X20CM8323

1 General information

The module has digital outputs for switching electromechanical loads (e.g. valves, relays) and additional functions.

- 8 digital outputs
- Current trace
- Switching time detection
- Pulse width modulation

2 Order data

Order number	Short description	Figure
	Other functions	
X20CM8323	X20 PWM module, 8 digital outputs for switching electromechanical loads, 0.6 A continuous current, 2 A peak current, current monitoring, switching time detection	
	Required accessories	
	Bus modules	
X20BM11	X20 bus module, 24 VDC keyed, internal I/O supply continuous	
X20BM15	X20 bus module, with node number switch, 24 VDC keyed, internal I/O power supply connected through	
	Terminal blocks	
X20TB12	X20 terminal block, 12-pin, 24 VDC keyed	

Table 1: X20CM8323 - Order data

3 Technical data

Order number	X20CM8323
Short description	
I/O module	8 digital outputs for switching electromechanical loads, current monitoring, switching instant detection, pulse width modulation
General information	
B&R ID code	0x1D43
Status indicators	I/O function per channel, operating state, module status
Diagnostics	
Module run/error	Yes, using LED status indicator and software
Outputs	Yes, using LED status indicator and software (output error status)
Power consumption	
Bus	0.01 W
Internal I/O	1 W (Rev. ≥ G0), 1.5 W (Rev. < G0)
External I/O	Corresponding to external load
Additional power dissipation caused by actuators (resistive) [W]	-
Certifications	
CE	Yes
ATEX	Zone 2, II 3G Ex nA nC IIA T5 Gc IP20, Ta (see X20 user's manual) FTZÚ 09 ATEX 0083X
UL	cULus E115267 Industrial control equipment
HazLoc	cCSAus 244665 Process control equipment for hazardous locations Class I, Division 2, Groups ABCD, T5
EAC	Yes
KC	Yes
Digital outputs	
Nominal voltage	24 VDC
Nominal output current	0.6 A
Total nominal current	4.8 A
Connection type	1-wire connections
Output circuit	Sink
Output protection	Thermal shutdown in the event of overcurrent or short circuit, integrated protection for switching inductive loads
Pulse width modulation	
Period duration	1 ms (1 kHz) or 20 µs (50 kHz)
Pulse duration	0 to 100%
Resolution for pulse duration	1%
Inrush current	Max. 2 A for max. 25.5 ms
Braking voltage when switching off inductive loads	39 VDC
Reverse polarity protection	No (must be protected externally)
Output voltage	
Minimum	18 VDC
Nominal	24 VDC
Maximum	42 VDC
Protective circuit	
External	24 VDC power supply - maximum current 10 A (melting fuse)
Electrical properties	
Electrical isolation	Bus isolated from channel and internal I/O power supply Channel not isolated from channel and internal I/O power supply
Operating conditions	
Mounting orientation	
Horizontal	Yes
Vertical	Yes
Installation elevation above sea level	
0 to 2000 m	No limitation
>2000 m	Reduction of ambient temperature by 0.5°C per 100 m
Degree of protection per EN 60529	IP20
Ambient conditions	
Temperature	
Operation	
Horizontal mounting orientation	0 to 60°C (Rev. ≥ G0), 0 to 55°C (Rev. < G0) [1]
Vertical mounting orientation	0 to 50°C [2]
Derating	-
Storage	-25 to 70°C
Transport	-25 to 70°C

Table 2: X20CM8323 - Technical data

Order number	X20CM8323
Relative humidity	
Operation	5 to 95%, non-condensing
Storage	5 to 95%, non-condensing
Transport	5 to 95%, non-condensing
Mechanical properties	
Note	Order 1x terminal block X20TB12 separately. Order 1x bus module X20BM11 separately.
Pitch	12.5$^{+0.2}$ mm

Table 2: X20CM8323 - Technical data

1) Rev. G0 or later: At above 55°C, only a maximum of 6 channels are permitted to be switched on simultaneously.
2) Rev. G0 or later: At above 45°C, only a maximum of 6 channels are permitted to be switched on simultaneously.

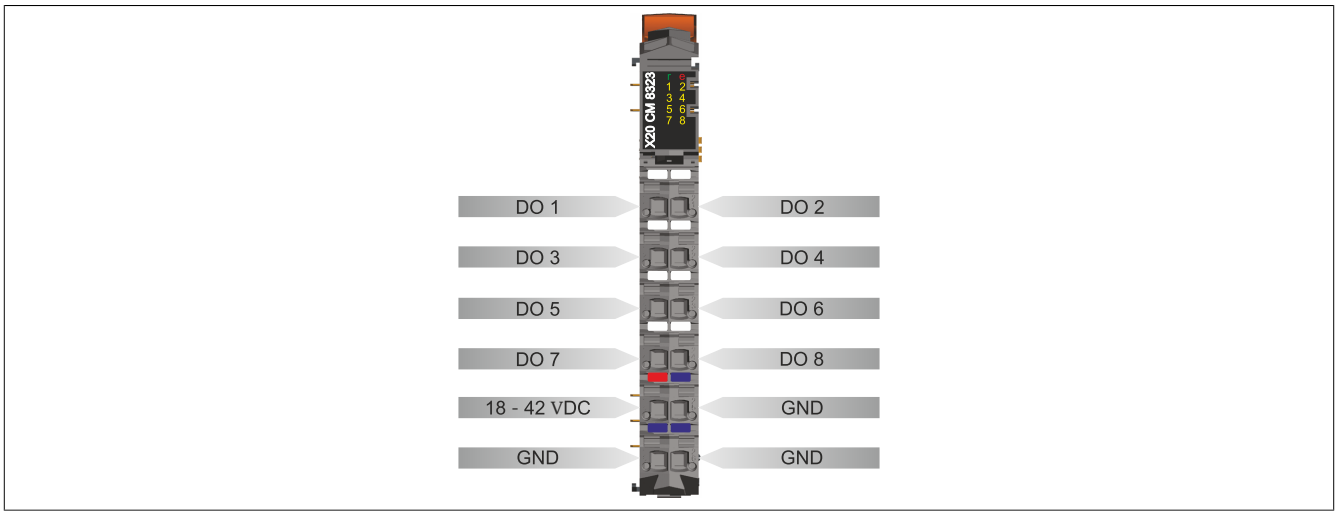
4 LED status indicators

For a description of the various operating modes, see section "Additional information - Diagnostic LEDs" in the X20 system user's manual.

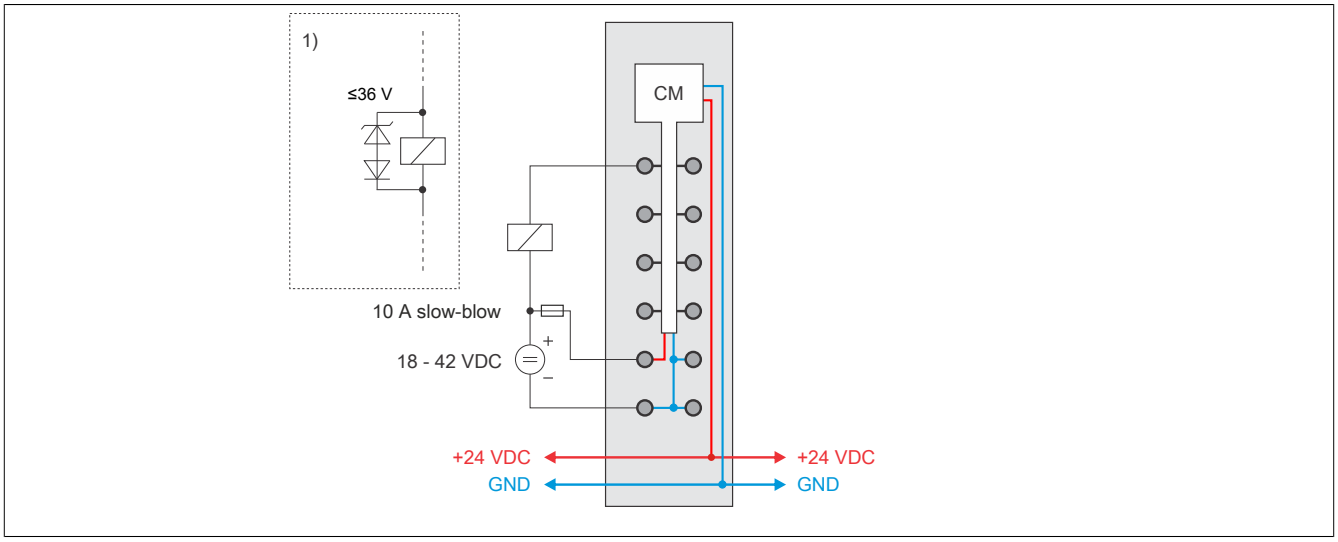
Figure	LED	Color	Status	Description
	r	Green	Off	No power to module
			Single flash	RESET mode
			Double flash	BOOT mode (during firmware update)[1]
			Blinking	PREOPERATIONAL mode
			On	RUN mode
	e	Red	Off	No power to module or everything OK
			Single flash	Warning/Error on an I/O channel. Level monitoring for digital outputs has been triggered.
	e + r	Red on / Green single flash		Invalid firmware
	1 - 8	Orange	On/Off	Status of the digital outputs
			Blinking	Short-circuit / overcurrent cutoff **Information:** **The output is not automatically activated after an overcurrent cutoff. It must be switched on again.**

1) Depending on the configuration, a firmware update can take up to several minutes.

5 Pinout

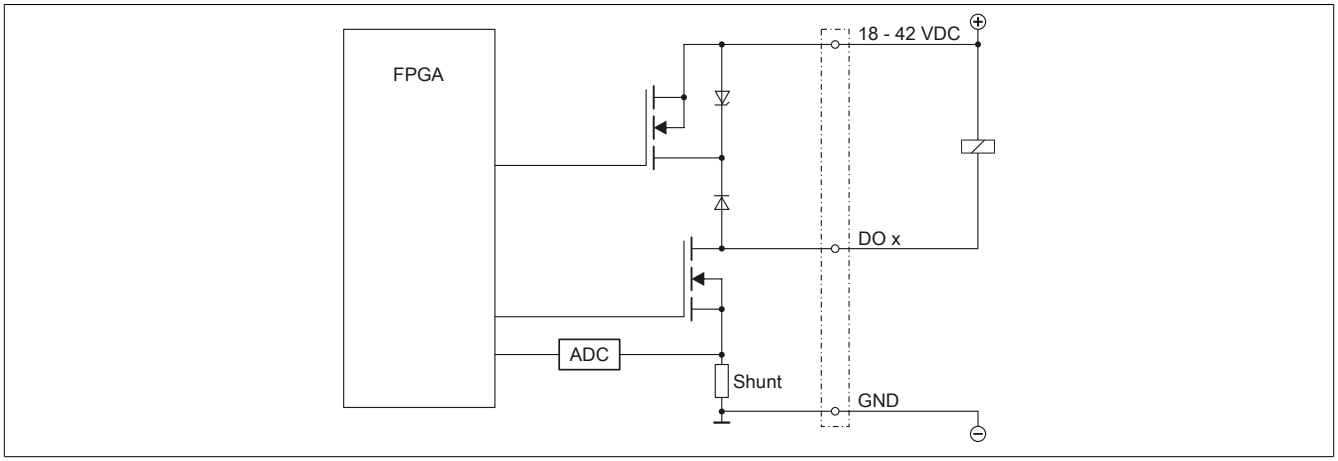


6 Connection example



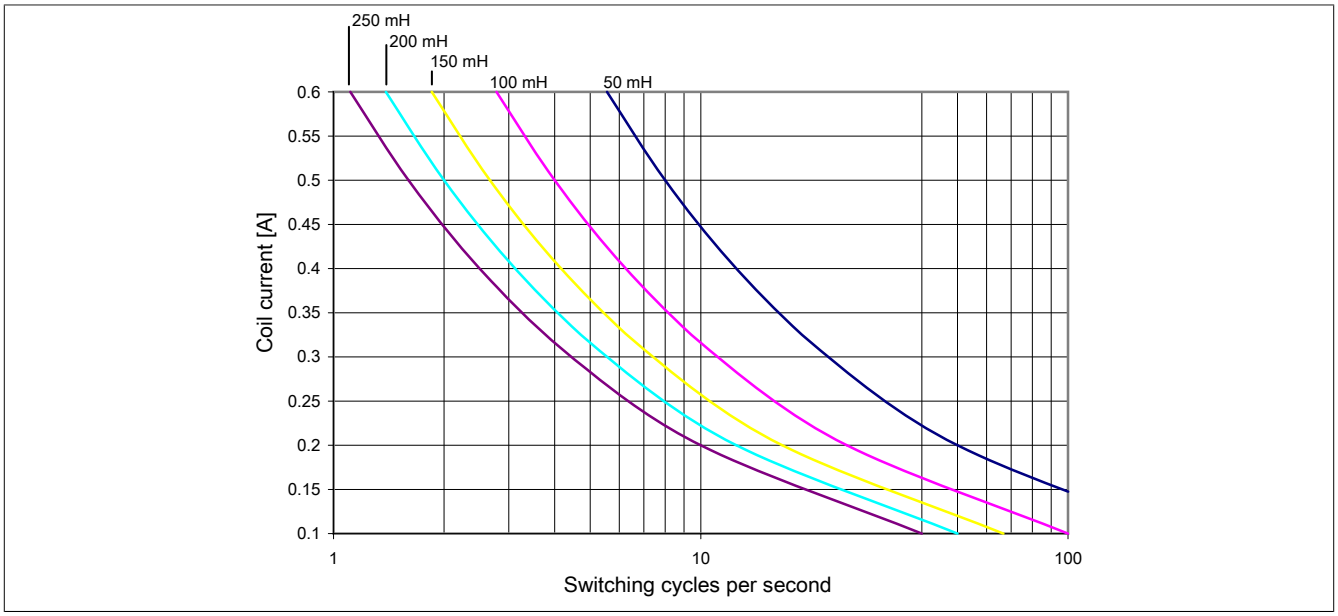
1) If larger inductances or more current should be handled, the "transil-diode combination" must be set externally on the relay/valve.

7 Output circuit diagram

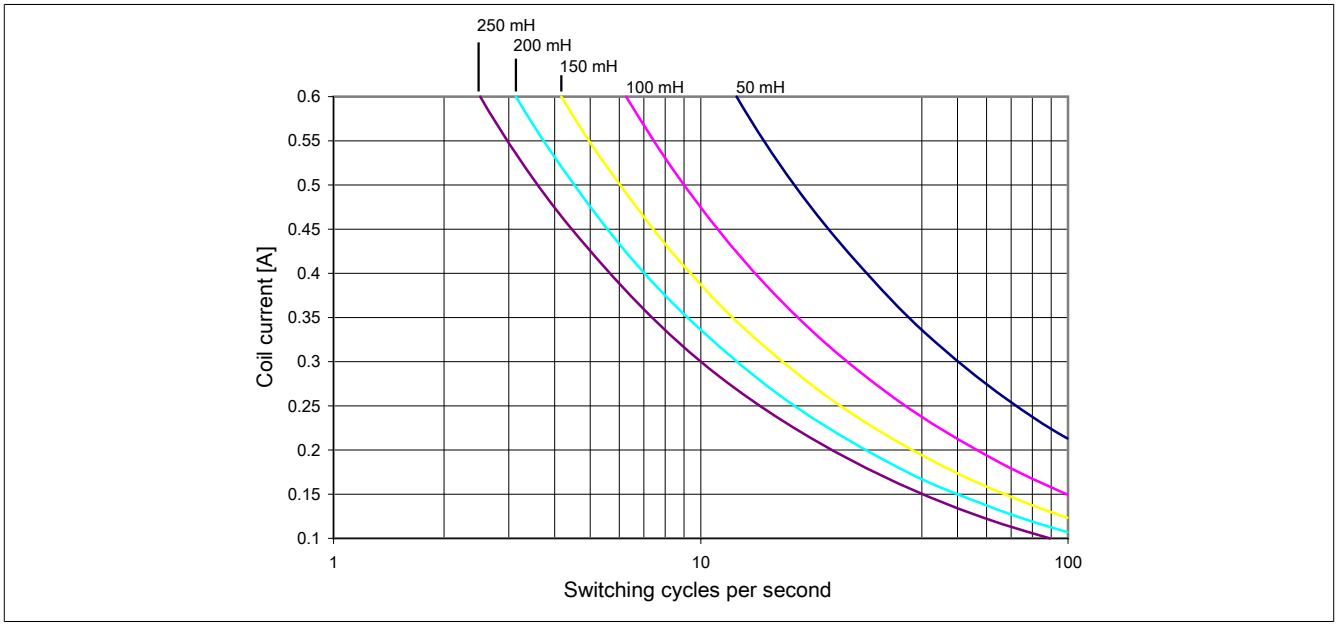


8 Switching inductive loads

Prior to revision G0



From revision G0



In principle, the inductance that is connected is limited by the maximum power dissipation of the module.

If larger inductances or more current are used, the the "transil-diode combination" must be placed externally on the relay/valve (see "Connection example" on page 4).

Information:

The inductance of a relay/valve depends greatly on the core material being used. Therefore, an inductance must be used that corresponds to the diagram at 1Hz. This information can be found in the data sheet of the connected inductance (relay/valve).

9 Register description

9.1 General data points

In addition to the registers described in the register description, the module has additional general data points. These are not module-specific but contain general information such as serial number and hardware variant.

General data points are described in section "Additional information - General data points" in the X20 system user's manual.

9.2 Function model 0 - Standard

Register	Name	Data type	Read		Write	
			Cyclic	Non-cyclic	Cyclic	Non-cyclic
Configuration						
12	ConfigOutput02 (Excitation time)	USINT				•
13	ConfigOutput03 (PWM duty cycle)	USINT				•
14	ConfigOutput04 (Module configuration)	USINT				•
Index + 10	ConfigOutputN (Index N = 05 to 20) (Current and time differential)	USINT				•
38	ConfigOutput21 (Disables high-speed cutoff)	USINT				•
Communication						
9	Digital outputs	USINT			•	
	DigitalOutput01	Bit 0				
	...	...				
	DigitalOutput08	Bit 7				
9	StatusInput01	USINT	•			
10	StatusInput02	USINT		•		
0	AnalogInput01	USINT	•			
Index - 1	AnalogInput0N (Index N = 2 to 9)	USINT	•			
10	StatusOutput01	UINT			•	
Index + 47	Current0N (Index N = 1 to 8)	USINT	•			
56	StatusCurrent	USINT	•			
	StatusCurrent01	Bit 0				
	...	...				
	StatusCurrent08	Bit 7				

9.3 Function model 1

Register	Name	Data type	Read		Write	
			Cyclic	Non-cyclic	Cyclic	Non-cyclic
Configuration						
12	ConfigOutput02 (Excitation time)	USINT				•
13	ConfigOutput03 (PWM duty cycle)	USINT				•
14	ConfigOutput04 (Module configuration)	USINT				•
Index + 10	ConfigOutputN (Index N = 05 to 20) (Current and time differential)	USINT				•
38	ConfigOutput21 (Disables high-speed cutoff)	USINT				•
Communication						
9	DigitalOutput	USINT			•	
9	StatusInput01	USINT	•			
10	StatusInput02	USINT		•		
0	AnalogInput01	USINT	•			
Index - 1	AnalogInput0N (Index N = 2 to 9)	USINT	•			
10	StatusOutput01	UINT			•	
Index + 47	Current0N (Index N = 1 to 8)	USINT	•			

9.4 Function model 254 - Bus controller

Register	Offset[1)]	Name	Data type	Read		Write	
				Cyclic	Non-cyclic	Cyclic	Non-cyclic
Configuration							
12	-	ConfigOutput02 (Excitation time)	USINT				•
13	-	ConfigOutput03 (PWM duty cycle)	USINT				•
14	-	ConfigOutput04 (Module configuration)	USINT				•
Index + 10	-	ConfigOutputN (Index N = 05 to 20) (Current and time differential)	USINT				•
38	-	ConfigOutput21 (Disables high-speed cutoff)	USINT				•
48	-	TimeBase	UINT				•
Communication							
9	0	Digital outputs	USINT			•	
		DigitalOutput01	Bit 0				
		...	...				
		DigitalOutput08	Bit 7				
9	6	StatusInput01	USINT	•			
10	-	StatusInput02	USINT		•		
Index + 1	Index + 1	AnalogInput0N (Index N = 1 to 4)	USINT	•			
10	2	StatusOutput01	UINT			•	
0	4	AddressSet	UINT			•	
	4	LineID_Set	USINT				
	5	BlockID_Set	USINT				
0	0	IndexAct	UINT	•			
	0	LineID_Act	USINT				
	1	BlockID_Act	USINT				

1) The offset specifies the position of the register within the CAN object.

9.4.1 Using the module on the bus controller

Function model 254 "Bus controller" is used by default only by non-configurable bus controllers. All other bus controllers can use other registers and functions depending on the fieldbus used.

For detailed information, see section "Additional information - Using I/O modules on the bus controller" in the X20 user's manual (version 3.50 or later).

9.4.2 CAN I/O bus controller

The module occupies 1 analog logical slot on CAN I/O.

9.5 Configuration registers

9.5.1 Excitation time

Name:
ConfigOutput02

The excitation time is configured in this register.
The output is switched fully on for the time set in this register after the module is switched on. After the excitation time expires, the module goes into PWM mode.

Data type	Value	Information
USINT	0 to 255	In steps of 100 µs or 1000 µs. Bus controller default setting: 0

9.5.2 PWM duty cycle

Name:
ConfigOutput03

In this register, a configuration is made for the percentage of the PWM cycle (in 1% steps) that the PWM output is logical 1, i.e. ON.

Data type	Value	Information
USINT	0	PWM output always off
	1 to 99	Switch-on time in 1% steps. Bus controller default setting: 50
	100	PWM output always on

9.5.3 Module configuration

Name:
ConfigOutput04

This register is used to configure the module's general parameters.

Data type	Values	Bus controller default setting
USINT	See the bit structure.	0

Bit structure:

Bit	Description	Value	Information
0	PWM frequency	0	1 kHz (bus controller default setting)
		1	50 kHz
1	Reserved		
2	Excitation time base	0	100 µs (bus controller default setting)
		1	1000 µs
3	Reserved		
4	Switching point search	0	Low-point method (bus controller default setting)
		1	Curvature method
5 - 7	Reserved		

9.5.4 Current and time differential

Name:
ConfigOutput05 to ConfigOutput20

The switching point search is configured with the parameters dI and dt in these non-cyclic registers.

- dI - Current differential in LSB
- dt - Time differential in 100 µs steps

For an example of the configuration, see "Configuring dI and dt" on page 16.

Data type	Values	Information
USINT	0 to 255	Bus controller default setting: 0

Registers	Description	
ConfigOutput05	**dI**	Channel 1
ConfigOutput06	**dt**	
...		...
ConfigOutput19	**dI**	Channel 8
ConfigOutput20	**dt**	

9.5.5 Disabling the high-speed cutoff

Name:
ConfigOutput21

The high-speed cutoff can be enabled or disabled for individual channels in this register.

Data type	Values	Bus controller default setting
USINT	See the bit structure.	0

Bit structure:

Bit	Description	Value	Information
0	High-speed cutoff	0	Enabled for channel 1 (bus controller default setting)
		1	Disabled for channel 1
...		...	
7	High-speed cutoff	0	Enabled for channel 8 (bus controller default setting)
		1	Disabled for channel 8

9.5.6 Configuration of the time base

Name:
TimeBase

This register can be used to configure the time base for the distance between current measuring points.
This distance between current measuring points normally corresponds to a quarter of the set X2X cycle. This value is not available with a CAN controller. The time base for the 1/4 measuring cycle must therefore be configured separately with Function model 254 - Bus controller.

Data type	Value	Information
UINT	400 to 10000	Measurement point interval in µs for 1/4 measurement cycle. Bus controller default setting: X2X cycle time

9.6 Communication registers

9.6.1 Uploading the current curves (function models 0 and 1)

A current curve with 200 values is recorded for each channel. The interval between measurement points is equal to a quarter of the defined X2X Link cycle.

The following registers are used to read the current curve recorded by the module:

- "AnalogInput01" on page 9
- "AnalogInput02 to AnalogInput09" on page 9

9.6.1.1 Set the channel number and line index

Name:
AnalogInput01

If this register contains a valid value (i.e. index is in the valid range) then registers "AnalogInput02 to AnalogInput09" on page 9 provide a block of 8 current values for Channel X.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0 - 2	Channel number	0	Channel 1
		...	
		7	Channel 8
3 - 7	Index	0 to 24	Line index

The index specifies which part of the current curve is represented by the block of 8 values:

Value X of the current curve	Index	Register
1	0	AnalogInput02
2		AnalogInput03
...		...
8		AnalogInput09
9	1	AnalogInput02
...	:	...
193	24	AnalogInput02
...		...
200		AnalogInput09

Table 3: Relationship between index, channel and AnalogInput02 - AnalogInput09

Examples

The 200th value of the curve contains the switching point of the connected valve/relay found by the module.

- Value 200 = 78: The 78th measurement point corresponds to the switching point of the valve/relay.
- Value 200 = 255: No switching point was found.

9.6.1.2 Analog input values

Name:
AnalogInput02 to AnalogInput09

A current curve with 200 values is recorded for each channel. These registers provide a block of 8 current values from Channel X.
The following register is required for configuration:

- The "AnalogInput01" on page 9 register defines the channel used and the block index.
- The interval between measurement points is equal to a quarter of the defined X2X Link cycle.

Data type	Values
USINT	0 to 255

9.6.1.3 Programming example in ANSI C for uploading the curves:

```
#include <bur/plctypes.h>
#define ILEN 200

typedef struct {
      USINT                         data[ILEN];
}     curve_typ;
typedef struct {
      BOOL                          ok;
      UDINT                         serial;
      UINT                          id, hw, fwver;
      BOOL                          out[8];
      UINT                          delay;
      USINT                         i_addr;
      USINT                         i_ch1_in, i_ch2_in, i_ch3_in, i_ch4_in;
      USINT                         i_ch5_in, i_ch6_in, i_ch7_in, i_ch8_in;
      curve_typ                     curves[8];
      USINT                         switched;
}     cm8323_typ;
_LOCAL cm8323_typ                   cm;
_LOCAL USINT                        ventilNummer, adrPtr;

void _INIT up() {}

void _CYCLIC cycle() {
      ventilNummer = cm.i_addr & 0x07;
      adrPtr = cm.i_addr >> 3;

      if(cm.i_addr != 200 && ventilNummer <= 7) {
            cm.curves[ventilNummer].data[adrPtr * 8 + 0] = cm.i_ch1_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 1] = cm.i_ch2_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 2] = cm.i_ch3_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 3] = cm.i_ch4_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 4] = cm.i_ch5_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 5] = cm.i_ch6_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 6] = cm.i_ch7_in;
            cm.curves[ventilNummer].data[adrPtr * 8 + 7] = cm.i_ch8_in;
      }
}
```

I/O mapping of following data points for curve evaluation:

Data point	Variable
AnalogInput01	cm.i_addr
AnalogInput02	cm.i_ch1_in
AnalogInput03	cm.i_ch2_in
AnalogInput04	cm.i_ch3_in
AnalogInput05	cm.i_ch4_in
AnalogInput06	cm.i_ch5_in
AnalogInput07	cm.i_ch6_in
AnalogInput08	cm.i_ch7_in
AnalogInput09	cm.i_ch8_in

9.6.2 Uploading the current curves with CAN I/O

A current curve with 200 values is recorded for each channel. The interval between measurement points is equal to the value set in the "TimeBase" on page 8 register.

The following registers are needed in order to read the current curve recorded by the module in the Function model 254 - Bus controller:

- "BlockID_Set" on page 11
- "BlockID_Act" on page 11
- "LineID_Set" on page 11
- "LineID_Act" on page 12
- "AnalogInput01 to AnalogInput04" on page 12

9.6.2.1 Summary of set registers

Name:
AddressSet

This register is a summary of the "LineID_Set" on page 11 and "BlockID_Set" on page 11 registers.

Data type	Bit	Information
UINT	0 - 7	LineID_Set
	8 - 15	BlockID_Set

9.6.2.2 Summary of read registers

Name:
IndexAct

This register is a summary of the "LineID_Act" on page 12 and "BlockID_Act" on page 11.

Data type	Bit	Information
UINT	0 - 7	LineID_Act
	8 - 15	BlockID_Act

9.6.2.3 Sets the channel number

Name:
BlockID_Set

The channel for the data stream can be selected in this register. The value of this register can be read using "BlockID_Act" on page 11.

Data type	Value	Information
USINT	0	Channel 1
	...	...
	7	Channel 8

9.6.2.4 Reads the channel number

Name:
BlockID_Act

Reads the "BlockID_Set" on page 11 register. This register allows you to determine which channel is providing the current values in registers "AnalogInput01 to AnalogInput04" on page 12. If the selected channel or line does not exist, then this register returns the value 255.

Data type	Value	Information
USINT	0 to 7	Channel or line currently being used
	255	Invalid selection

9.6.2.5 Setting the line index

Name:
LineID_Set

The line index for the data stream can be selected in this register. The value of this register can be read using "LineID_Act" on page 12.

Data type	Value	Information
USINT	0 to 49	Line index currently used

9.6.2.6 Reading the line index

Name:
LineID_Act

Reads the "LineID_Set" on page 11 register. This register allows you to determine which line is providing the current values in registers "AnalogInput01 to AnalogInput04" on page 12. If the selected channel or line does not exist, then this register returns the value 255.

If the channel number and index are in the valid range, then registers "AnalogInput01 to AnalogInput04" on page 12 provide a block of 4 current values for Channel X.
The index specifies which part of the current curve is represented by the block of 4 values:

Data type	Value	Information	
USINT	**Value X of the current curve**	**Index**	**Register**
	1	0	AnalogInput01
	...		...
	4		AnalogInput04
	5	1	AnalogInput01
	...		...
	197	49	AnalogInput01
	...		...
	200		AnalogInput04
	255	Invalid selection	

9.6.2.7 Analog input values - CAN I/O

Name:
AnalogInput01 to AnalogInput04

A current curve with 200 values is recorded for each channel. These registers provide a block of 4 current values from Channel X.
The following registers are required for configuration:

- The "BlockID_Set" on page 11 register defines the channel used.
- The "LineID_Set" on page 11 register defines the block index within the channel.
- The interval between measurement points is equal to the value set in the "TimeBase" on page 8 register.

Data type	Values
USINT	0 to 255

9.6.3 Digital outputs

Name:
DigitalOutput
DigitalOutput01 to DigitalOutput08

Registers "DigitalOutput01" to "DigitalOutput08" set the output value of Channels 1 to 8.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0	DigitalOutput01	0 or 1	Output value of digital output 01
...		...	
7	DigitalOutput08	0 or 1	Output value of digital output 08

9.6.4 Status of the outputs

Name:
StatusInput01

This register indicates whether a switching point has been found for a channel.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0	Switching point	0	Channel 1 was not switched or no switching point was found
		1	Switching point found for Channel 1
...		...	
7	Switching point	0	Channel 8 was not switched or no switching point was found
		1	Switching point found for Channel 8

9.6.5 Module status

Name:
StatusInput02

The current module status is indicated in this register.

Data type	Values
USINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0 - 2	Reserved	0	
3	Overload cutoff	0	No overcurrent
		1	Overcurrent cutoff activated
4 - 7	Reserved	0	

9.6.6 Switching delay of channels

Name:
StatusOutput01

2 bits of this register are used to set the switching delay for each channel. Values of the switching delay are specified in quarter-steps of the X2X Link cycle.

Data type	Values
UINT	See the bit structure.

Bit structure:

Bit	Description	Value	Information
0 - 1	Switching delay of channel 1	00	No delay
		01	1/4 of the X2X Link cycle
		10	2/4 of the X2X Link cycle
		11	3/4 of the X2X Link cycle
2 - 3	Switching delay of channel 2	x	For possible values, see channel 1.
...		...	
14 - 15	Switching delay of channel 8	x	For possible values, see channel 1.

9.6.7 Reads actual values of the current

Name:
Current01 to Current08

These registers are used to read the actual value of the current from channels 1 to 8. These values have no units and are used only as characteristic values. A more precise, compensated current measurement is not possible using this module.

Relationship between register name and channel number:

Register name	Channel number
Current01	Actual value of the current of Channel 1
...	...
Current08	Actual value of the current of Channel 8

If an output is switched off, the corresponding register returns the value 0. After the output is switched on, valid current measurements are not available on the module until after two X2X Link cycles. The measurements in the registers are delayed by two cycles to account for this.

When the output is switched on, the corresponding bit in the "StatusCurrent" on page 14 register can be used to check whether the register contains valid measurements. The first measured value is provided with the rising edge of this bit.

Data type	Value	Information
USINT	0	Output is switched off
	1 to 255	Current value

9.6.8 Checking for measured values

Name:
StatusCurrent
StatusCurrent01 to StatusCurrent08

This register can be used to check whether valid measured values are present in registers "Current01 to Current08" on page 14.

Data type	Values
USINT	See the bit structure.

Bit structure:

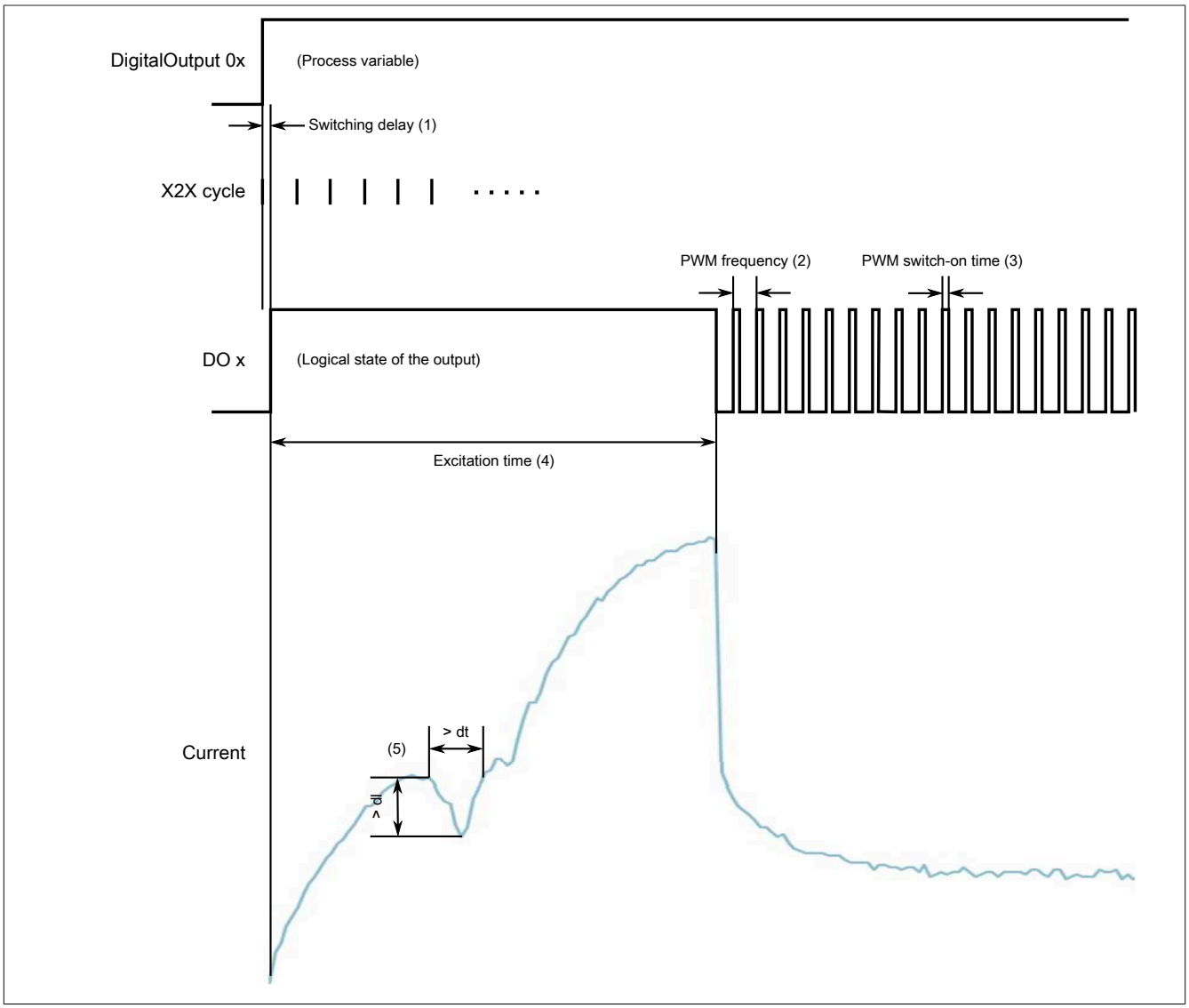
Bit	Description	Value	Information
0	StatusCurrent01	0	Output switched off
		1	The current value of channel 01 is valid.
...		...	
7	StatusCurrent08	0	Output switched off
		1	The current value of channel 08 is valid.

9.7 Functionality of the digital outputs

The following image shows the configuration and functionality of a digital output.

Configuration registers

1) Switching delay: See register "StatusOutput01" on page 13
2) PWM frequency: See bit 0 of register "ConfigOutput04" on page 8
3) PWM duty cycle: See register "ConfigOutput03" on page 7
4) Excitation time = ConfigOutput02 * Excitation time base (bit 2 of "ConfigOutput04" on page 8)
5) dI / dt: See registers "ConfigOutput05 to 20" on page 8



9.8 Configuring dI and dt

9.8.1 Procedure - Searching for switching points

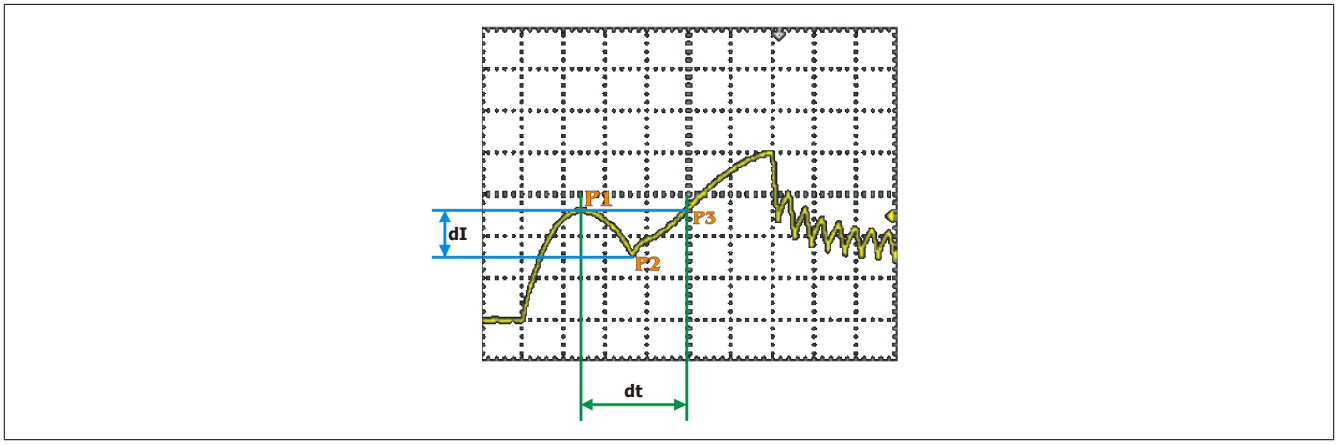


Figure 1: Searching for switching points

The current in the inductance gradually rises when the valve is switched on. The valve starts to move mechanically at a certain point. This process becomes noticeable due to a current dip that occurs as a result of the braking voltage (anti-EMF) (point P1).

When this mechanical process is complete, the current returns to its original curve and continues to rise (point P2).

Point P3 and point P1 have the same current value, but different times.

A valid low-point, which simultaneously corresponds to the switching point, must meet the following criteria:

- Point 2 must be lower than P1 by dI
- The time between P1 and P3 must be longer than dt

9.8.2 Configuration example for dI and dt with trace data from Automation Studio

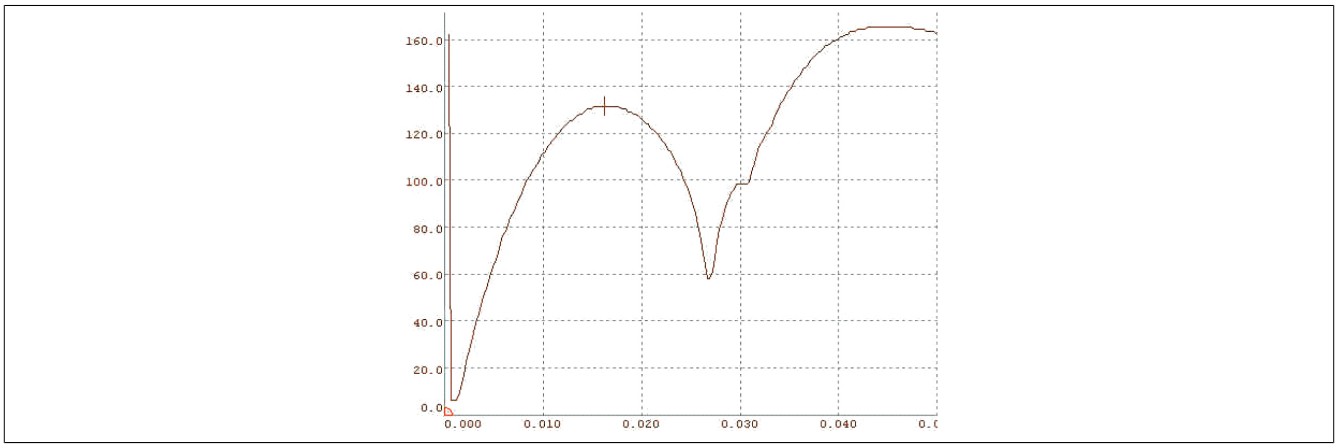


Figure 2: Search for the switching point with trace data from Automation Studio

The difference between the "current high-point" (P1 = 131) and the subsequent low-point (P2 = 58) is calculated (P1 - P2 = 73). The module compares this difference to the configured parameter dI.

If the difference measured by the module is larger than the configured dI value, then the first condition for a switching point search is met:

- In the module, the parameter dI should therefore be set to at least 72.

The next criteria is the time between P1 and P3. This must be larger than the value set for the parameter dt.

According to the trace data, this is 4.43 ms:

- In the module, the parameter dt should therefore be set to 43 (4430 µs / 100 µs).

With that, the second condition is met and a valid switching point can be detected.

It is recommended to avoid setting values all the way to the limits, since valves and relays change mechanically over time, which can lead to faulty readings (unless you wish to detect every minor deviation from the reference curve).

9.8.3 Modified switching point search (curvature method)

The described method for searching and detecting switching points by means of a low-point search in the current trace does not work with the desired reliability for some valve types or external influences (such as pneumatic pressure).

For this reason, an alternative method of switchover detection is provided. This method is based on an evaluation of the curvature of the current curve. In the module configuration, the user can select which method to use for switchover detection (see "Module configuration" on page 8).

The modified switching point search calculates the first derivative (slope) and then the second derivative (curvature) for every point in the current curve. At the switching point this second derivative has a local maximum, which is found by the module. More specifically, in order to improve the signal/noise ratio, a summation window is moved over the second derivative and the maximum of this summation is searched for.

This is not only valid when the current trace itself has a more or less low minimum in the switching point, but also in cases where the current increase only levels-out in the area of the switching point, but never becomes negative. Therefore, it can be said that the curvature method should generally be more sensitive.

Like the switching point search with the low-point method, valid switching points are configured using the parameters dI and dt. The meaning of these parameters is different here, however.

- dI - minimum curvature sum
- dt - width of the summation window in 1/4 X2X Link cycles

Meaningful values for this parameter can no longer be obtained simply by reading / measuring the current trace. That is why the module provides, in addition to the switching point (200th value of the current curve), also the following measurement and calculation values that can be used for the configuration:

Value X of the current curve	Description
1	1. Value of the current curve
:	:
197	Peak position of the first valid or highest invalid curvature peak
198	Height of the peak sum of the first valid or highest invalid peak
199	Width of the first valid or highest invalid peak (**Important:** not standardized to 100 µs)
200	255 at invalid peak, otherwise peak position in the current trace

When a valid maximum curvature has been found (Value 198 ≥ dI) then Values 197 to 199 represent the position (= Value 200), height and width of the first maximum that meets the criteria. Any higher and/or wider maximum that occurs later will not be found!

If no maximum curvature reaches the necessary height, then Values 197 through 200 represent the highest invalid maximum.

9.8.3.1 Determining the parameters dI and dt

dI << Value 198	Set dI much lower than 198
dt ≈ Value 199	dt should be set approximately the same as Value 199 **Note**: Maximum value for dt = 16

A certain amount of jitter in Value 198 must be assumed due to the high sensitivity of the modified switching point search. It is therefore recommended to monitor Value 198 over several switching cycles before setting dI with a safety clearance from the lowest monitored value.

As can be seen in the figures of the following examples, the switching point peak in the cumulative curves exceeds all other peaks by factors.

The switching point peak is also still the first peak that occurs in the positive range. Therefore, it should not be a problem to set dI far enough from the minimum of the Value198 and far above the highest peak that arises from the noise (or valve chatter).

Example 1:

Configuration example of the modified switching point detection for a valve with a distinctive switching point.

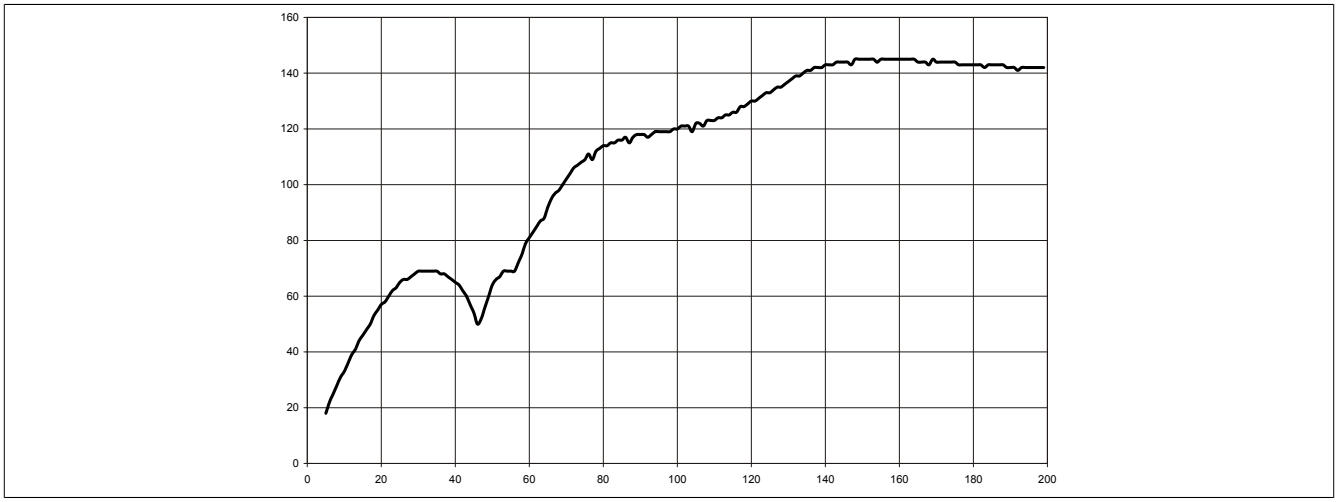


Figure 3: Example 1 - Valve current

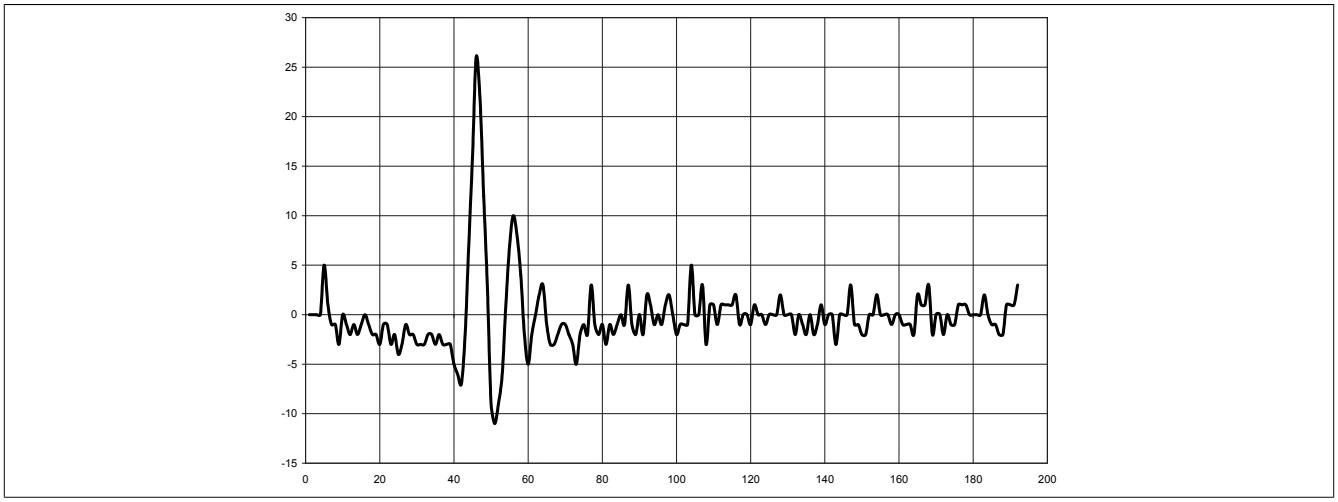


Figure 4: Example 1 - Calculated curvature (2nd derivative) of the current curve

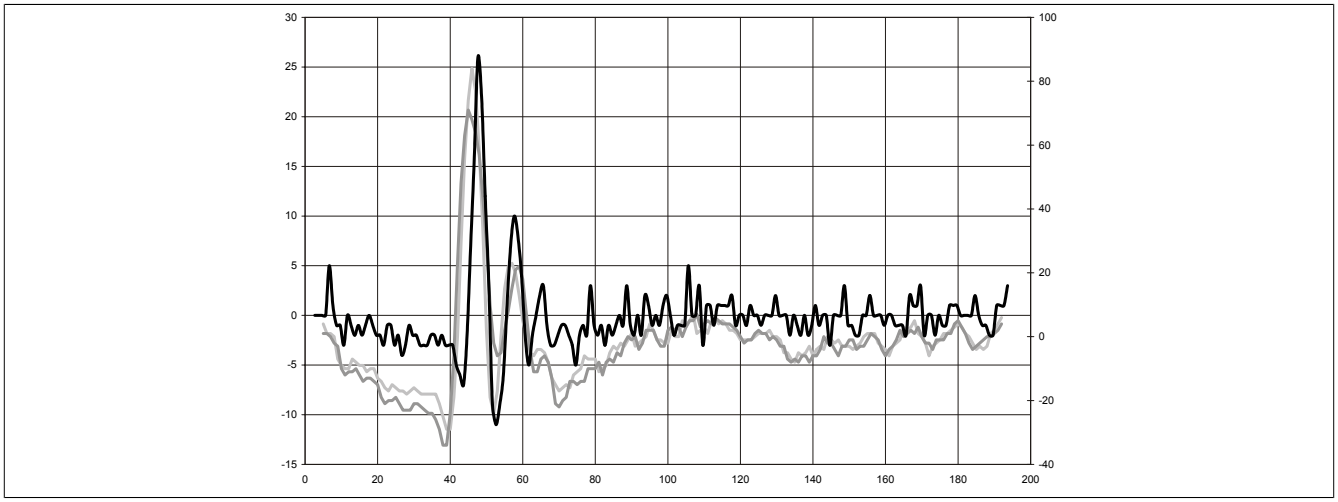


Figure 5: Example 1 - Calculated curvature (2nd derivative) of the current curve including overlapping sum with 3 different window widths

Example 2:

Configuration example of the modified switching point detection for a valve with a faintly distinctive switching point.

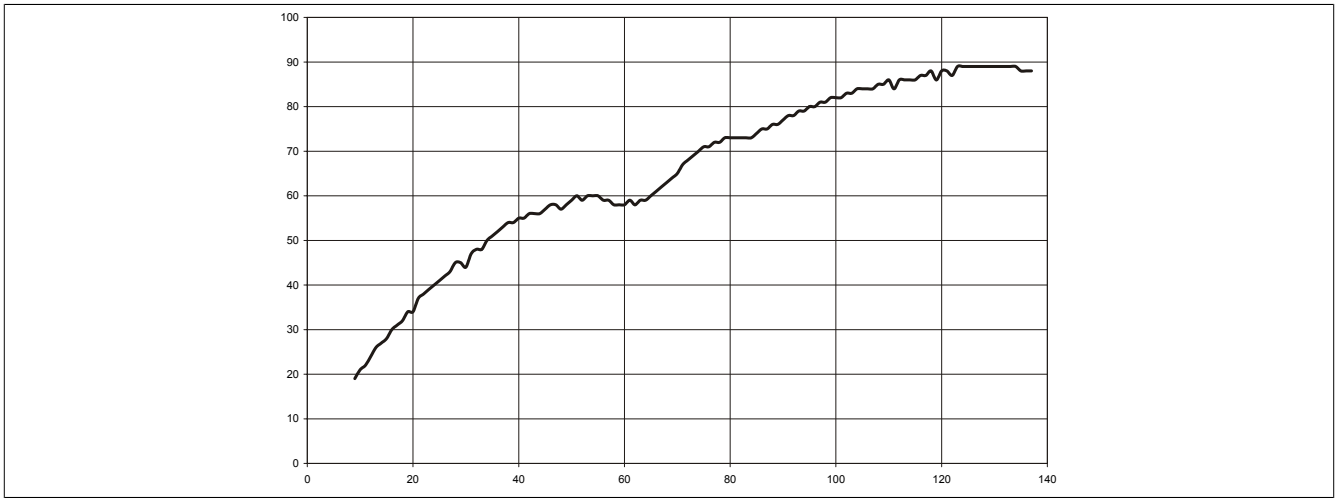


Figure 6: Example 2 - Valve current

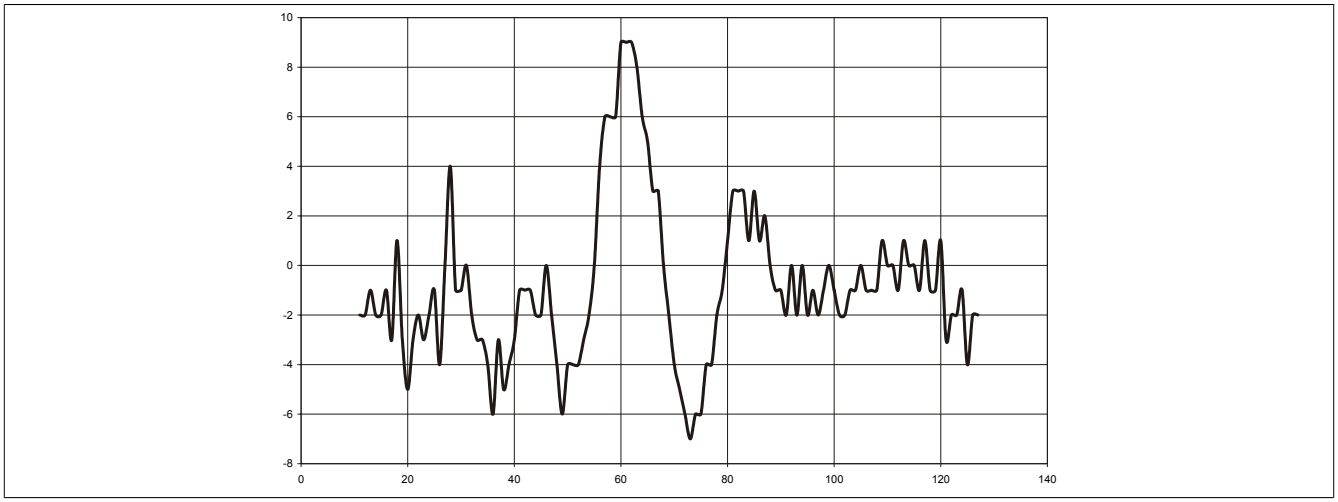


Figure 7: Example 2 - Calculated curvature (2nd derivative) of the current curve

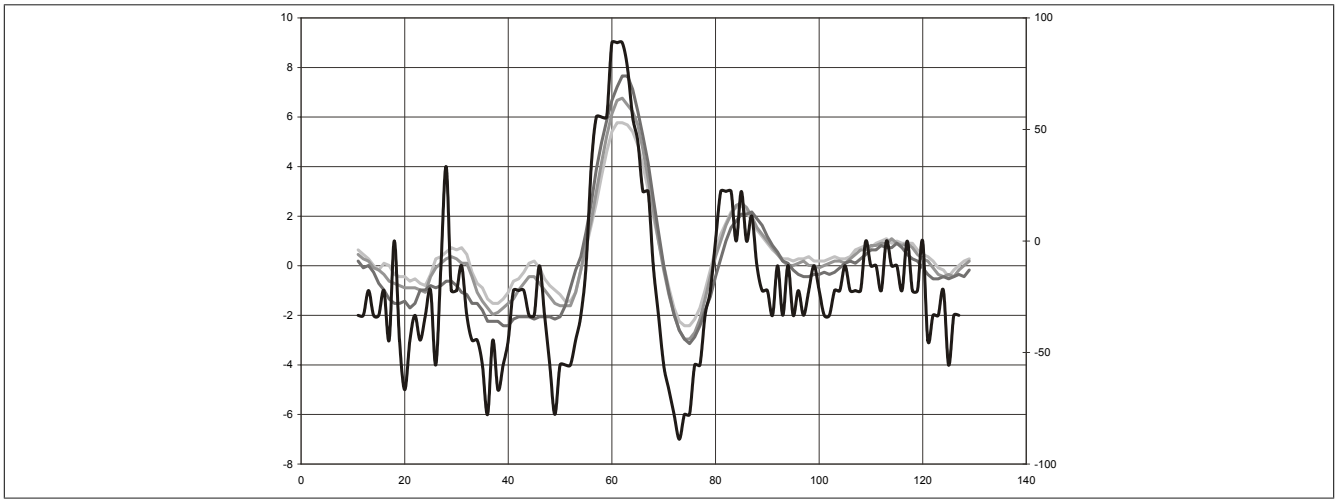


Figure 8: Example 2 - Calculated curvature (2nd derivative) of the current curve including overlapping sum with 3 different window widths