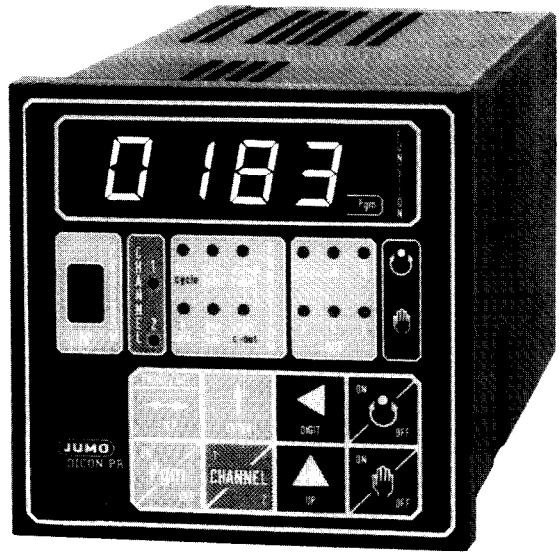
JUMO MEASUREMENT AND CONTROL®

JUMO DICON PR

Microprocessor-controlled Program controller

Housing to DIN 43 700 for flush panel mounting
Bezel 96 x 96 mm



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Operating Instructions

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IMPORTANT NOTE:

All necessary settings and, where appropriate, alterations are described in these Operating Instructions. If, however, any difficulties should arise during start-up you must not carry out any manipulation on the instrument which is not permitted. – You could endanger your rights under the instrument warranty. Please contact the nearest office or the main factory.

1 DESCRIPTION

The DICON PR is a single-channel or 2-channel program controller to DIN size 96 x 96 mm.
It operates as single or double setpoint controller, as modulating controller, or as proportional controller. Built-in signal contacts are provided to monitor limit settings.
In addition up to 6 programmable outputs (relays) are provided.
These timing switches can be used to operate interlock circuits or additional functions such as "fan on", "solenoid valve on", "feed off" etc. while the program is running.
The assignment of the programmable outputs to the channels can be freely selected.
The controller is designed for direct operation from thermocouples, resistance thermometers in 3-wire or 4-wire circuit and current or voltage signals. Self-calibration ensures that measurement errors in the input circuit are compensated, ensuring a very high class accuracy.

Programming the program controller does not require any special knowledge of programming. Programs with up to 100 program sections can be programmed and stored. 20 control parameters for each channel can be entered with the membrane keys. Interactive operation leads to a dialogue between the operator and the controller. The operator can input or request data either manually or through the serial interface, without interrupting the automatic program run.

The serial interface provides for communication with host data systems. Fully isolated signal inputs for programming/ keyboard block and fast forward on channels 1 and 2 can be provided. Starting and stopping of the two channels can be synchronised or non-synchronised. The running time of the programs are independent of each other.

Mains failure monitor, watchdog circuit, and specially secured software, in conjunction with special mechanical construction, provide a large measure of security against interference.

1.1 Type designation

On-off controllers can have 8 relay/switched transistor outputs on channels 1 and 2.
Proportional controllers or analogue outputs on channels 1 and 2 can have 6 relay or switched transistor outputs.

Basic model | Channel 1 | Channel 2

Program controller	No. of channels	Bezel 96x96 mm	Controller type	Limit comparator	Controller type	Limit comparator	Timing switches
PR	_	-96/	_	_	—	_	_	_
	Code 1 2	Code	Code	Code	Code	Code	Code
					No control 0			
					Single setpoint controller with max. contact 1			
					Single setpoint controller with min. contact 2			
					Double setpoint controller 3			No ZS 0
					Modulating controller 4			1 ZS 1
					Proportional controller 5			2 ZS 2
				No lim. c. 0				3 ZS 3
				1 limit c. 1	**Climatic controller (hum.):**			4 ZS 4
			Climatic controller (temp.):	2 limit c. 2	Double setpoint controller 6	No lim. c. 0		5 ZS 5
			Double setpoint controller 6	3 limit c. 3	Proportional controller 7	1 limit c. 1		6 ZS 6
			Proportional controller 7	PR1 only	Modulating controller 8	2 limit c. 2		
			Modulating controller 8					

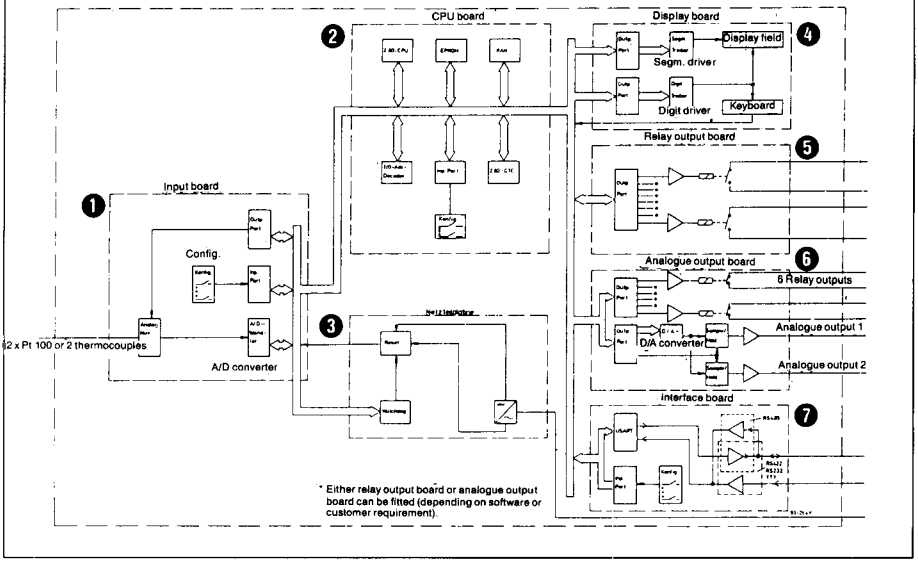
1.2 Extra Codes

Ext. inputs		Interfaces	
/	_ _	—	_ _
	Code		Code
Ext. stop Channel 1 / Ext. stop Channel 2 / Keyboard block	11	V.24 (RS232-C)	21
		TTY	22
Ext. stop Channel 1 / Ext. stop Channel 2 / Programming block	12	RS422/485	23
		V.24gt	24
Ext. stop Channel 1 + 2 / Keyboard block/ Ext. fast forward	13		
		TTYgt	25
Ext. stop Channel 1 + 2 / Programming block/ Ext. fast forward	14	RS422/485gt	26

1.3 Standard accessories

2 Mounting brackets
1 Operating Instructions

1.4 Block diagram



1.5 Operation

❶ Signal input

The input signals together with the zero potentials and reference signals pass to the multiplexer, are amplified, and digitised in the A/D converter. As the input signals and reference signals pass along the same signal path, measurement errors are compensated by the software.

❷ CPU

The CPU board carries a microprocessor, 4 timers, also three EPROMs and one CMOS-RAM. A lithium battery backs up the CMOS-RAM in case of mains failure. The battery voltage is monitored by a comparator which signals an error message on the display when the battery is discharged (Err-4).

❸ Power supply

Three voltage ranges are available on the primary side:
93–264 V a.c. 40/60 Hz, 20–47 V a.c. 40/60 Hz, 20–63 V d.c.
The reset circuit monitors the supply voltage for the microprocessor. The watchdog circuit monitors the sequential operation of the program run and initiates an error message when errors are recognised.

❹ Digital display

The 5-digit setpoint or process indication, the program number display and the 16 LEDs operate in multiplex.

❺ Relay outputs

The controller can be provided with up to 8 relay/switched transistor outputs (on proportional controllers or setpoint/process outputs up to 6 relay/switched transistor outputs).

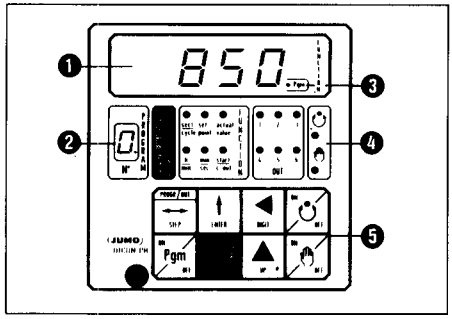
❻ Analogue outputs

The output board carries two analogue outputs protected against short-circuit on proportional controllers (setpoint/process output); they can supply accurately defined currents or voltages. These signals are assigned to the two channels by a 12-bit D/A converter.

❼ Interface

Interface modules for data lines link the program controller to other systems. Isolation between program controller and system can be provided by optocouplers (option). Three external inputs (isolated) are available for program stop, keyboard/programming block and for the external fast forward run.

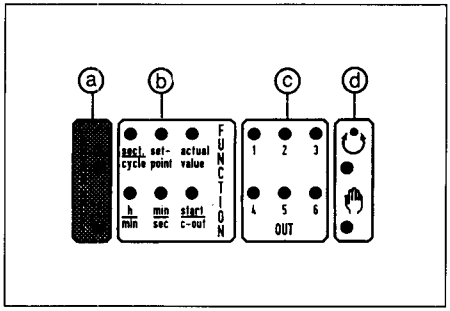
1.6 Displays and controls



❶ Interactive 5-digit 7-segment display for setpoint, process and elapsed time

❷ Program number display
0 to 9 = program 1 to 10
0. to 9. = program 11 to 20
manual operation
(display "H")
changes in the program run
(display "L")
special functions Cd01–45
(display "F")

❸ Indication for operating mode "Pgm" (programming)



❹ **Information field**

LEDs for:

ⓐ Channel display 1 or 2 (CHANNEL)

ⓑ Program section (section)
Repeats (cycle)
Setpoint
Process (actual value)
Time (h:min or min:sec)
Start delay
Controller output (c-out)

ⓒ Timing switches (OUT 1–6)*

ⓓ Automatic operation and manual operation

* Display of switching status (C-out LED alight)

- Single setpoint controller: Y ⎓ (relay energised); Y ⎓ (relay de-energised)
- Double setpoint controller: Y ⎓ (heating relay energised); Y ⎓ (cooling relay energised); Y — (both relays de-energised)
- Proportional controller: Y 0–100%

❺ **Membrane keyboard**

Ranges and transducers

Controller for use with resistance thermometers

Input

Pt 100, Pt 500
in 3-wire or 4-wire circuit

Ranges

– 200 + 850 °C
– 200.0 + 850.0°C

Line adjustment

not required with 3-wire or 4-wire circuit.
When connecting an existing 2-wire resistance thermometer it is necessary to provide line adjustment.

Signal circuit protection

a break or short-circuit in the resistance thermometer de-energises all relays, the display flashes (–) 19999.
On the proportional controller the output signal goes to minimum.

Climatic controller

the relative humidity is determined from the psychrometric difference between two Pt 100 resistance thermometers (dry and wet).
The dry probe is also used for temperature control. The air velocity must be at least 2 – 5 m/sec. The reference temperature for humidity control is compensated to the actual operating temperature.

Ranges

Channel 1:
– 200 + 850 °C, Pt 100
– 200.0 + 850.0°C

Channel 2:
0 – 100% rH relative humidity
within the range 0 + 100°C independent of reference temperature

Signal circuit protection

the wet and dry probes have failure and short-circuit protection. Under fault conditions all relays are de-energised; the display flashes (–)19999.
On the proportional controller the output signal goes to minimum.

Controller for use with thermocouples

Input

Cu-Con, Fe-Con, NiCr-Ni, Pt10Rh-Pt, Pt13Rh-Pt, Pt30Rh-Pt6Rh, MoRe5-MoRe41, to DIN, IEC or ISA specification.
Other inputs to special order.

Ranges

to DIN 43 710 Cu-Con U – 200 + 600 °C – 200.0 + 600.0°C	Fe-Con L – 200 + 900 °C – 200.0 + 900.0°C
to DIN IEC 584-1 NiCr-Ni K – 200 + 1300 °C – 200.0 + 1300.0°C	Pt10Rh-Pt S 0 + 1600°C
Pt13Rh-Pt R 0 + 1700°C	Pt30Rh-Pt6Rh B 0 + 1800°C
not standardised MoRe5-MoRe41 0 + 2000°C	

Quasi-isolation

(between signal input channel 1 and signal input channel 2).
up to ± 5 V

Signal circuit protection

on failure of the thermocouple or interruption of the probe circuit all relays are de-energised; the display flashes (–)19999.
On the proportional controller the output signal goes to minimum.

Temperature compensation

fitted as standard

Controller for use with linearised current or voltage signals

Input

0 – 1mA	Ri = 50 Ω
0 – 20 mA	Ri = 2.5 Ω
4 – 20 mA	Ri = 2.5 Ω
0 – 5 mA	Ri = 10 Ω
0 – 10 mV	Ri = 100 kΩ min.
0 – 1 V	Ri = 50 kΩ min.
0 – 10 V	Ri = 500 kΩ
0 – 20 mV	Ri = 100 kΩ min.
0 – 100 mV	Ri = 5 kΩ

Indication range

±9999 digits

Controller for use with non-linearised current or voltage signals

Input

as for linearised current or voltage signals

Ranges

as for resistance thermometers and thermocouples

Controller data

A/D converter

resolution: 15 bit

Update rate

0.5 sec on 1-channel model
1.0 sec on 2-channel model

Control accuracy/ambient temperature error

with resistance thermometer input
in 3-wire or 4-wire circuit
and resistance transmitter
with 3-wire connection
0.05% max./0.01% max. per 10°C

with thermocouple input
0.25% max. within operating range/
0.05% max. per 10°C

with current or voltage input

current
0.05% max./0.05% max. per 10°C

voltage
0.2% max./0.1% max. per 10°C
for 0 – 10 mV input

0.05% max./0.05% max. per 10°C
for 0 – 1(10) V input

These values include the linearisation tolerance.

Analogue outputs

Calibration accuracy

0.25% or better

Resolution

0.025%
output signal: 0 – 100%
in 4095 steps (12 bit)
data output: 0.5 sec on 1-channel model
1.0 sec on 2-channel model

Current

burden 500 Ω	burden 10 kΩ
0(4) – 20 mA	0 – 1 mA
or 20 – 0(4) mA*	or 1 – 0 mA*
– 20/0/ + 20 mA	– 1/0/ + 1 mA

Voltage

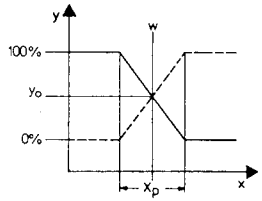
load resistance 500 Ω	load resistance 50 Ω
0 – 10 V	0 – 1 V
or 10 – 0 V*	or 1 – 0 V*
– 10/0/ + 10 V	– 1/0/ + 1 V

* Only possible with setpoint/process outputs

No isolation between channels 1 and 2 or between the probe inputs

2 TECHNICAL DATA

Output on proportional controller
The output of the proportional controller can have either a rising or a falling characteristic.



----- = rising characteristic
——— = falling characteristic
X_p = proportional band
Y_o = operating point

Definition
falling characteristic:
the output signal falls on process above setpoint
rising characteristic:
the output signal rises on process above setpoint
= standard setting

Action on supply failure
stop or continue

Program start of channels 1 and 2:
non-synchronised start
or synchronised start

Supply
93–264 V a.c., 40–60 Hz
20– 47 V a.c., 40–60 Hz or
20– 63 V d.c. (full isolation)
= standard setting

Loading
approx. 20 VA

Electrical connection
through faston connectors to DIN 46 244/A, 4.8 x 0.8 mm

External inputs
non-synchronised operation:
- ext. stop for channel 1
- ext. stop for channel 2
- keyboard/programming block

synchronised operation:
- ext. stop for channels 1+2
- ext. fast forward
- keyboard/programming block

= standard setting

Programs
up to 20 programs can be stored per channel

Program sections per program
up to 100

Memory locations
single-channel and two-channel units 1170 max.
Memory locations required per section for each:
setpoint 4
timing contact 2
repeat (cycle) 4

Program running time
1 sec – 99 h : 59 min per program section

Selection of start time
through keyboard from 1 sec to 99 h : 59 min

Program repeat
0–99 and cyclic repeat;
the repeats can apply to the complete program or to one or several program sections.

Function and data keys
8 membrane keys with pressure click for parameter input and function selection

Displays
5-digit 7-segment display
for programming, setpoint and process;
1-digit program number indication

Data back-up
lithium battery,
back-up time 3 – 5 years

Housing
polycarbonate
with plug-in controller chassis

Permitted ambient temperature
0 to 50°C

Permitted storage temperature
– 10 to + 70°C

Climatic conditions
Class KWF to DIN 40 040,
relative humidity not exceeding 75%
annual mean, no condensation

Protection
to DIN 40 050
front IP 54
rear IP 20

Operating position
unrestricted

Weight
1200 g approx.

Interfaces

no isolation	full isolation
V.24(RS232-C) TTY RS422/485	V.24gt TTYgt RS422/485gt

gt = interface with fully isolated supply,
isolation voltage: 100 V max.

Choice of transfer rate (Bd)

75	150	300	600
1200	2400	4800	**9600**

Data format

parity odd	parity even
no parity	parity bit
1 stop bit	2 stop bits
2 data bits	7 data bits

Operating modes

communication
DICON operation

= standard setting

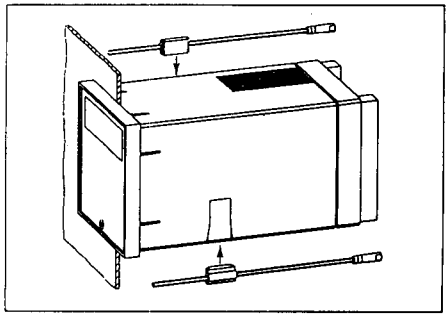
3.1 Location and climatic conditions

The instrument location should as far as possible be free from vibrations. Stray electro-magnetic fields, e.g. from motors, transformers etc., should be avoided. The ambient temperature at the instrument location should be between 0 and 50°C at a relative humidity up to 75%. Corrosive air or fumes reduce the life of the instrument.

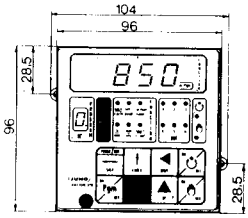
3.2 Fitting in position

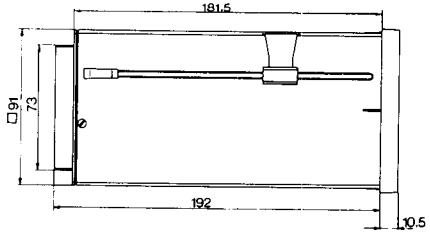
Insert the controller from the front into the panel cut-out. The dimensions of the panel cut-out are shown in the drawing below.

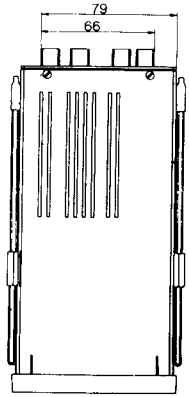
Slide the two mounting brackets into the dovetail guides at the side and tighten them evenly with a screwdriver.



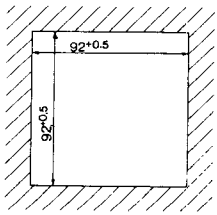
3.3 Dimensions







Panel cut-out



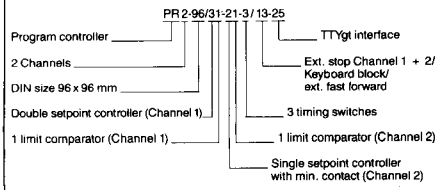
4.1 Important notes on installation

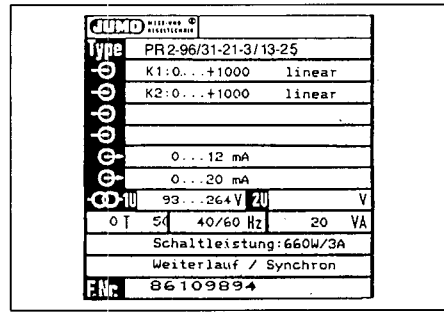
- All sensor and signal lines should where possible be run separately from the control and supply cables.
- Where several electronic units are installed it is preferable for each to have a separate supply cable including ground.
- Screened signal cables should only be grounded at the controller.
- Where possible provide physical separation between electronic units and contactor circuits.
- If there are inductive loads close to the unit, such as contactors, solenoid valves etc., it is advisable to reduce interference by fitting an RC module to the contactor coil.
- No control circuit (relays, contactors) should be connected to the supply terminals of the instrument.
- Please observe the appropriate safety regulations for overtemperature monitoring.

4.2 Identifying the model

- Identify the model according to the instrument label and type designation.
- Identify the relay designations X_{k1} to X_{k8} in accordance with the relay connection diagram (Section 4.3).
- Make the connections in accordance with the connection diagram.

Example





4.3 Connection table for the relay contacts for controllers, limit comparators and timing switches

Relay board: 8 relays

Channel 1			Channel 2			Timing switches
Controller		LK[1]	Controller		LK[1]	
		1 2 3			1 2	1 2 3 4 5 6
Xk.	1		Xk.			2 3 4 5 6 7
	1	7			—	2 3 4 5 6
	1	6 7				2 3 4 5
	1	5 6 7				2 3 4
	1		Xk.	2		3 4 5 6 7 8
	1	8		2		3 4 5 6 7
	1			2	8	3 4 5 6 7
	1	7 8	Single	2		3 4 5 6
	1		setpoint	2	7 8	3 4 5 6
	1	7	controller	2	8	3 4 5 6
	1	6 7		2	8	3 4 5
	1	6		2	7 8	3 4 5
Single setpoint controller	1	5 6		2	7 8	3 4
	1		Xk.	2 3		4 5 6 7 8
	1	8		2 3		4 5 6 7
	1			2 3	8	4 5 6 7
	1	7 8	Double	2 3		4 5 6
	1		setpoint	2 3	7 8	4 5 6
	1	7	controller	2 3	8	4 5 6
	1	6 7		2 3	8	4 5
	1	6		2 3	7 8	4 5
	1	5 6		2 3	7 8	4
Xk.	1 2		Xk.			3 4 5 6 7 8
	1 2	8			—	3 4 5 6 7
	1 2	7 8				3 4 5 6
	1 2	6 7 8				3 4 5
	1 2		Xk.	3		4 5 6 7 8
	1 2	8		3		4 5 6 7
	1 2			3	8	4 5 6 7
	1 2	7 8	Single	3		4 5 6
	1 2		setpoint	3	7 8	4 5 6
	1 2	7	controller	3	8	4 5 6
Double setpoint controller	1 2	6 7		3	8	4 5
	1 2	6		3	7 8	4 5
	1 2	5 6		3	7 8	4
	1 2		Xk.	3 4		5 6 7 8
	1 2	8		3 4		5 6 7
	1 2			3 4	8	5 6 7
	1 2	7 8	Double	3 4		5 6
	1 2		setpoint	3 4	7 8	5 6
	1 2	7	controller	3 4	8	5 6
	1 2	6 7		3 4	8	5
	1 2	6		3 4	7 8	5
	1 2	5 6		3 4	7 8	

LK[1] Limit comparators

Xk. The numbers indicated represent the relay designations Xk1 to 8

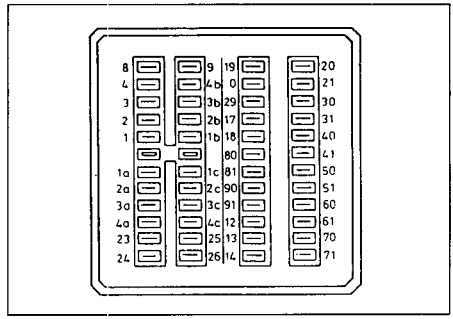
Analogue output board: 2 analogue outputs/6 relays

Channel 1			Channel 2			Timing switches
Controller		LK[1]	Controller		LK	
		1 2 3			1 2	1 2 3 4 5 6
Xk.	3					4 5 6 7 8
	3	8			—	4 5 6 7
	3	7 8				4 5 6
	3	6 7 8				4 5
	3		Xk.	4		5 6 7 8
	3	8		4		5 6 7
	3			4	8	5 6 7
	3	7 8	Single	4		5 6
	3		setpoint	4	7 8	5 6
	3	7	controller	4	8	5 6
	3	6 7		4	8	5
	3	6		4	7 8	5
Single setpoint controller	3	5 6		4	7 8	
	3		Xk.	4 5		6 7 8
	3	8		4 5		6 7
	3			4 5	8	6 7
	3	7 8	Double	4 5		6
	3		setpoint	4 5	7 8	6
	3	7	controller	4 5	8	6
	3	6 7		4 5	8	
	3	6		4 5	7 8	
	3		Xk.			4 5 6 7 8
	3	8				4 5 6 7
	3			8		4 5 6 7
	3	7 8	Proportional	4 5 6		
	3		controller	7 8		4 5 6
	3	7	(i/u2)	8		4 5 6
	3	6 7		8		4 5
	3	6		7 8		4 5
	3	5 6		7 8		4
Xk.	3 4		Xk.			5 6 7 8
	3 4	8			—	5 6 7
	3 4	7 8				5 6
	3 4	6 7 8				5
	3 4		Xk.	5		6 7 8
	3 4	8		5		6 7
	3 4			5	8	6 7
	3 4	7 8	Single	5		6
	3 4		setpoint	5	7 8	6
	3 4	7	controller	5	8	6
	3 4	6 7		5	8	
	3 4	6		5	7 8	
Double setpoint controller	3 4		Xk.	5 6		7 8
	3 4	8		5 6		7
	3 4			5 6	8	7
	3 4	7 8	Double	5 6		
	3 4		setpoint	5 6	7 8	
	3 4	7	controller	5 6	8	
	3 4		Xk.			5 6 7 8
	3 4	8				5 6 7
	3 4			8		5 6 7
	3 4	7 8	Proportional	5 6		
	3 4		controller	7 8		5 6
	3 4	7	(i/u2)	8		5 6
	3 4	6 7		8		5
	3 4	6		7 8		5
	3 4	5 6		7 8		
Xk.			Xk.			3 4 5 6 7 8
		8			—	3 4 5 6 7
		6 7 8				3 4 5
			Xk.	3		4 5 6 7 8
		8		3		4 5 6 7
				3	8	4 5 6 7
		7 8	Single	3		4 5 6
			setpoint	3	7 8	4 5 6
		7	controller	3	8	4 5 6
		6 7		3	8	4 5
		6		3	7 8	4 5
		5 6		3	7 8	4
			Xk.	3 4		5 6 7 8
Proportional controller (i/u1)		8		3 4		5 6 7
				3 4	8	5 6 7
		7 8	Double	3 4		5 6
			setpoint	3 4	7 8	5 6
		7	controller	3 4	8	5 6
		6 7		3 4	8	5
		6		3 4	7 8	5
		5 6		3 4	7 8	
			Xk.			3 4 5 6 7 8
		8				3 4 5 6 7
				8		3 4 5 6 7
		7 8	Proportional			3 4 5 6
			controller	7 8		3 4 5 6
		7	(i/u2)	8		3 4 5 6
		6 7		8		3 4 5
		6		7 8		3 4 5
		5 6		7 8		3 4

4.4 Connection diagram

Rear view with faston connectors

The electrical connection to the program controller is made with faston connectors to DIN 46 244/A, 4.8 x 0.8 mm.
The appropriate VDE regulations or local regulations have to be observed.



Connection for*		Terminals		
Analogue output	i/u 1	20 + 21 –		
Analogue output	i/u 2	30 + 31 –		
Connection for**		Terminals		
Relay output with contact protection	x_{k1}	20 (P) common 21 (S) closing	Switched transistor output i20/u5	
	x_{k2}	30 (P) common 31 (S) closing		
	x_{k3}	40 (P) common 41 (S) closing		
	x_{k4}	50 (P) common 51 (S) closing		
Relay output	x_{k5}	60 (P) common 61 (S) closing		
	x_{k6}	70 (P) common 71 (S) closing		
	x_{k7}	80 (P) common 81 (S) closing		
	x_{k8}	90 (P) common 91 (S) closing		
Supply		12 L1 line 13 N neutral 14 ⏚ ground		
Serial interface RS232-C (V.24)	RxD	23 29 GND	IN	Receiving line
	TxD	25 29 GND	OUT	Sending line
	CTS	24 29 GND	IN	Clear to send
	RTS	26 29 GND	OUT	Switch on transmitter
Serial interface RS422	RxD	23 + (A) 24 – (B) 29 GND	IN	Receiving lines
	TxD	25 + (A) 26 – (B) 29 GND	OUT	Sending lines
Serial interface RS485	RxD TxD	25 + (A) 26 – (B) 29 GND	IN / OUT	Sending/receiving pair

4 ELECTRICAL CONNECTION

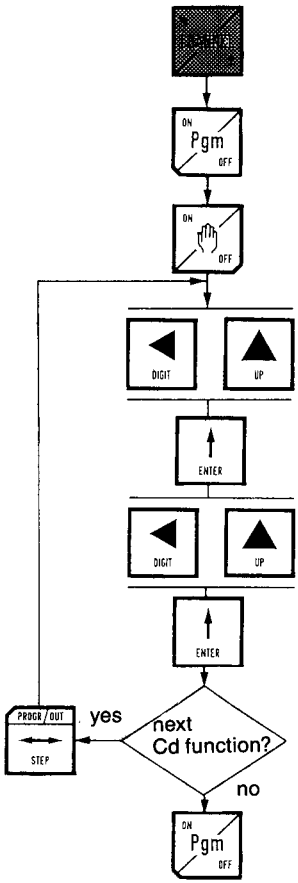
Connection for*	Terminals			
Serial interface TTY	23 24 29 GND	IN	Receiving lines	
	25 26 29 GND	OUT	Sending lines	
Channel 1 external stop (non-synchronised start) Channel 1 + 2 external stop (synchronised start)	0 17		floating contact	
Channel 2 external stop (non-synchronised start) External fast forward (synchronised start)	0 18			
External keyboard/programming block	0 19			

Input	Terminals			
	channel 1	channel 2		
Thermocouple	1 2	1a 2a	– +	
Voltage or current	1 2	1a 2a	– +	
Resistance thermometer, 2-wire circuit	1 2	1a 2a		
Resistance thermometer, 3-wire circuit	1 2 3	1a 2a 3a		
Resistance thermometer, 4-wire circuit	1 2 3 4	1a 2a 3a 4a		

* analogue output board, from X_{k3} identical with * * relay output board

5.1 Entering the controller parameters

The controller parameters are preset at the factory; see Table of parameters. If required the parameter values can be changed within the adjustment range indicated. The controller parameters are called up with the Cd functions and entered separately for channel 1 and 2.



Select channel 1 or 2,
LED 1 or 2 is alight

Call up programming,
–Pro– flashes on the display

Select controller parameter (Cd functions),
"F" appears on the program display,
Cd-00 is flashing in the display.

Select parameter (Cd function 21–45)
according to Table of parameters

Enter parameter

Input or change value

Enter value of parameter

Input terminated

The input can be terminated with "Pgm" at any time.

5.2 Table of parameters

Single-setpoint controller

Cd function	Para-meter	Name	Feedback action none	PD	PID*	PD/PID	Adjustment range	Factory setting
							0 digit without feedback	
Cd-21	Xp1	Proportional band	0 digit	x	x	x	1 – 9999 digit	0 digit
Cd-24	Tv	Derivative time	-	x	0 sec	x	0(8) – 999 sec	80 sec
Cd-25	Tn	Reset time	-	0 sec	x	x	0(32) – 9999 sec	350 sec
Cd-26	Xd1	Differential	x	-	-	-	0 – 99.9 digit	30 digit
Cd-27	Cy1	Cycle time	-	x	x	x	1 – 99 sec	20 sec
Cd-30	Y1	Max. valve stroke	-	x	x	x	0 – 100 %	100 %

Double-setpoint controller

Cd function	Para-meter	Name	Feedback action none	PD	PID*	PD/PID	Adjustment range	Factory setting
							0 digit without feedback	
Cd-21	Xp1	Proportional band (heating contact)	0 digit	x	x	x	1 – 9999 digit	0 digit
Cd-22	Xp2	Proportional band (cooling contact)	0 digit	x	x	x	1 – 9999 digit	0 digit
Cd-23	Xsh	Contact spacing (sym.)	x	x	x	x	0 – 999.9 digit	0 digit
Cd-24	Tv	Derivative time	-	x	0 sec	x	8 – 999 sec	80 sec
Cd-25	Tn	Reset time	-	0 sec	x	x	32 – 9999 sec	350 sec
Cd-26	Xd1	Differential (heating contact)	x	-	-	-	0 – 99.9 digit	30 digit
Cd-27	Cy1	Cycle time (heating contact)	-	x	x	x	1 – 99 sec	20 sec
Cd-28	Xd2	Differential (cooling contact)	x	-	-	-	0 – 99.9 digit	30 digit
Cd-29	Cy2	Cycle time (cooling contact)	-	x	x	x	1 – 99 sec	20 sec
Cd-30	Y1	Max. positive valve stroke	-	x	x	x	0 – 100 %	100 %
Cd-31	Y2	Max. negative valve stroke	-	x	x	x	– 100 – 0 %	– 100 %

Modulating controller

Cd function	Para-meter	Name	Feedback action none	PI	PID*	Adjustment range	Factory setting
						0 digit without feedback	
Cd-21	Xp1	Proportional band	0 digit	x	x	1 – 9999 digit	0 digit
Cd-23	Xsh	Contact spacing (sym.)	x	x	x	0 – 999.9 digit	0 digit
Cd-24	Tv	Derivative time	-	8 sec	0 sec	8 – 999 sec	80 sec
Cd-25	Tn	Reset time	-	x	x	32 – 9999 sec	350 sec
Cd-26	Xd1	Differential	x	-	-	0 – 99.9 digit	30 digit

Proportional controller

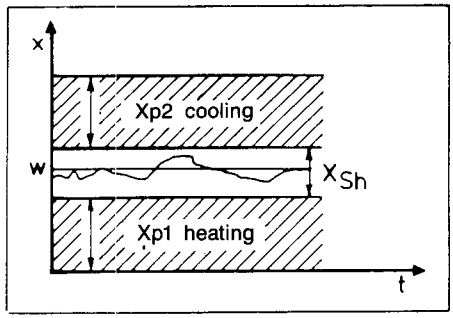
Cd function	Para-meter	Name	Feedback action P	PI	PD	PID	Adjustment range	Factory setting
Cd-21	Xp1	Proportional band	x	x	x	x	1 – 9999 digit	100 digit
Cd-24	Tv	Derivative time	0 sec	0 sec	x	x	8 – 999 sec	0 sec
Cd-25	Tn	Reset time	0 sec	x	0 sec	x	32 – 9999 sec	0 sec
Cd-30	Y1	Max. valve stroke	x	x	x	x	0 – 100 %	100 %
Cd-31	Y2	Operating point	x	-	x	-	0 – 100 %	50 %

x: adjustable

*with PID action Tv = Tn/4.5 (except proportional controller)

= factory setting without feedback

Explanation to Table of parameters



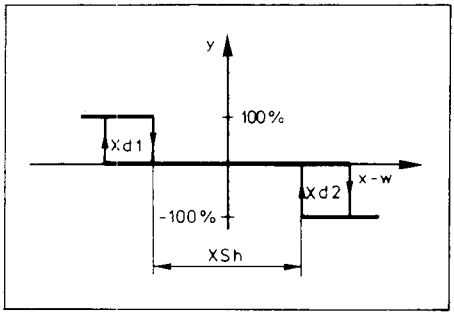
- **contact spacing Xsh**

(only with double setpoint controller and modulating controller)

With feedback switched off, PD action, or on modulating controller the contact spacing defines a dead band in which the controlled variable is not controlled. On double setpoint controllers with PID or PD/PID action the effect of integral action is to annul the contact spacing.
The controller sensitivity in the output range around 0% can, however, be reduced by increasing the contact spacing; this prevents hunting between heating and cooling.

- **switching differential Xd1, Xd2**

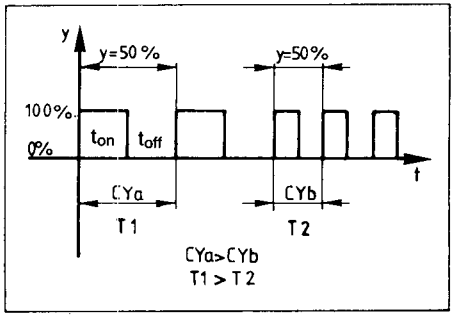
With feedback switched off the switching differential can be programmed Xd = 0 – 999 digit.



- **Switching frequency Cy1, Cy2**

If the feedback is switched on, CY determines the maximum switching frequency. Adjustment is through the cycle time from 1 to 99 sec. The on/off ratio remains unchanged.

Example: Cy = 10 sec
with y = 50% t on = 5 sec
and t off = 5 sec

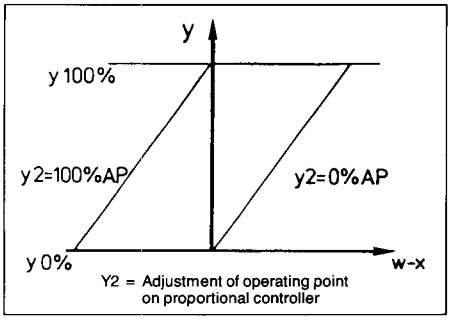


Limitation of output signal Y

Outside the proportional band the controller output signal is either 100% or 0% (– 100%). The proportional controller has an output signal which over the proportional band varies continuously between 0 and 100%.
On single and double setpoint controllers the output signal in the proportional band Xp varies between 0 and 100% and is determined by the switching ratio of the controller.

$$Y = \frac{t\,on}{t\,on + t\,off}$$

Limitation of the output signal (limitation of the output outside the proportional band to 70% for example) can provide a better start-up action. The flattening of the start-up curve is provided through the ON/OFF ratio or continuously in the case of the proportional controller. The process has to be designed so that correct control at the setpoint (within the proportional band) can be achieved at the reduced power.



Single setpoint controller: Y1 Limitation stroke

Double setpoint controller: Y1 Limitation heating
Y2 Limitation cooling

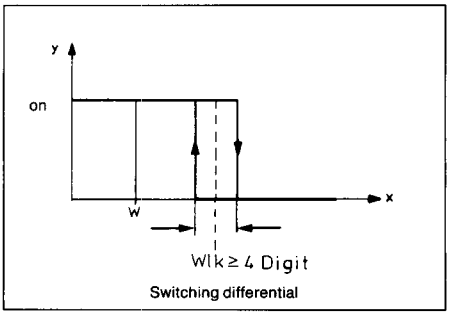
Modulating controller: ———

Proportional controller: Y1 Max. stroke
Y2 Operating point AP

5.3 Setting the limit comparators

The program controller can be provided with up to 3 limit comparators in the single-channel version, and up to 4 in the 2-channel version (2 per channel) (see label). The limit comparators are called up through the Cd functions as already described for the control parameters, and are entered within the adjustment range.

Note:
With limit comparator function 1 and 2 the setpoint Wlk must be set to at least 2 digit otherwise the function is not ensured.



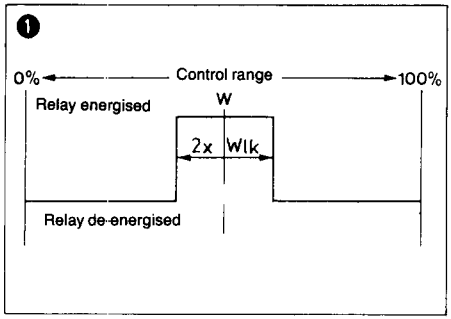
Cd function	Para-meter	Description	Adjustment range	Factory setting
Cd-34	Ik1	Setpoint for limit comparator 1 (Ik1 – Ik8)	1 – 8	1
Cd-35	W Ik1	Setpoint of limit comparator 1	± 9999 digit	0 digit
Cd-36	Ik2	Setpoint for limit comparators (Ik1 – Ik8)	1 – 8	1
Cd-37	W Ik2	Setpoint of limit comparator 2	± 9999 digit	0 digit
Cd-38	Ik3	Setpoint for limit comparators (Ik1 – Ik8)	1 – 8	1
Cd-39	W Ik3	Setpoint of limit comparator 3	± 9999 digit	0 digit

Functions

❶ Limit comparator "Ik1"

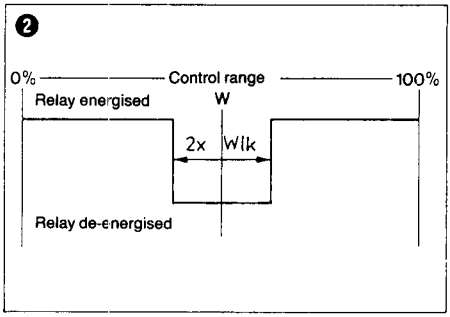
The relay is energised when the process is within the set window, and is de-energised when the process is outside the window.

Window adjustment: ±9999 digits



❷ "Ik2" as ❶

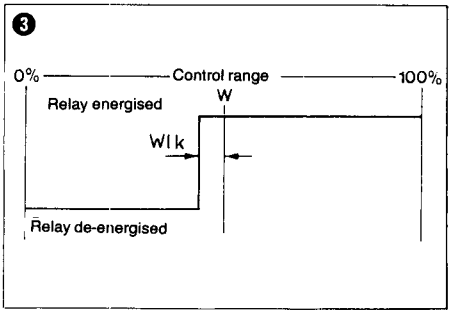
but relay action reversed



❸ Low alarm only "Ik3"

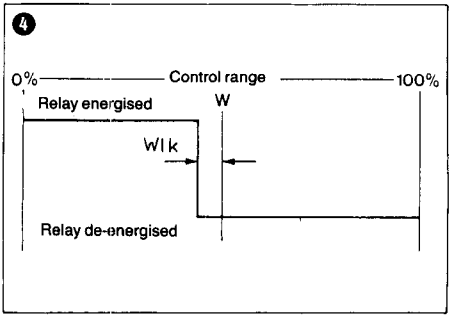
Relay is energised when process is above alarm setting

Switching point adjustable: ±9999 digits



❹ "Ik4" as ❸

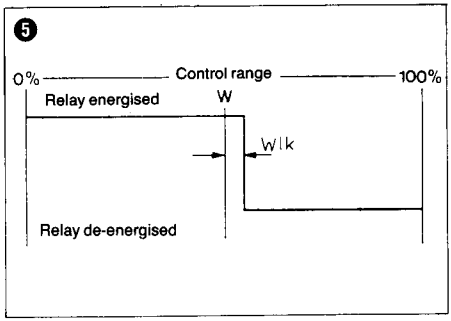
but relay action reversed



❺ High alarm only "Ik5"

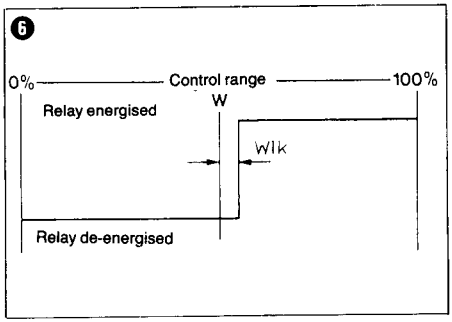
Relay is de-energised when process is above alarm setting.

Switching point adjustable: ±9999 digits



❻ "Ik6" as ❺

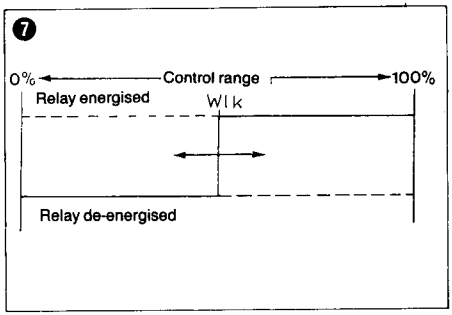
but relay action reversed



❼ "Ik7" adjustable over the entire control span

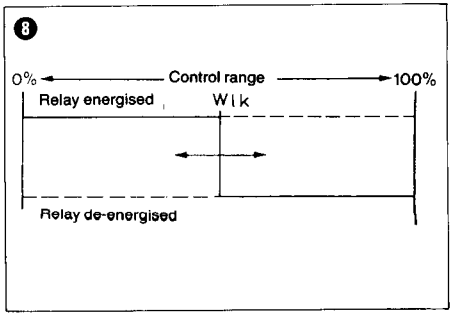
Relay is energised when process is above alarm setting.

Adjustment range: ±9999 digits



❽ "Ik8" as ❼

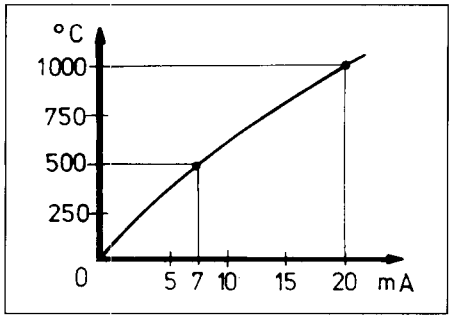
but relay action reversed



5.4 Determining the range limits

This input is required only with current or voltage input.

Example:
Input 0–20 mA
Required display range: 0+1000°C
Input: Xa = 0 and Xe = 1000
i.e. 0 mA = 0°C, 20 mA = 1000°C



Cd function	Parameter	Description	Adjustment range	Factory setting
Cd-42	Xa	Start of range	±9999 digit	Start of range
Cd-43	Xe	End of range	±9999 digit	End of range

5.5 Process correction to customer specification

A process indication which differs from the desired or actual value can be corrected through the keyboard. This is desirable, for example, to match the display of several units or to compensate for the resistance of the probe line. Two values are entered; the intermediate values are interpolated or extrapolated by the controller.
When altering X0 and X1 the desired corresponding values must be available at the probe input.

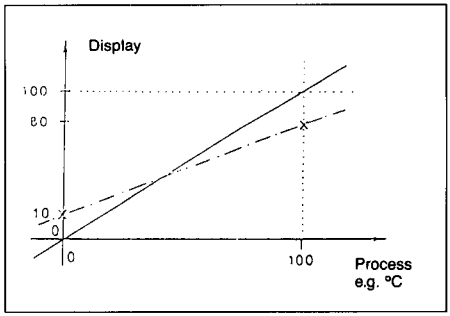
Cd-44: Start of range X0

At a temperature near the start of range the desired process indication is entered in the configuration plane.
Example: Probe temperature (process) 0°C; Display 10°C, Input: 0

Cd-45: End of range X1

Proceed similarly at the end of range:
Process 100°C; Display 80°C; Input: 100

If an input is made only for X0 the controller corrects all other values by the same amount.



– · – · – · – : Display before correction

———— : Display after correction;
the display was corrected at two points, 0°C and 100°C, to the desired displays 0 and 100.

Cd function	Parameter	Description	Adjustment range	Factory setting
Cd-44	X0	Start of range	±9999 digit	0 digit
Cd-45	X1	End of range	±9999 digit	0 digit

6.1 Programming the setpoint curve

Before programming the curve is marked in graphical and tabulated form on the program data table (see Appendix Chapter 16).

The minimum and maximum setpoint permitted for each channel are shown on the instrument label.
Setpoints which are outside the preset ranges are not accepted. The segments on the display are flashing.

The sign for the numerical value is selected with the keys "Digit" and "Up".

Please mark in the time column of the table whether the values will be given in min:sec or h:min. The subsequent data input is made in minutes and seconds or hours and minutes. It must be noted here that a maximum of 59 sec or 59 min can be programmed. This means, for example, an entry of 2'10 for a section time of 130 sec.

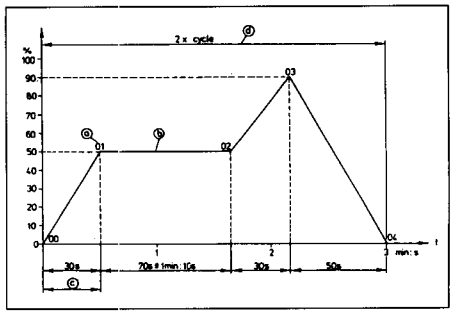
Each program section is defined by:

ⓐ the section number starting with 00

ⓑ the setpoint

ⓒ the section time (h:min/min:sec)

ⓓ possible repeats (cycles)

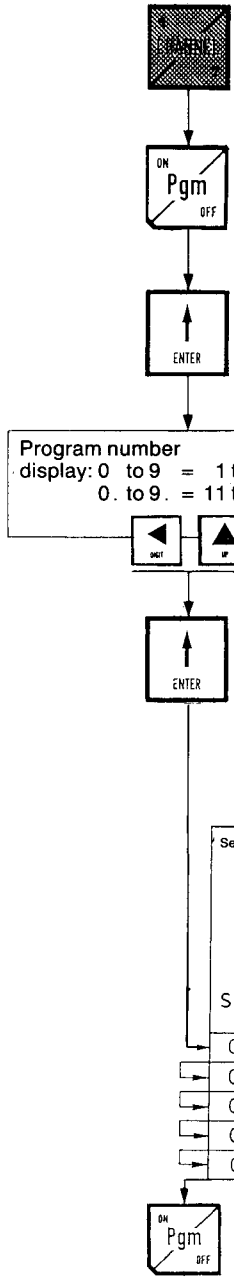


6.2 Data check and data correction of setpoint curve

The data check is performed in the same way as the programming of the setpoint curve. If required the values for setpoint, times, repeats can simply be overwritten.

Notes:

- The input can be aborted at any time with the "Pgm" key.
- When the memory location is full the message "S-END" appears on the display.



Select channel,
(only on 2-channel model)
LED 1 or 2 is alight

Call up programming,
-Pro- flashes on the display

Enter programming,
display -YES- = program present
display -NO- = no program present
program display flashes

Select program number,
◀ select digit
▲ increase digit

Enter program number

Section		Setpoint		Section time			Repeat cycles		
	ENTER	DIGIT UP	ENTER	DIGIT UP ZONE/INT SELF		ENTER	DIGIT UP 00␣00		ENTER
Sc				00'00 h'min	00'00 min's		from which section	how often*	
00		0		'	'30				
01		50		'	1'10				
02		50		'	'30				
03		90		'	'50		00	2	
04		0		'	'00				

* CC = cyclic repeat

Terminate programming

6.3 Programming the timing switches

Before programming the ON and OFF periods are marked on the program data table (see Appendix Chapter 16).

Entries for time

Mark in the column ON/OFF period whether the values will be in min:sec or h:min.
The input is made in minutes and seconds or hours and minutes. It must be noted here that a maximum of 59 sec or 59 min can be programmed. This means, for example, that an OFF period of 130 sec is entered as 2'10.

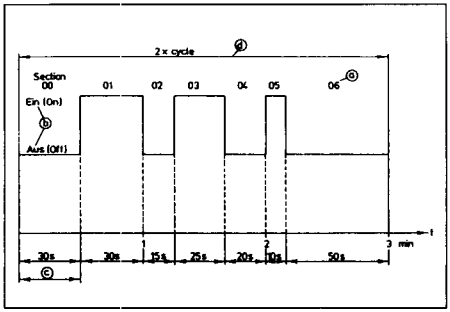
Each program section is defined by:

ⓐ the section number starting with 00

ⓑ the contact status (OFF/ON)

ⓒ the section time (h:min/min:sec)

ⓓ possible repeats (cycles)

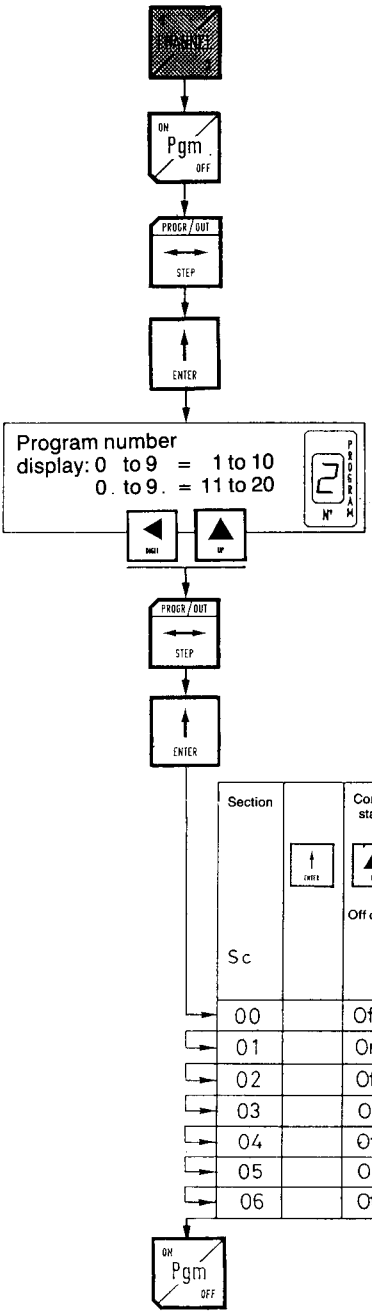


6.4 Data check and data correction of timing switches

The data check is performed in the same way as the programming of the timing switches. If required the contact states, times, repeats can simply be overwritten.

Notes:

- The section times of the timing switches may differ from the times of the corresponding setpoint program.
- The input can be aborted at any time with the "Pgm" key.
- **A timing switch program can only operate if a setpoint program has already been stored under the same program number.**


Select channel,
(only on 2-channel model)
LED 1 or 2 is alight
Call up programming,
-Pro- flashes on the display
Select timing switch
(display -Out-)
Enter programming,
display -YES- = program present
display -NO- = no program present
program display flashes
Program number
display: 0 to 9 = 1 to 10
0. to 9. = 11 to 20
Select program number,
◀ select digit
▲ increase digit
Select timing switch Out 1–6,
the corresponding LED flashes
Enter program number and timing switch number
Section
Sc
Contact status
Off or On
Section time
00 00 h'min
00 00 min's
Repeat cycles
00 00
from which section
how often*
00 Off '30
01 On '30
02 Off '15
03 On '25
04 Off '20
05 On '10
06 Off '50 00 2
Terminate programming
* CC = cyclic repeat

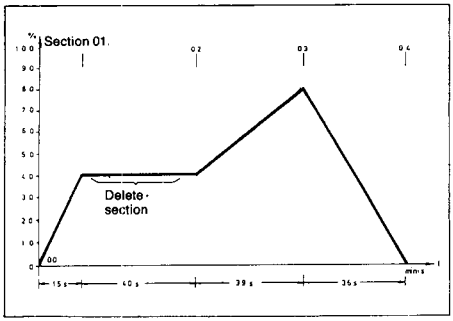
7 DELETING/INSERTING SECTIONS

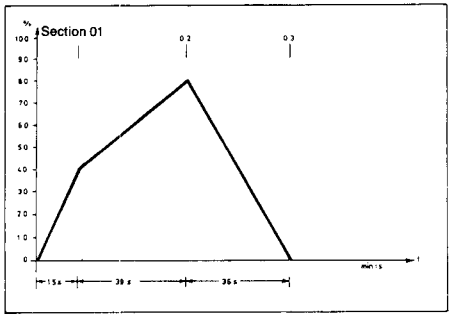
Sections can be inserted or deleted at any time.

7.1 Deleting program sections

In this example the program section 01 is to be deleted.

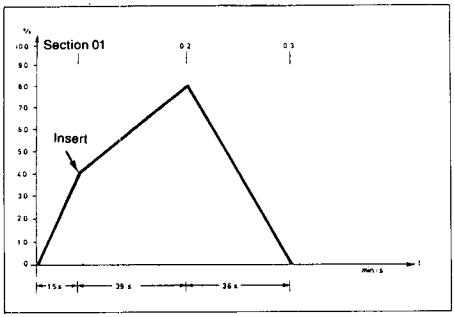
The new program curve shows that the program has been reduced by one program section. The program in the subsequent sections has not been changed. The program controller automatically updates all section numbers, i.e. it renumbers the sections so that they are then numbered consecutively.





7.2 Inserting program sections

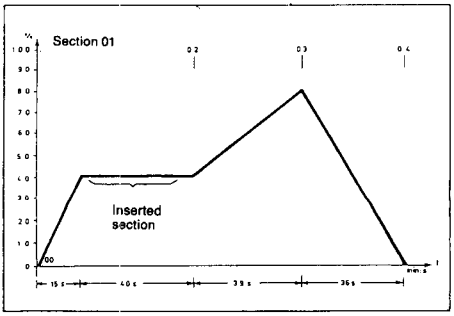
Similarly in this example the program has been extended by one section. The program in the subsequent sections has not been changed. The program controller updates all section numbers so that they form a continuous sequence.



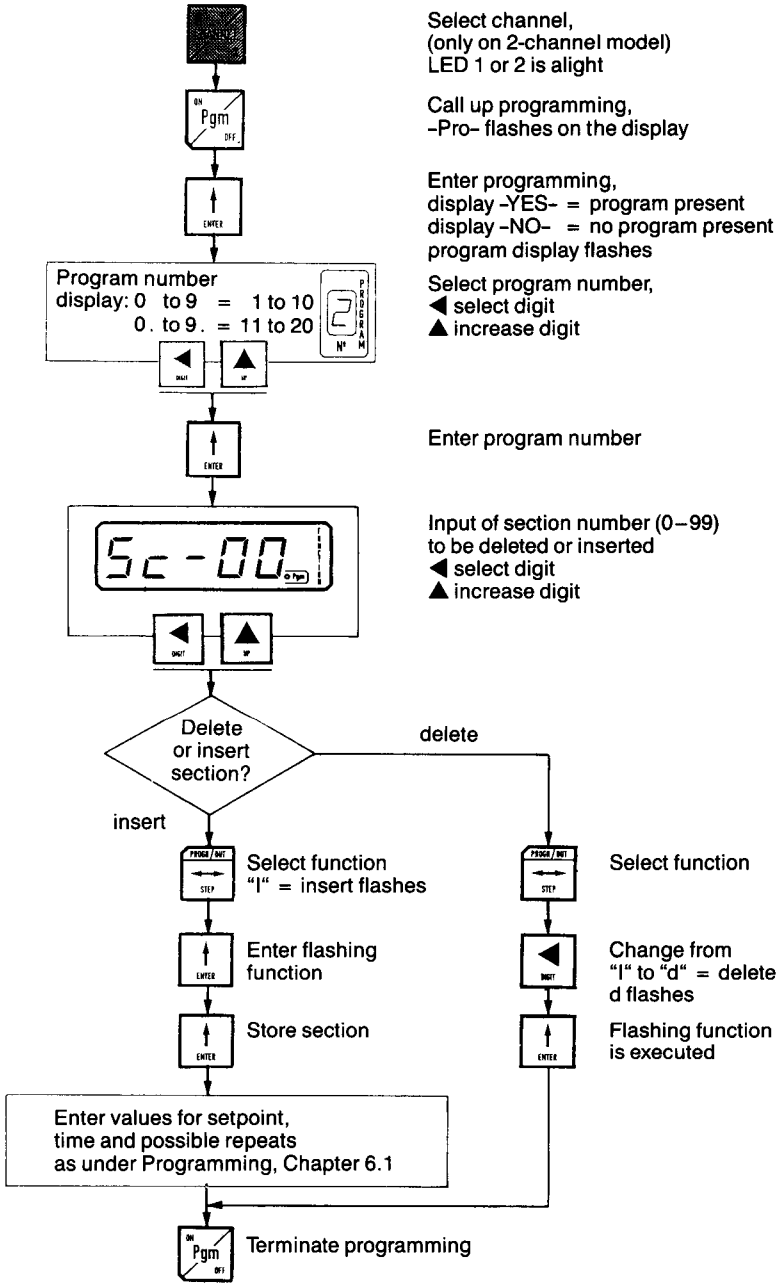
Note:

- Deleting/inserting can be aborted at any time with the "Pgm" key.

During insertion the data of the new program section are automatically set to zero. The data for this program section (setpoint, time and repeats) are input as described under "Programming" and entered with the "ENTER" key.



7 DELETING/INSERTING SECTIONS



A synchronised or non-synchronised start is possible with the 2-channel model depending on the factory setting (see instrument label).

8.1 Synchronised start

On starting the instrument a program with the same program number is run on both channels.
The synchronised start can be operated from either channel, i.e. starting program 6 on channel 2 also starts program 6 on channel 1 and vice versa.
If the two programs operate the same timing relays, channel 1 has preference. The total running time is determined by the longer program.

8.2 Non-synchronised start

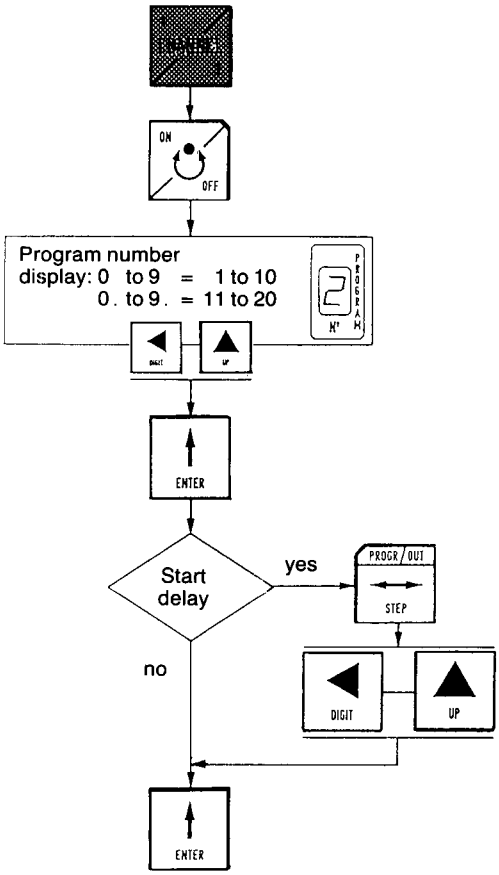
In this operating mode it is possible to start on each of the two channels a program with any program number at different times.

8.3 Displays during automatic operation

The following parameters can be called up during automatic operation with the key 

- the actual value
- the controller output
- the setpoint
- the section number
- the residual section running time

8.4 Program start



Select channel,
(only on 2-channel model and non-synchronised start, see Chapter 8.2)
LED 1 or 2 is alight

Call up automatic operation
display -YES- = program present
display -NO- = no program present
program display flashes

Select program number,
◀ select digit
▲ increase digit

Enter program number

Select time base
(h:min/min:sec)

Input start delay
◀ select digit
▲ increase digit

Program starts immediately
or after the selected time
has elapsed

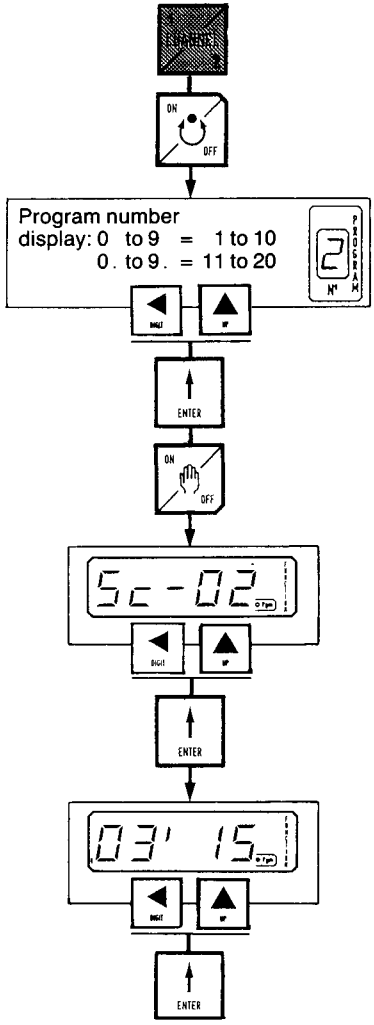
Program abort

The instrument returns to the base setting

Program stop

The time base is stopped.
Input of fixed values possible,
see manual operation

8.5 Program start at any point (fast forward run)



Select channel,
(only on 2-channel model and non-synchronised start)
LED 1 or 2 flashes

Call up automatic operation
display -YES- = program present
display -NO- = no program present
program display flashes

Select program number
◀ select digit
▲ increase digit

Enter program number

Select section

Select section of program start
◀ select digit
▲ increase digit

Enter section

Input residual running time of section selected

◀ select digit
▲ increase digit

Enter residual running time,
program starts immediately (depending on the program the message "busy" may appear on the display for a few seconds)

This page is left blank because of the layout of the next chapter!

A program run can be changed in three different ways:

- by overwriting the program (see Chapter 6). This change is stored in the program memory. However the changed values will only be incorporated with the next automatic program start.

Manual operation in the program run

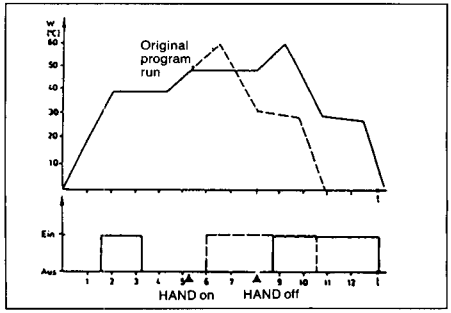
- by stopping the program at any time with the "HAND" key and changing setpoints and relay switching states. These changes are not retained in the memory. The program is continued at the current position.

Changing the active program

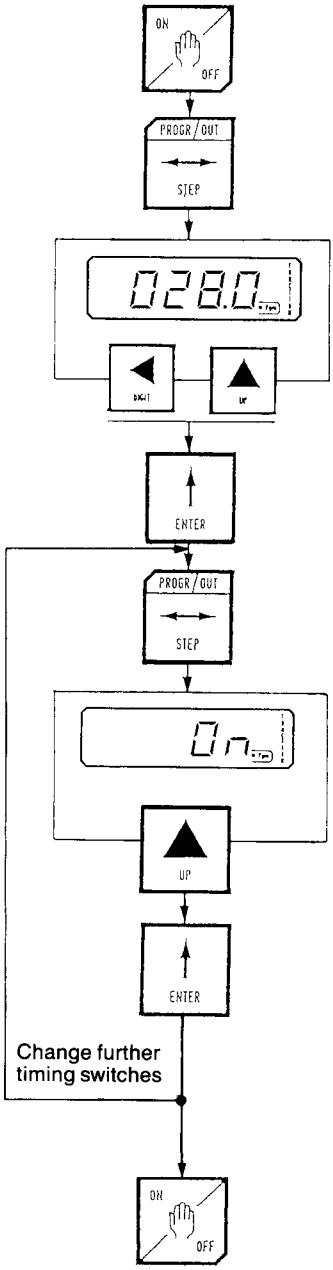
- by stopping the program with the manual key and changing the active program by operating the "Pgm" key.
  These program changes are only stored in the working memory for the current program run and are no longer effective after a supply failure or after the program end. The "L" in the program display identifies the temporary program change.

9.1 Manual operation in the program run

The program is stopped at any point. The instrument controls at the current setpoint and retains the relay states of the timing switches. Setpoints and timing switches can be changed in this operating status.
These values are retained until the "HAND" key is operated again and the instrument returns to the automatic program.
The remaining program is then run with a time displacement.
The changes are not stored so that the original values are called up again when the program is re-started.



9 CHANGES IN THE ACTIVE PROGRAM



Stop the automatic program run

Change to setpoint

Change numerical values if required

◀ select digit

▲ increase digit

Enter value

Select timing switch
(OUT 1–6)

Switching timing switch on/off,
("On" = relay energised,
"OFF" = relay de-energised),
the corresponding OUT LED flashes

Enter settings

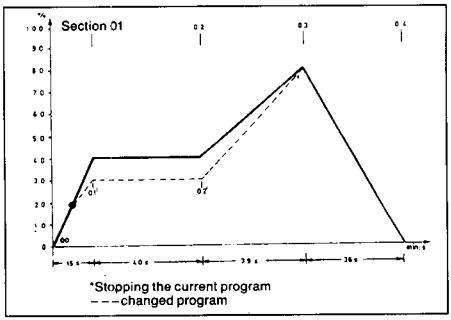
Return to automatic program run

9.2 Changing the active program (changing the setpoint/timing switch program)

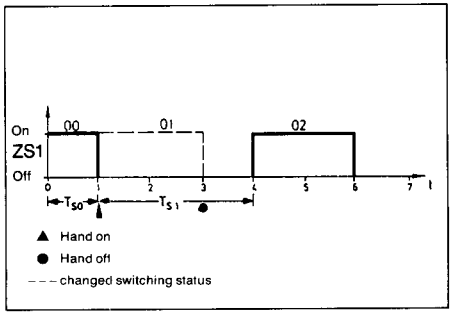
The program is stopped at any point.
The instrument controls at the current setpoint and retains the current relay states of the timing switches.

The setpoint program or timing switch program can now be changed in accordance with the flow diagram.

In the example alongside the changes in sections 01 and 02 are limited to the setpoints. The section times are retained but these can also be changed. The changed sections are 01' and 02'.



In the diagram alongside the switching status of ZS1 has been changed in section 01. The time of section 01 has also been changed.



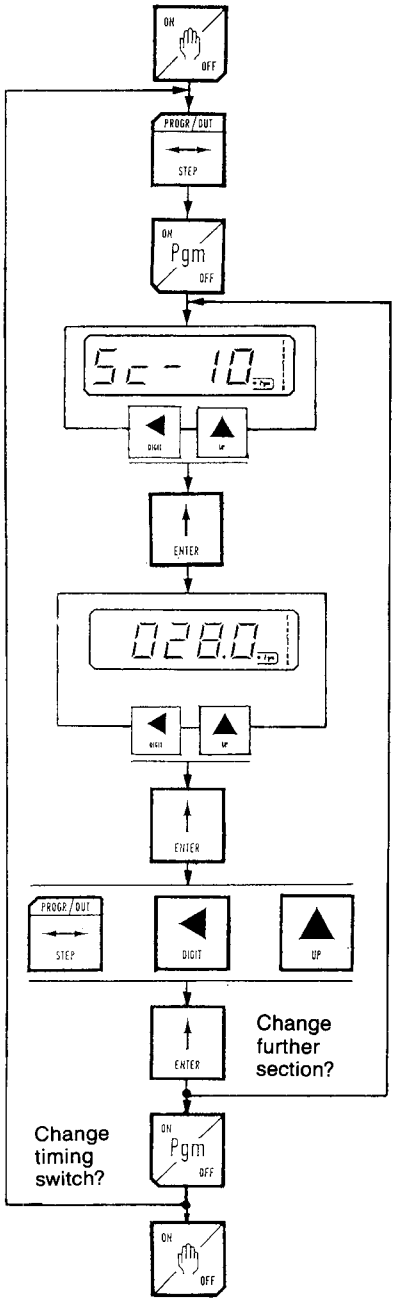
When the operator returns to the automatic program the instrument continues to run with the changed program.

Important: After a mains failure the changed data are no longer effective.

The changes affect only the current program run; when the program is started again the original program is operated.

Note:
It is only possible to change those sections which have already been programmed.

9 CHANGES IN THE ACTIVE PROGRAM



Stop the automatic program run

Changeover between setpoint program and timing switch program
Relay status (OUT 1–6)

Initiate change,
"L" appears on the program display,
the LED "Pgm" is alight

Input the section to be changed
◀ select digit

▲ increase digit

Enter the section

Select the desired setpoint or change the relay status
OFF = contact open
On = contact closed
(the OUT LED of the corresponding relay flashes) – change the contact only with the "Up" key

Enter value

Select time base
(h:min; min:sec),
enter the section running time for the current section

Enter the new value

Terminate programming

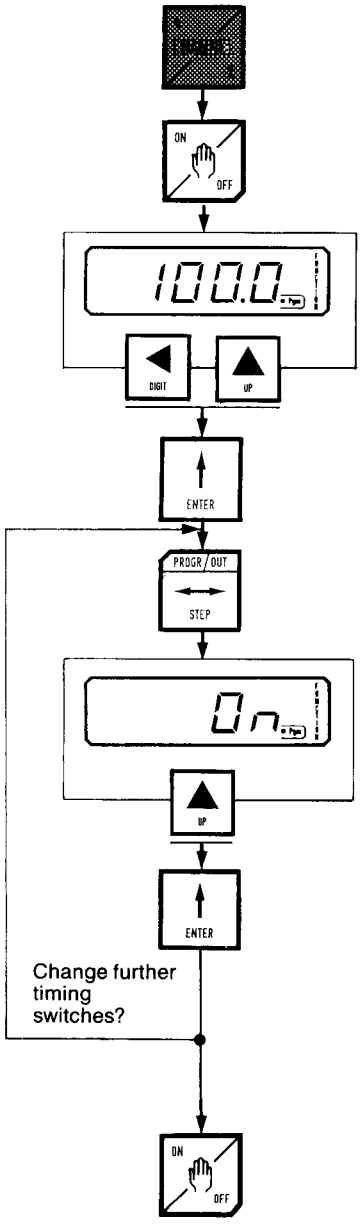
Return to automatic operation
(program runs with the changed values)

10 MANUAL OPERATION

During manual operation the setpoints and timing switch states can be set manually. If both channels are in the base setting, manual operation is selected with the "HAND" key. The program number display shows "H". The display then shows the value programmed in Cd-11 for the channel selected.

With the "STEP" key the displays can be changed cyclically to setpoint, OUT1–OUT6; the function LED of the relay selected is flashing. During the setpoint display the desired setpoint is set with the "UP" and "DIGIT" keys and entered with "ENTER".

During the display of the selected relay OUT1–OUT6 the switching status ("On", "OFF") is changed with the "UP" key (display flashes) and entered with "ENTER". Pressing the "HAND" key returns the instrument to the base setting. The data entered during manual operation are deleted.



Select channel 1 or 2,
(only on 2-channel model)
LED 1 or 2 is alight

Initiate manual operation,
"H" appears in the program number display.

Set fixed setpoint
◀ select digit
▲ increase digit

Enter setpoint

Select timing switch
(OUT1–6)

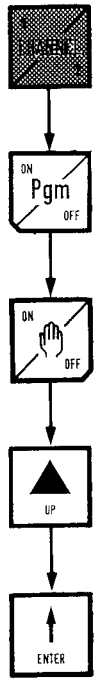
Change relay status,
OFF = contact open
On = contact closed
the corresponding function LED flashes

Enter setting

Terminate manual operation

11.1 Selecting the special functions

A total of six special functions (Cd functions) can be selected and executed. The programming can be aborted at any time with the "Pgm" key.



Select channel
(only on 2-channel model)
LED 1 or 2 is alight

Select programming,
-Pro- flashes in the display

Select special function,
the display shows "Cd-00",
"F" appears in program number display

Select special function Cd-01 to Cd-06
according to the Table

Enter special function

Cd-01	Erasing all programs	the display shows CLEAR confirm deletion with "ENTER"
Cd-02	Erasing one program	the display shows C . Pr-0 input the desired program number, confirm with "ENTER"
Cd-03	Displaying start of range	confirm with "ENTER"
Cd-04	Displaying end of range	confirm with "ENTER"
Cd-05	Displaying type of probe	00 = linear characteristic – 9999 to + 9999°C 01 = Pt100; Pt500 – 200 to + 850°C 02 = Pt10Rh-Pt S 0 to + 1600°C 03 = NiCr-Ni K – 200 to + 1300°C 04 = Fe-Con L – 200 to + 900°C 05 = Pt13Rh-Pt R 0 to + 1700°C 06 = Pt30Rh-Pt6Rh B 0 to + 1800°C 07 = Cu-Con U – 200 to + 600°C 08 = MoRe5-MoRe41 0 to + 2000°C 09 = table to user specification 10 = table to user specification confirm with "ENTER"
Cd-06	Displaying decimal places	the display shows the number of digits after the decimal point, confirm with "ENTER"

12 ERROR MESSAGES

Any errors which occur during operation are recognised by the instrument and are shown on the display by the message "Err-.". The display is held until the error has been rectified and acknowledged by pressing the "ENTER" key.

Error message	Possible error	Remedy
-Err-1 -Err-2 -Err-8	Error in analogue or timing switch program (e.g. RAM faulty or data corrupted by external fault)	Erase the program with special function Cd-01, Cd-02 and input it again. If the fault cannot be rectified in this way notify the service organisation.
-Err-3	Fast forward error. The program cannot be started at the required point because an unlimited repeat program (CC) is located before the section to be started.	(Error message can be acknowledged with "ENTER" key). Delete the unlimited program repeat, or start again at a different point.
-Err-4	Internal battery voltage too low, the controller continues operating automatically. After reset or "supply on" the battery voltage is checked once.	The error message is acknowledged with the "ENTER" key. Battery change by the service engineer. Important! If the battery is faulty it is possible for programs to be lost completely or partly.
-Err-5	Hardware watchdog faulty.	By service engineer or repair at the factory. This error message cannot be acknowledged.
-Err-6	Restart after supply failure not possible. Internal start-up data in RAM are corrupted.	Error message can be acknowledged with the "ENTER" key, the display changes to the base setting. Try to start the program again.
-Err-7	Internal configuration table in RAM is corrupted.	By service engineer or repair at the factory. This error message cannot be acknowledged.
-Err-9	Factory-set controller calibration data faulty.	Error message can be acknowledge with the "ENTER" key. Controller continues to operate with a standard value. Full accuracy of process is no longer ensured.
-Err-10	Process value higher or lower than display range +9999 digit	Error cannot be acknowledged! The causes have to be rectified. Possible errors: 1. calibration constant incorrect 2. setting of range limits (Cd 42/43) incorrect 3. re-calibration to customer specification (Cd 44/45) incorrect.
-Err-11	Error during programming the "Recalibration to customer specification"	Error message can be acknowledged with the "ENTER" key. The values entered are reset to the factory settings.
r.	Serious hardware faults e.g. RAM faulty	By service engineer or repair at the factory.

13 ACTION ON SUPPLY FAILURE

13.1 Data back-up

The data stored in RAM are protected by a lithium battery against loss on supply failure. An internal fault monitoring circuit monitors the battery. In case of insufficient battery voltage the error message "Err-4" is displayed. The error message is acknowledged with the "ENTER" key.

13.2 Model "Continue"

The instrument continues the program exactly from the point where it was interrupted.
There is no message that there was a supply failure.
Between restoration of supply and continuation of the program the display flashes "-busy" (internal calculation).

13.3 Model "Stop"

The instrument does not continue the program. The display shows briefly "-busy" (internal calculation) and then "-Stop".

- The program is aborted with the  key.
- The program is continued exactly from the point where it was interrupted by pressing the  key.

13.4 Supply failure during "HAND" operation

After restoration of the supply during manual operation the status before supply failure is restored. The setpoints and switching states of the relays are displayed as they were immediately before the supply failure.

14 EXTERNAL INPUTS

3 external inputs are available. Each of them is activated by a floating contact. The inputs can be used as follows:

Order Code*	Contacts 0/17	Contacts 0/18	Contacts 0/19
11	External stop channel 1	External stop channel 2	Keyboard block
12	External stop channel 1	External stop channel 2	Programming block
13	External stop channels 1 + 2	Fast forward	Keyboard block
14	External stop channels 1 + 2	Fast forward	Programming block

* see Extra Codes

14.1 External stop

The action corresponds to the "HAND" function during automatic operation. The time base is stopped. The instantaneous values are held. After releasing the "External stop" the remainder of the program is operated.
With synchronised operation both channels are stopped simultaneously, with non-synchronised operation the two channels are stopped separately.

14.2 External keyboard/ programming block

- Keyboard block:
  Protection against unauthorised operation (all keys are blocked)
- Programming block:
  Protection against unauthorised programming
  (only the "Pgm" key is blocked)

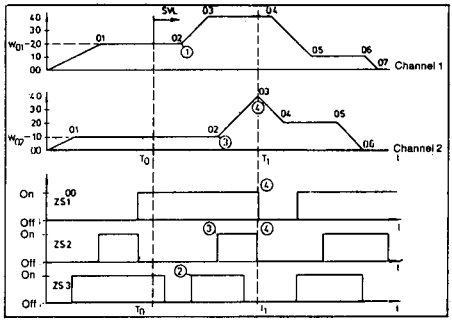
14.3 External fast forward

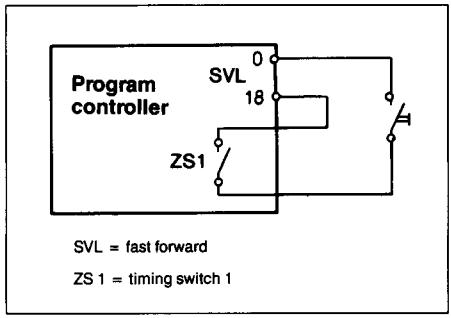
The fast forward mode permits rapid forward shift of the program to particular sections.
Limitation: fast forward run is not possible on the 2-channel model with non-synchronised start.

Operation

During the external fast forward mode a program is run in 1 sec steps from section to section. (see example 1–4)
(A setpoint section as well as a timing switch section are considered as a section provided that they are not of equal duration.) The signal of the analogue outputs is not changed; the values present at the start of the fast forward run are retained. The timing switches however change in accordance with the program.

The external fast forward run can be used, for example, to omit certain parts of the program through the operation of a switch or the occurance of an event. The fast forward run is stopped by a timing switch to ensure that it stops at a defined section.





(Matching the controller parameters Xp, Tn, Tv to the process)

Optimum adjustment means:

1. Good start-up action, i.e. start-up curve as steep as possible without overshoot.
2. Good disturbance and control correction, i.e. to ensure rapid control action without oscillations in case of an external disturbance or if the setpoint is changed.

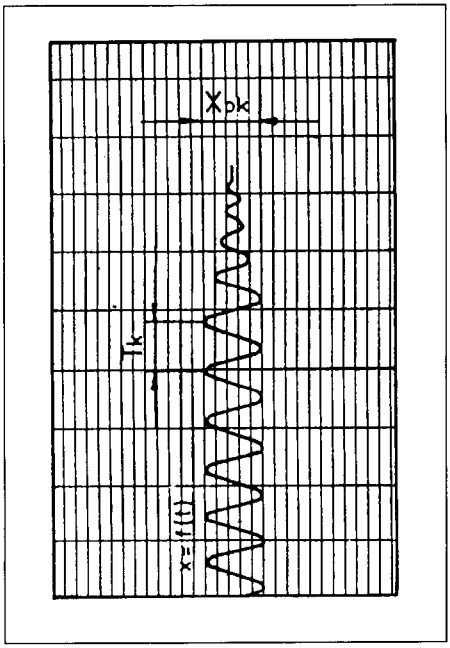
When precise process characteristics are available the control parameters for a defined operating point can be determined precisely by an involved mathematical procedure. In practice, however, precise characteristics are rarely available, and practical adjustment criteria have therefore been developed which have proved satisfactory.
Even here the assumed conditions (e.g. sudden changes of the disturbance or setpoint at the loop input) are in most cases only approximately correct so that the results obtained can only be considered as a rough indication.
In practice it is useful to record a curve of the process variable under operating conditions and to ascertain the optimum setting by stepwise changes of one parameter at a time.
A basic setting for controllers with PID action, based on the parameter values obtained, can be obtained by the procedure described below.

15.1 Oscillation method according to ZIEGLER and NICHOLS

This method applies to processes which may be rendered unstable for brief periods (Tg/Tu greater than 3). The controller is operated initially with the following settings: set Tn on PD (on proportional controllers on P action) and Tv on minimum; Xp1 or Xp1 and Xp2 on maximum. The proportional band Xp is then reduced slowly (by increasing the controller gain) to determine the stability limit at which the process performs undamped oscillations of constant amplitude. This test gives

a) the critical proportional band Xpk

b) the critical oscillation period Tk



The optimum settings are then:

$Xp = 1.7\ Xpk \qquad Tn = 0.5\ Tk$

$$Tv = \frac{Tn}{4.5}$$

15.2 Adjustment according to the process characteristics

Not all control loops can be rendered unstable for brief periods. This method is therefore based on the process loop and controller data. The transfer function (response to a sudden disturbance) is used to evaluate the following values:

Ks = process transfer coefficient

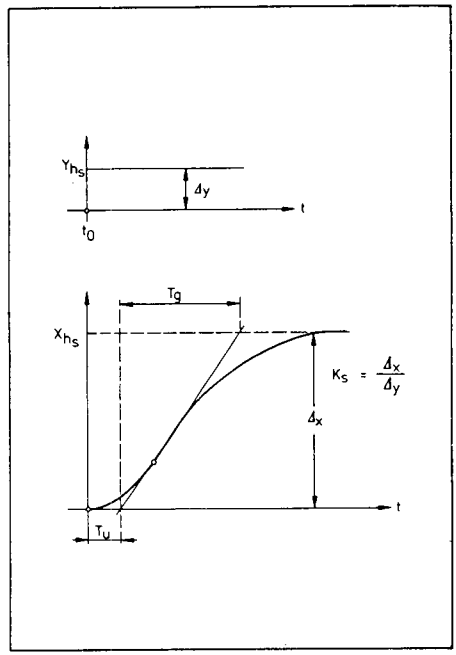
$$Ks = \frac{\Delta x}{\Delta y} = \frac{\text{output change}}{\text{input change}}$$

Tu = delay time and
Tg = response time

The controllability of the process loop can be estimated from the value of Tu/Tg.

For Tu/Tg less than 0.1	satisfactory control
0.1–0.3	just controllable
more than 0.3	difficult to control

The transfer function should be recorded near the operating point (setpoint). The input to the process is changed suddenly at time t_o by an amount Δy within the total adjustment range Yhs (for example 10% of Yhs).
The result is a transfer function with values for x, Tu and Tg. The controller is then adjusted according to the empirical formulae for processes without saturation as follows:



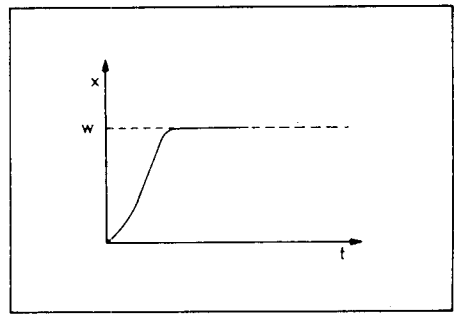
Optimisation according to CHIEN, HRONES and RESWICK

Aperiodic control action of minimum duration, optimised for:
Control

$$Xp = 1.7 \frac{Tu}{Tg} \cdot Ks \cdot Yhs$$

$$Tn = Tg$$

$$Tv = 0.5\ Tu$$

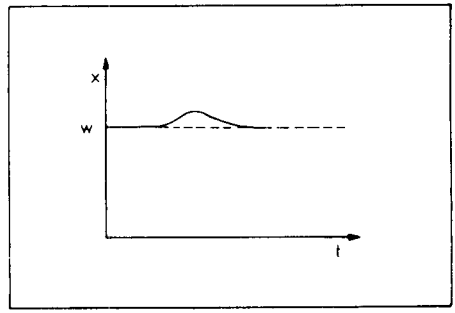


Disturbance

$$Xp = 1.05 \frac{Tu}{Tg} \cdot Ks \cdot Yhs$$

$$Tn = 2.4\ Tu$$

$$Tv = \frac{Tn}{4.5}$$

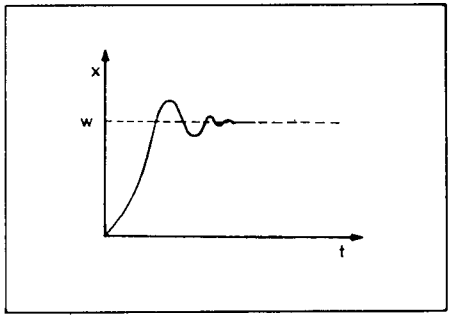


Control action with 20% overshoot and minimum oscillation period, optimised for: Control

$$Xp = 1.05 \frac{Tu}{Tg} \cdot Ks \cdot Yhs$$

$$Tn = 1.35\ Tg$$

$$Tv = 0.47\ Tu$$

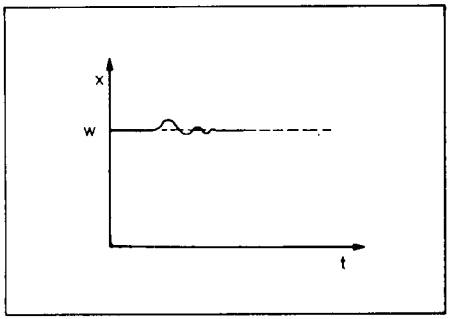


Disturbance

$$Xp = 0.83 \frac{Tu}{Tg} \cdot Ks \cdot Yhs$$

$$Tn = 2\ Tu$$

$$Tv = \frac{Tn}{4.5}$$

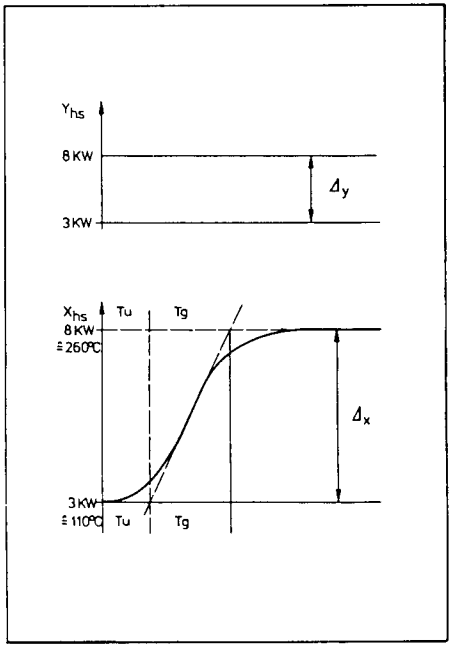


Example: electrically heated furnace as process

Input is the electric load in kW, for example 0–10 kW. Output is the temperature in °C, for example 20–320°C. The controller is a single setpoint controller with a range of 0–400°C. The operating point (setpoint) is to be at 200°C. The following values can be taken from this information:

Yhs = 10 kW – 0 kW = 10 kW
Xhs = 320°C – 20°C = 300°C

For recording the transfer function the power at the input to the furnace is suddenly increased, for example from 3 kW to 8 kW. With a linear relationship between input and output a transfer function is produced from 110°C to 260°C.



$\Delta x = 150\,°C$
$\Delta y = 5\,kW$

$$Ks = \frac{\Delta x}{\Delta y} = \frac{150\,°C}{5\,kW} = 30\,\frac{°C}{kW}$$

Optimisation for disturbance with 20% overshoot.

$Tu = 1\,min$
$Tg = 5\,min$

$$Xp = 0.83 \cdot Ks \cdot \frac{Tu}{Tg} \cdot Yhs$$

$$Xp = 0.83 \cdot 30\frac{°C}{kW} \cdot \frac{1\,sec}{5\,sec} \cdot 10\,kW$$

$Xp = 49.8\,°C$

$Tn = 2\,Tu = 2\,min$

$$Tv = \frac{Tn}{4.5} = 27\,sec$$

If the power supplied cannot be changed in steps, the transfer function is recorded with a 100% change in power. As the process does not always permit this due to technical reasons there is another possibility for determining the control parameters. Here the maximum rate of rise of the transfer function is evaluated.
Xmax = maximum value of process

$$Vmax = \frac{\Delta x}{\Delta t}$$

This gives the following values for PID controllers based on the example above:

$\Delta t = 3$ min
$\Delta x = 90°C$ $\quad Vmax = \frac{\Delta x}{\Delta t} = \frac{90°C}{3\ min} = 30\ \frac{°C}{min}$

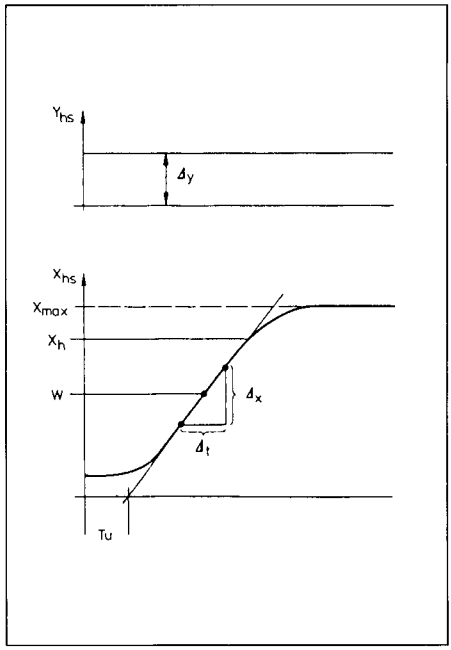
$$Xp = 0.83 \cdot Vmax \cdot Tu$$

$$Xp = 0.83 \cdot 30\ \frac{°C}{min} \cdot 2\ min$$

$$Xp = 49.8°C$$

$$Tn = 2\,Tu = 2\ min$$

$$Tv = \frac{Tn}{4.5} = 27\ sec$$



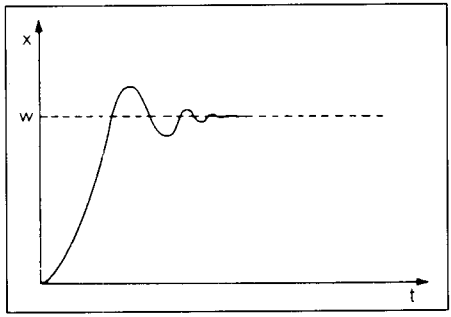
Empirical rules for parameter setting

Control action	Setting
P	Xp = Vmax · Tu(°C)
PI	Xp = 1.2 · Vmax · Tu(°C)
PD	Xp = 0.83 · Vmax · Tu(°C) Tv = 0.25 · Tu(min)
PID	Xp = 0.83 · Vmax · Tu(°C) Tn = 2 Tu(min) Tv = Tn/4.5(min)
PD/PID	Xp = 0.4 · Vmax · Tu(°C) Tn = 2 · Tu(min) Tv = 0.4 · Tu(min)

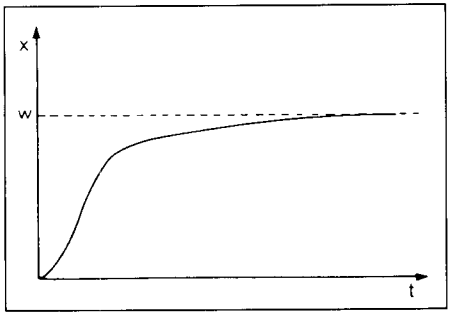
15.3 Checking the optimisation

The optimum adjustment of the controller to the process can be checked by recording a start-up with closed process loop.

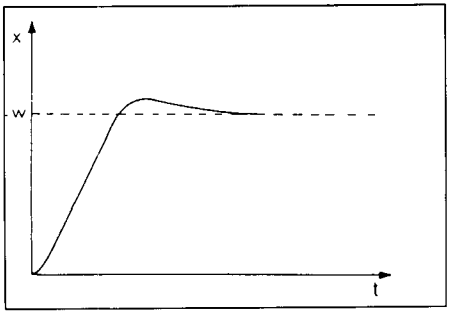
The diagrams below indicate possible incorrect adjustments and the correction required.



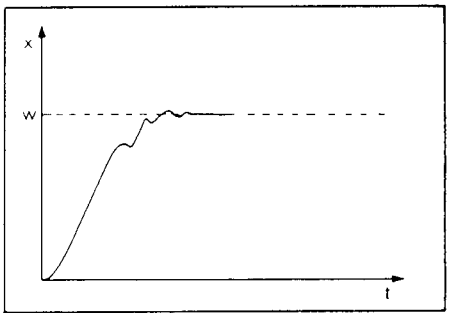
Tv and Tn too small



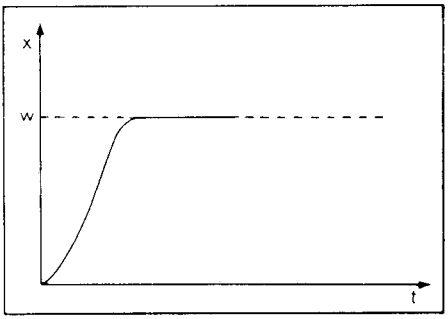
Tv and Tn too large



Xp too large



Xp too small



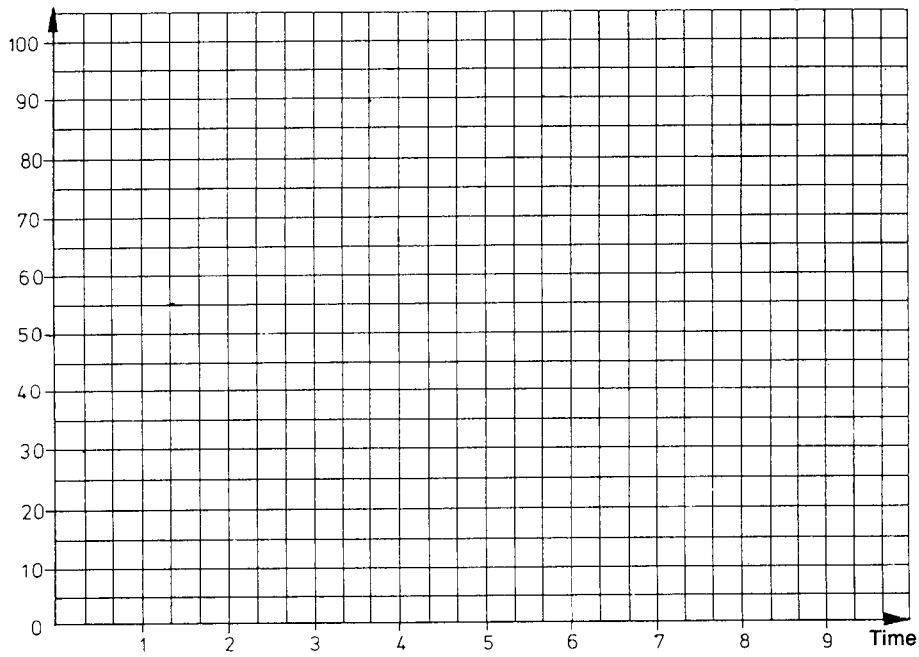
optimum adjustment

This shows that increased Xp and increased Tn both result in a more stable and more sluggish control action.
Smaller Xp or Tn produces a less damped control action.

mm	inch
0.8	0.031
4.8	0.19
10.5	0.41
28.5	1.12
66	2.60
73	2.87
79	3.11
91	3.58
$92^{+0.5}$	$3.62^{+0.02}$
96	3.78
104	4.09
181.5	7.15
192	7.65

16.1 Setpoint diagram

Program No.:
Channel No.:



Enter the setpoint curve in the diagram and number the sections consecutively at the slope change points.

Time unit (h:min) ☐[ ]
or (min:sec) ☐[ ]

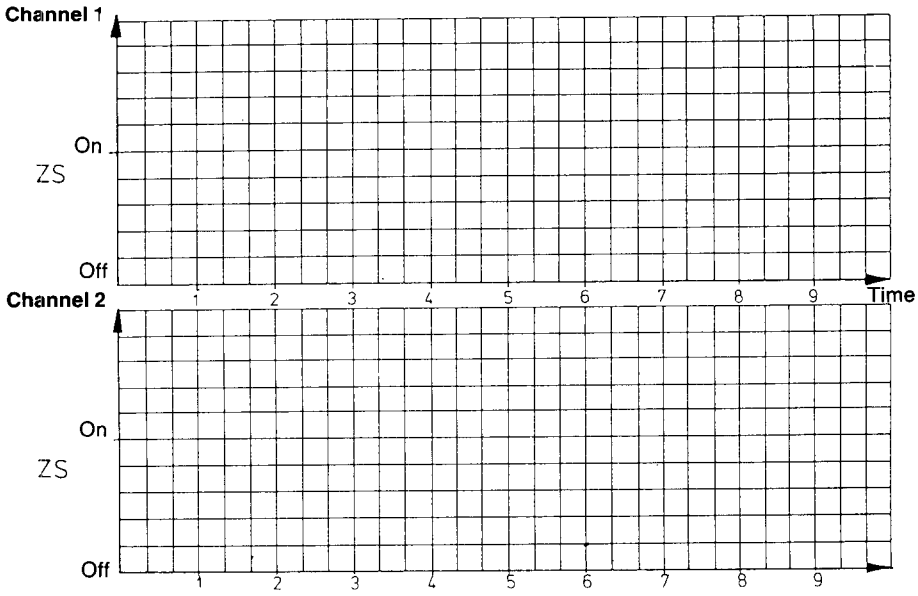
Perform the programming preparation of the setpoint curve in accordance with Chapter 6.1!

Section		Setpoint		Section time			Repeats (cycle)		
	ENTER	DIGIT UP	ENTER	DIGIT UP PROG / INT STEP		ENTER	DIGIT UP		ENTER
		%		h: min	min: s		from which section	how often	
00				:	:				
01				:	:				
02				:	:				
03				:	:				
04				:	:				

Terminate programming. ON Pgm OFF

16.2 Timing switch programs

Program No.:



Enter timing switch programs ZS. in the diagram.

Number sections consecutively.

Time

h:min ☐[ ]

min:sec ☐[ ]

Perform the programming preparation of the timing switches in accordance with Chapter 6.3!

Section		Contact status		Section time			Repeats (cycle)		
	ENTER	UP	ENTER	WAIT	UP	ENTER	WAIT	UP	ENTER
				PROGR / SET + STEP					
		On /Off		h: min	min: s		from which section	how often	
00				:	:				
01				:	:				
02				:	:				
03				:	:				
04				:	:				
05.				:	:				
06				:	:				

Terminate programming. Pgm