit value exceeded
4	First lower limit value fallen short of
5	Second lower limit value fallen short of
6	Impermissible parameter
7	Heating current monitoring error
8	Heating circuit error
9	Adaptation error
10	Analog error
11	Overload, heating current monitoring
12	Invalid characteristics combination
13	Reference junction error
14	EEPROM error
15	Group output error

6.5 Main Group 3: Device Specification

6.5.1 Table of Parameter Indices

PI	Parameter Designation	U/M	Format	Number	Setting Range	Comment
30h	Device ID	Bit	8 bit	1	60h	Read only
31h	Device features	Bit	8 bit	1	See chapter 6.5.2 on page 52	Read only
32h	Controlled variable quantity / device control	Bit	8 bit	1	See chapter 6.5.3 on page 52	
33h	Sensor type	Bit	8 bit	8	See chapter 6.2.2 on page 47	
35h	Software version	Bit	8 bit	1	(e.g. 57h = V5.7)	Read only
36h	Limit value configuration	Bit	8 bit	8	See chapter 6.5.4 on page 52	
37h	Output configuration	Bit	8 bit	20	See chapter 6.5.5 on page 53	

6.5.2 Device Features

PI = 31h

Bit Number	Value	Significance	Comment
0		**Version**	
	0 1	Standard version OEM hardware and software version	
1, 2		**Protocol, depending upon interface**	
	0	**For CAN:** CANOpen	
	0	**For Profibus DP:** EN 50170	
	0 1	**For RS 485:** EN 60870 Modbus	
3 ... 5		**Interface**	
	0 1 2	RS 485 CAN Profibus DP	Feature F4, F3 Feature F1 Feature F2
6, 7		**A Features**	
	0 1 2	16 binary inputs / outputs 20 binary inputs / outputs 16 binary inputs / outputs, 4 continuous outputs	Feature A0 Feature A1 Feature A2

6.5.3 Controlled Variable Quantity and Device Control

PI = 32h

Bit Number	Value	Significance	Comment
0	0 1	Controlled variable quantity °C Controlled variable quantity °F	
0 ... 7	0Fh 1Eh 1Fh 2Eh 2Fh	Load default settings to current parameter set Save current parameters to parameter set 1 Load parameter set 1 to current parameters Save current parameters to parameter set 2 Load parameter set 2 to current parameters	Cannot be read back
0 ... 7	AAh	Check sensor-heater assignments	currently no function

6.5.4 Limit Value Function and Heating Circuit Monitoring

PI = 36h

Bit Number	Value	Significance
0	0 / 1	Alarm 1: setting relative/absolute to setpoint
1	0 / 1	Alarm 1: actuation suppression inactive/active
2	0 / 1	Alarm 2: setting relative/absolute to setpoint
3	0 / 1	Alarm 2: actuation suppression inactive/active
4	0 / 1	Heating circuit monitoring inactive/active
5	0 / 1	Limiter inactive / active
6	0 / 1	Alarm 1: Memory inactive / active
7	0 / 1	Alarm 2: Memory inactive / active

6.5.5 Output Configuration

PI = 37h

If all bits = 0, the output is inactive and has no function as an input.

The continuous output can only be configured for manipulated variable read-out.

Standard Output Configuration of an Output (bit 0 = 0, bit 1 = 1)

Bit Number	Value	Discontinuous Output Manipulated Variable	Discontinuous Output Alarm	Continuous Output
0	0	Output		
1	1	Standard		
2 ... 4	0 ... 7	Channel number		
5	0 / 1	Heating / cooling	– / –	Heating / cooling
6	0 / 1	More / less	Operating current / closed-circuit current	Dead / live zero
7	0 / 1	0 = manipulated variable	1 = alarm	Manipulated variable

Special Output Configuration of an Output (bit 0 = 0, bit 1 = 0)

Bit Number	Value	Discontinuous Output	Continuous Output
0	0	Output	
1	0	Special	
2 ... 6	0 ... 9	Group error selection (see page 53)	Read-out zero
	> 9	Reserved	Reserved
7	0 / 1	Operating current / closed-circuit current	Dead / live zero

Standard Output Configuration of an Input (bit 0 = 1, bit 1 = 1)

Bit Number	Value	Discontinuous Output	Continuous Output
0	1	Input	Output
1	1	Standard	
2 ... 4	0 ... 7	Channel number	Same as for configuration as output
5 ... 7	0 ... 7	Function (see page 53)	

Special Output Configuration of an Input (bit 0 = 1, bit 1 = 0)

Bit Number	Value	Discontinuous Output	Continuous Output
0	1	Input	Output
1	0	Special	
2, 3	0 ... 3	Group number	Same as for configuration as output
4 ... 7	0 ... 15	Function (see page 53)	

Group Error Selection

Value	Significance
0	Output deactivated
1 ... 8	Group error 1 ... 8
9	Adaptation in progress, or adaptation error

Function

Value	Significance	Comment
0	Proxy setpoint active	Channel control or group control
1	Actuation circuit	
2	Feed-forward control	
3	Start automatic heating current transfer	
4	Switching controller active	
5	Clear error	
6	Controller on	
7	Start self-tuning	
8	Bit 0 of the message word (controller status channel 9) is set	Message input group number = 0
...	...	
15	Bit 7 of the message word (controller status channel 9) is set	

6.6 Main Group 6: Heating Current Monitoring

6.6.1 Table of Parameter Indices

PI	Parameter Designation	U/M	Format	Number	Setting Range	Comment
60h	Nominal heating current	0.1 A	± 15 bit	8	0 = off, 1 ... 30000	
64h	Summation current transformation ratio	0.1 A	± 15 bit	1	0 ... 10000	
69h	Heating voltage transformer secondary voltage	0.1 V	± 15 bit	1	0, 100 ... 500	

6.7 Main Group A: Interface

Interface parameters can be set with this function.
Changes do not become effective until after reset has taken place.

6.7.1 Table of Parameter Indices

PI	Parameter Designation	U/M	Format	Number	Setting Range	Comment
A0h	Interface configuration	Bit	8 bit	1		

6.7.2 Interface Configuration

Bit Number	Value	Significance
0 ... 3		**Baud Rate**
	0	4800
	1	9600
	2	19.2 K
4 ... 6		**Parity**
	0	Even
	1	Odd
	2	None
	3	Space

6.8 Main Group B: Temporary Values

6.8.1 Table of Parameter Indices

PI	Parameter Designation	Unit	Format	Quantity	Setting Range	Comment
B0h	Current setpoint	0.1°	± 15 bit	1		Read-only

1 Repair and Replacement Parts Service DKD Calibration Lab and Rental Instrument Service

When you need service, please contact:

GOSSEN-METRAWATT GMBH
Service-Center
Thomas-Mann-Strasse 20
90471 Nürnberg • Germany
Phone +49 911 86 02 - 410 / 256
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e-mail service@gmc-instruments.com

This address is only valid in Germany.
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