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Product Description

Amplifier Controller Combination MAC4.0

Special Features

- ❒ Amplifier with 2 voltage outputs
- ❒ Current output can be connected to either voltage outputs (Option C and N)
- ❒ PID-Controller with simple adjustment with pointer potentiometers
- ❒ Command signal input / influence of diameter change
- ❒ Smooth start and quick stop function
- ❒ Space saving standard housing
- ❒ Power supply and signal outputs galvanically isolated

Scope of Supply

- **Amplifier in DIN Rail Mount Enclosure**
- **Plug-in terminal blocks**
- **Standard** (Option U):
  2 voltage outputs, no current output

Versions

- **Option C:** 2 voltage outputs
  1 current output 4…20 mA
- **Option N:** 2 voltage outputs
  1 current output 0…20 mA

Additional Accessories

- **Option E:** Enlarged excitation supply 160 mA
- **Option F** (potentially explosive atmospheres):
  Use with safety barriers

Application

As a compact cost effective unit, the **MAC** is designed to provide a closed loop control function for strain gauge transducers (e. g. web tension measurement).
The MAC is optimized for use in electrical cabinets. There it can be DIN rail mounted or directly on a mounting plate.

The enclosure of the **MAC** contains an amplifier and controller.

The amplifier supplies the auxiliary power to the strain gauge transducers and conditions the output signals. Two voltage outputs with different filters are available.

The independend function of the current output (option C and N) can be connected either to the high or low dampened voltage output. The external use of as 10 Volts / 20 mA signal converter is also possible.

The PID components of the controller can be individually adjusted and also partially switched off. Additional adder and multiplier circuits enable the processing of other signals, e. g. diameter signal.

24 volts control signals can shut off the controller portion or gradually activate or deactivate the output signal.

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Controlsignal		Description of Functions
ISP	0 V	I portion switched off
	24 V	I portion active
RSF	0 V	Controller disabled (V_{14} = 0 V)
	24 V	Controller enabled (with smooth start)
RSP	0 V	Controller disabled(V_{14}) can be adjusted with level potentiometer)
	24 V	Controller enabled
RW	0 V	Roll change switched off
	24 V	Roll change switched active
COM		Common 0 Volts connection for 24 V control voltage

Dimensions in mm (terminal blocks incl.):
L × W × H: 100 mm × 105 mm × 110 mm

Ordering Data
MAC4.0-U
Option
Type

Ordering data option F:
Indicate the total resistance from measuring chain for option F (e. g. 350 Ohm):
MAC4.0-UF350

Technical Data		
Amplifier		
Strain gauge excitation supply	Voltage (V_4):	10 V
	Max. current:	60 mA
	Option E / Option F	160 mA
Zero adjust compensation voltage	(Relative to the voltage outputs)	- 25…0…+ 25 mV
Amplification	Adjustment range:	400…3200 V/V
	Standard factory adjustment:	667 V/V
Signal outputs	Voltage (V_2, V_3):	- 10…0…+ 10 V
	Min. load resistance:	5 kΩ
	Signal rising time (10…90 %)	V_2 filter 1: 7 ms…145 ms
		V_3 filter 2: 130 ms…4,8 s
Voltage/current converter		
Signal input	Voltage (V_6):	0…+ 10 V
Signal output	Current (I_1):	Option C: 4…20 mA,
		Option N: 0…20 mA
	Max. load resistance:	600 Ω
Controller		
Signal inputs	Voltage (V_8,V_9, V_{10},V_{11}, V_{12},V_{13}):	- 10…0…+ 10 V
	Voltage (ISP, RSF, RSP,RW):	24 V at terminal COM
Signal outputs	Voltage (V_{14}):	- 10…0…+ 10 V
	Min. load resistance (V_{14}):	5 kΩ
	Reference voltage (V_7):	10 V ± 0,5 %
Temperature range		0...60 °C
Terminal cross-section		AWG 22-12
Standard enclosure protection		IP 20
Power supply voltage *)	Voltage (V_5):	24 V DC, ± 10 %
	Current consumption (at 24 V):	appr. 150 mA
	Fine-wire fuse:	0,4 AT

*) The power supply voltage V_5 must be grounded. In the power supply loop the current of the supply voltage should not be exceed 2 Amps.

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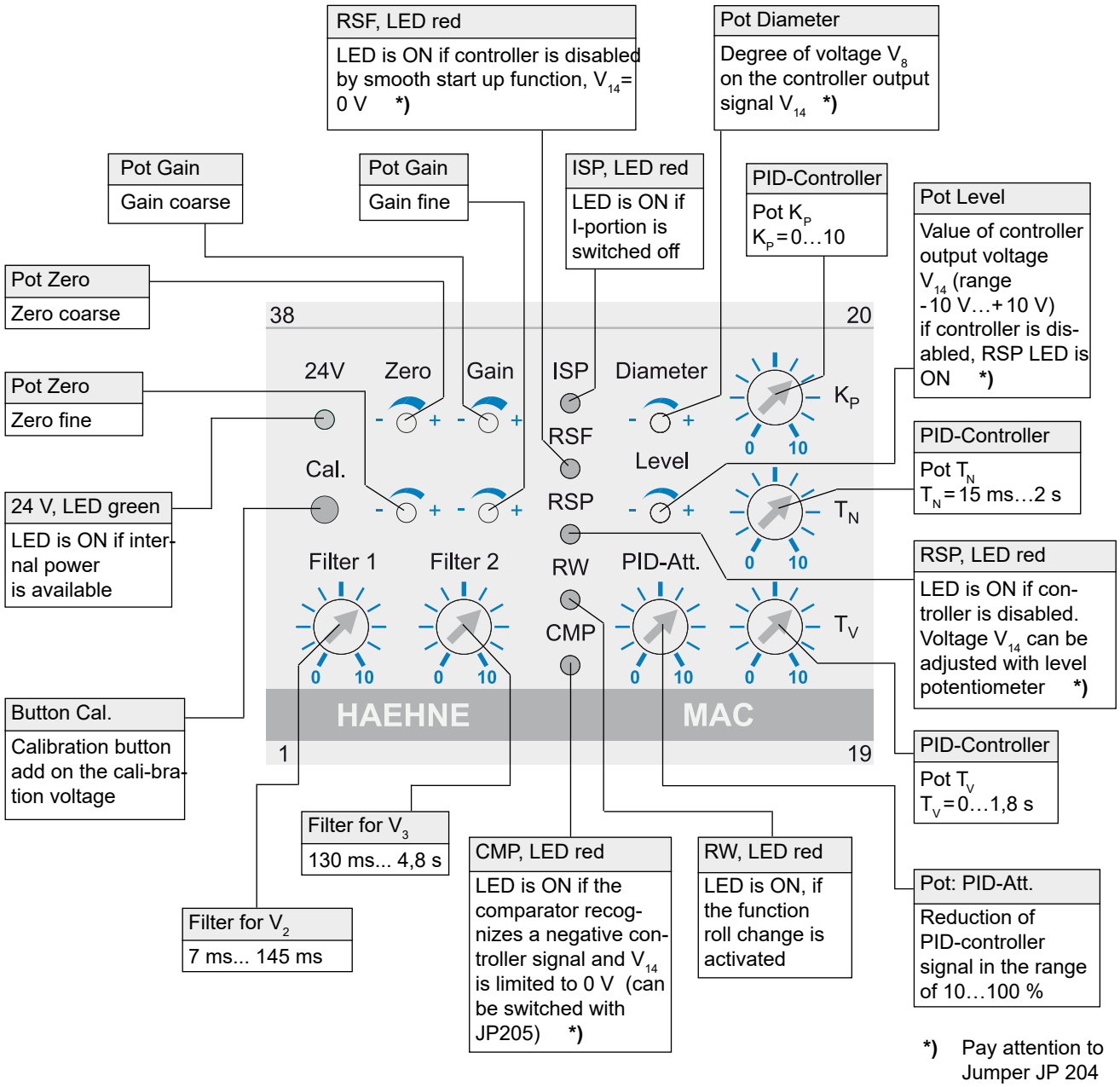
Technical Information

Amplifier-Controller-Combination MAC4.0

Upper Terminal Block

No.	38	37	36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	21	20
Function	GND	V_{14}	GND	V_{13}	GND	V_{12}	GND	V_{11}	V_{10}	GND	V_9	V_8	GND	V_7	COM	RW	RSP	RSF	ISP



*) Pay attention to Jumper JP 204

Lower Terminal Block

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Function	24V	24V	0V	0V	PE	V_6	I_1	GND	V_2	GND	V_3	V_{4+}	V_{4-}	V_{1+}	V_{1-}	V_{4+}	V_{4-}	V_{1+}	V_{1-}

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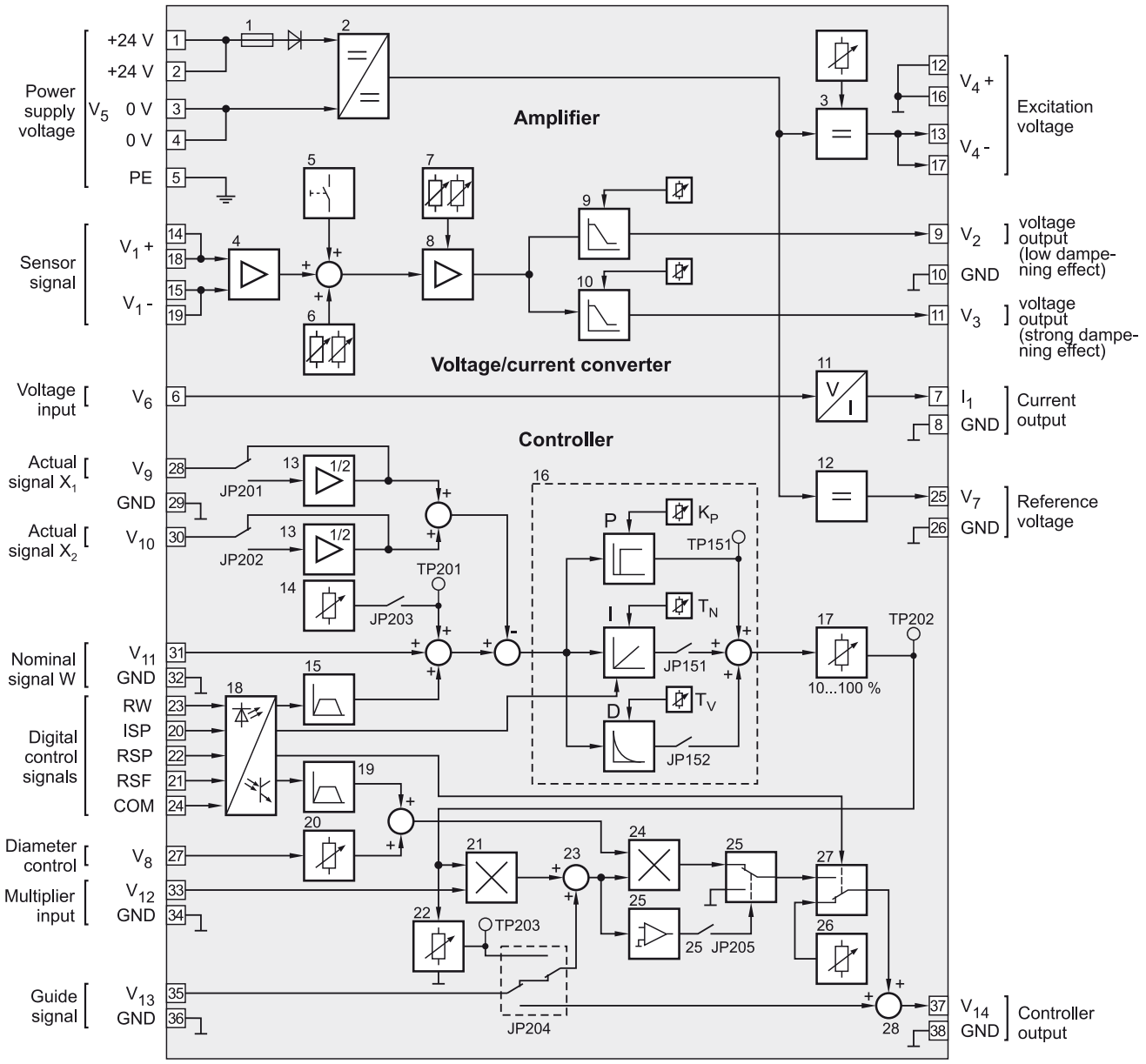

1 Fine-wire fuse 0,4 AT
2 DC/DC converter for galvanical isolation of 24 V supply
3 Excitation voltage V_4 = 10 V
4 Input amplifier
5 Calibration button
6 Zero adjust potentiometer: ‘coarse’, ‘fine’
7 Pot.: Gain ‘coarse’, ‘fine’
8 Second gain stage
9 Low pass filter 1 (low dampening effect)
10 Low pass filter 2 (strong dampening effect)
11 Voltage/current converter (Option C: 4...20 mA or Option N: 0...20 mA)
12 Reference voltage V_7 = 10 V
13 Halving of actual signal
14 Pot. for internal reference signal
15 Roll change
16 PID-controller
17 Pot PID-Att: Reduction of PID controller signal in the range 10…100 %
18 Galvanic isolation of the digital control signals
19 Ramp function for smooth start/smooth stop
20 Pot diameter: Influence of diameter
21 Multiplier
22 Basic adjustment of PID signal (0...30 %)
23 Adder 1
24 Multiplier for smooth start and V_8
25 Voltage comparator: suppression of negative output signals **)
26 Pot Level:Value of V_{14} if controller lock is activated **)
27 Switching of controller lock
28 Adder 2

**) Pay attention to Jumper JP 204

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Description of function

Amplifier-Controller-Combination MAC4.0

Description of function

The amplifier and controller combination **MAC** consists of three functional blocks: the strain gauge amplifier, the voltage/current converter and the PID controller with special functions.

Measuring amplifier
The measuring amplifier supplies the connected sensor (strain gauge full bridge) with the bridge supply voltage V_4. The signal voltage V_1 of the connected sensor ist amplified in the amplifier stage (8)*. The signal voltage V_1 then passes two filters with different low pass characteristics (9,10).
The amplification is adjusted with the gain pots "coarse', 'fine' (7). The zero adjust potentiometer 'coarse' and 'fine' (6) allow the adjustment of the output voltage V_2 and V_3 to 0 V even with a preload of the sensor. (See adjustment instruction.)

Calibration button
The button 'Cal' (5) switches a reference voltage to the amplifier stage which simplifies the adjustment of the gain pots "coarse' and 'fine' to a predetermined value.

Voltage/Current converter (Option C and N)
The integrated voltage/current converter (11) changes the voltage applied to the voltage input (p. e. V_2) to an appropriate current signal. According to the selected option (JP3/JP4) input voltages of 0...10 V are converted into current from 0...20 mA(option N) or 4...20 mA (option C) respectively.

Controller with special function
The controller portion of the **MAC** contains a complete PID controller, analog and arithmetic functions as well as control input to realize special applications.

PID controller
The control difference resulting from the comparison between the nominal value (V_{11}) and actual value (V_9+V_{10}) is fed into the primary PID controller (16). Via jumper JP151/JP152 the I- and D-portions can be enabled individually.
With the potentiometers K_P, T_N and T_V on the front cover the control parameters are adjusted according to the desired close control loop characteristic. The potentiometer 'PID-Att.' (17) can be used to select the signal level of the PID output for further processing.
If in case of two sensors the sensor signals need to be seperatly amplified and displayed, then the second input X_2 (V_{10}) for actual values can be used for the additional amplifier. In order to determine the average it is necessary to halve the voltages with the jumpers JP201/202.
If an external nominal value pot should not available and the nominal value should not be changed under operating conditions, then it is possible to make the internal nominal value pot available via jumper JP203. The nominal value adjusted with pot P201 can be measured at TP201.

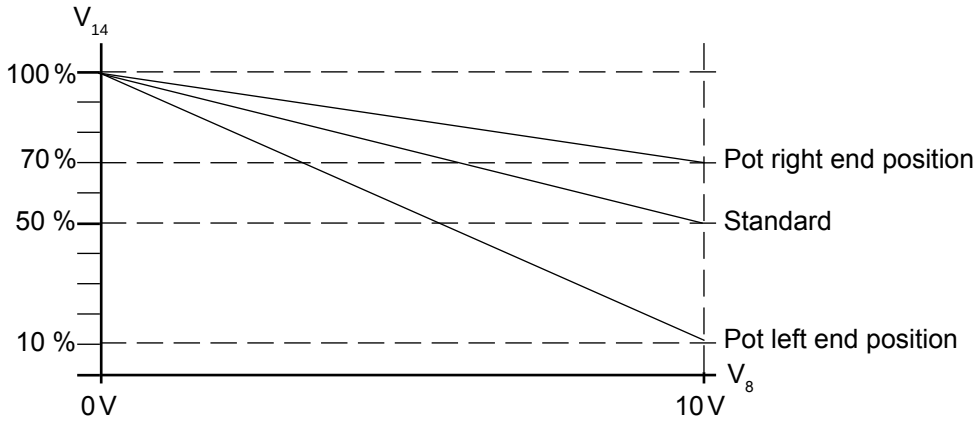
Multiplier input
A voltage applied to terminal 33 (V_{12}) influences the value of the PID output signal. In case of 10 V the signal is 100 % available, in case of 0 V the PID output signal is completely blocked. A voltage must always be applied to this input.In case of the appropriate position of jumper JP204 the base signal of the PID output can be adjusted between 0 and 30 % with the internal pot P202 (22).

Adder
If jumper JP204 is in the appropriate position and the voltage is applied to terminal 35 (V_{13}) then this voltage is added to the dampened PID signal via the integrated adder 1 (23). It is very important that the terminal 35 (V_{13}) is always connected. If the adder function is not necessary, it should be connected to GND.
If the additional functions (e. g. controller blockage, comparator) should not affect the voltage V_{13} at terminal 35 than it is necessary to switch the voltage onto the adder 2 (28) via jumper JP204.

*see designation in blockdiagram from adjustment instruction "Amplifier-Controller-Combination MAC 4.0"

Comparator *)
Negative voltages at the controller output V_{14} can be surpressed by the internal comparator (25). With jumper JP205 in position 1-2 this function is active. The red LED 'CMP' signals that the comparator recognizes a negative signal and limits the output of the voltage to 0 V.

Influence of diameter *)
The voltage at terminal 27 (V_8) has an effect on the level of the controller output signal V_{14}. The voltage V_8 has an influence of various dergrees on V_{14} (see sketch below) depending on the adjustment of the potentiometer 'diameter' (20).



The following description applies to the control to the special functions which can be enabled via control inputs. The control input (21) are galvanically isolated from the remainder circuits of the **MAC** and are controlled with 24 V DC.

I-switch off (ISP)
Control input ISP enables a switch off of the I-portion of the PID controller independent of the position of jumper JP 151. If there is no voltage at input ISP, then the I-portion is switched off - the red LED: 'ISP' is ON. In order to activate the I-portion (precondition: jumper 151 in position 1-2) it is sufficient to apply 24 V between terminals ISP and COM; the LED 'ISP' switches OFF.

Controller disabled with smooth start (RSF) *)
In contrast to the function 'controller disabled' here the controller output signal V_{14} is continuously lowered toward 0 V. This applies when there is no voltage at input RSF - LED 'RSF' is ON. If 24 V are applied to the input, the voltage V_{14} returns slowly to its original value.(approx. 9 sec.)

Controller disabled (RSP) *)
This function allows the immediate reduction of the controller output signal V_{14} to an adjustable value. Under normal operating conditions of the controller, 24 V (relative to terminal COM) are applied to the controller input RSP. If this voltage is switched off the controller output V_{14} returns immediately to the voltage level adjusted with potentiometer 'level' (26) - LED 'RSP' is ON.

Roll change over (RW)
If 24 V is applied to this input then approximately 14 V are added to the external reference value. If this function is used (as intended) for performing "roll change" than the actual value is very small or zero. This means that the controller output rises to maximum positive value. If the controller input signal 'RW' is switched off again, then the controller returns to the operation governed by the external reference value. This switch over is controlled by a ramp function and accomplished slowly without jumps.

*) Pay attention to Jumper JP 204

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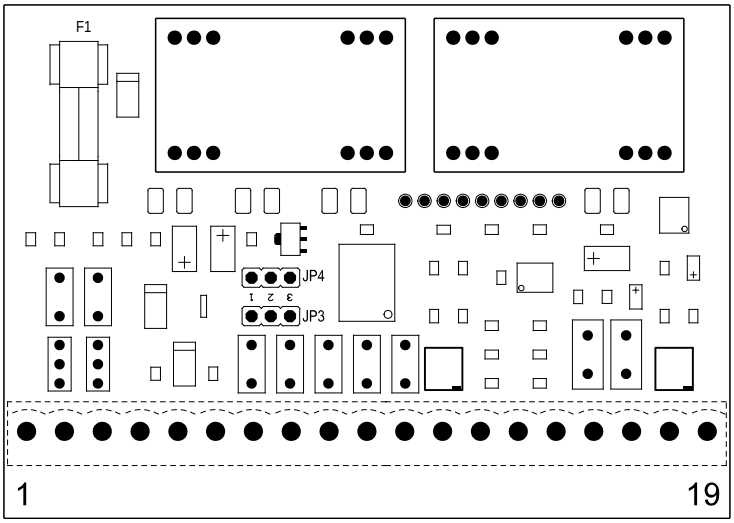
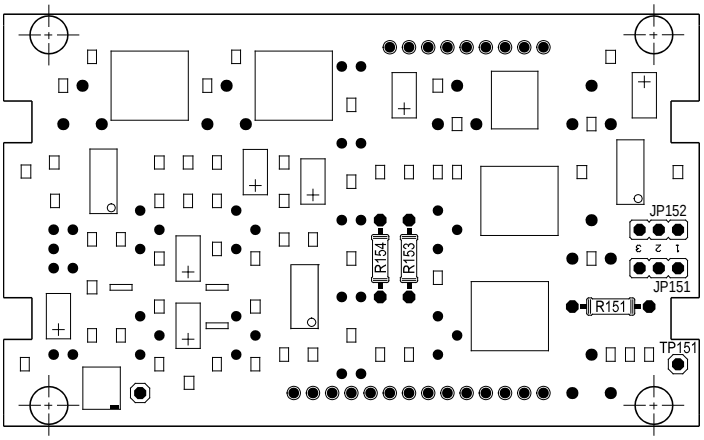
Adjustment instruction

Amplifier-Controller-Combination MAC4.0

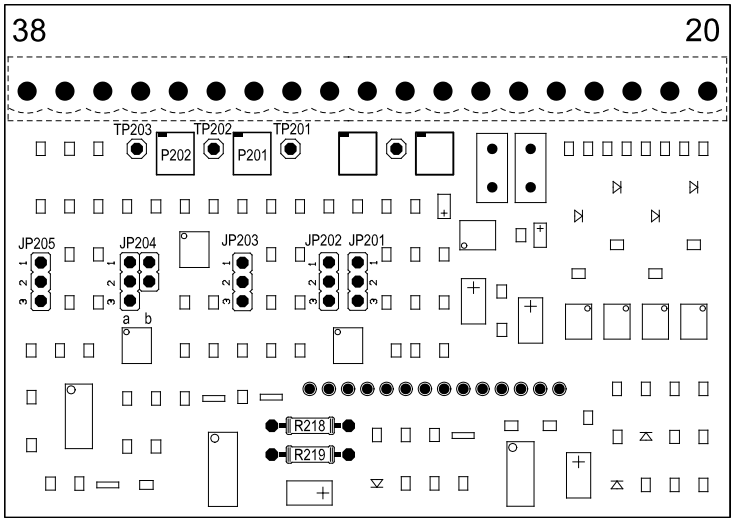
Amplifier/Converter PCB



Front PCB



Controller PCB



JP3 JP4	Current output
1 - 2	0...20 mA
2 - 3	4...20 mA

F1	Fine-wire fuse
0,4 A; slow blow	

JP151	I-portion
1 - 2	on
2 - 3	off

JP152	D-portion
1 - 2	on
2 - 3	off

R151	Resistor for adjusting the value range of K_P
$K_p = 0... \frac{100\ k\Omega}{R151}$ *)	

R153 R154	Resistors for adjusting the value range of T_N
$T_N = \frac{R154}{R153+R154} \cdot (15\ ms...2\ s)$	
$R154 > 10\ k\Omega$ *)	

JP201 JP202	Halving of actual signal
1 - 2	on
2 - 3	off

P202	Basic adjustment of PID signal
0...30 %	

P201	Internal reference value pot
0...10 V	

JP203	Internal standard reference value
1 - 2	on
2 - 3	off

JP205	Com-parator
1 - 2	on
2 - 3	off

JP204	Flexible wiring of adder
	Command signal V_{13} on adder 1
	Command signal V_{13} on adder 2
	basic adjustment of PID-signal on adder 1
	basic adjustment of PID-signal on adder 1, command signal V_{13} on adder 2

R218 R219	Resistors to change the rising-/descending times of RSF
rising-/descending times	about $\frac{R219}{1\ M\Omega}$ (9 s)
constant $\frac{R218}{R219} = 2$	$R219 > 10\ k\Omega$ *)

*) Please pay attention to the tolerance.

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All adjustments should be made approximately 10 minutes after applying power in order to insure stable temperature distribution within the amplifier controller unit.

Controller

The adjustment of the controller is made according to the following steps:

1. The desired control function (P, PI, PD, PID) is selected with jumpers JP151 and JP152.
2. Pot K_P on position 3, pot T_N on position 3, pot T_V on position zero, and pot 'PID Att.' on position 8.
3. Wire amplifier-controller-combination **MAC** according to wiring examples.
   Connect control inputs ISP, RSF, RSP, RW as well as analog inputs $V_{8,}$ $V_{12,}$ V_{13}.
   It is mandatory that all these inputs are connected.
4. Apply power and allow for 10 minutes warm-up.
5. Calibrate amplifier if necessary (see below).
6. Adjust control parameters K_P, T_V and T_N for optimum control.
   If necessary change controller level with potentiometer ’PID-Att.‘.

Measuring amplifier

Calibration of the closed loop control system consisting of sensor and the amplifier/controller unit **MAC** should be made according to the following steps:

1. Connection of voltmeter with V range to the undampened output V_2 of the amplifier/controller unit **MAC**.
2. Zero adjustment of the completely installed strain gauge sensor after the roll weight of the web tension sensor has been completely compensated. However, the web (foil, paper, …) is present to generate tension.
3. Use the zero-adjust potentiometers ’coarse‘ and ’fine‘ in order to adjust the voltage V_2 to a value close to 0 V.
4. Adjust voltmeter to measuring range > 10 V.
5. Apply the force close to the strain gauge web tension sensor acting under normal condition. The calibration load should be 80 to 100 % of regular operating load. Adjust output signal V_2 with gain pots ‘coarse' and 'fine' to the desired value (as the rule V_2 = 10 V). In case the calibration load is smaller than the nominal force (but at least 30 %), V_2 should be adjusted corresponding to the smaller value.
6. Remove force from strain gauge sensor and check output signal. If the current zero value differs considerably from the previous adjustment, then it is necessary to repeat the adjustment described under the points 2 to 5.

Alternatively to the above described adjustment procedure of the amplifier, the desired gain can also be calculated based on available data, e. g. web geometry. The amplification is adjusted by pushing the calibration button ’Cal‘ and adjusting the gain pots 'coarse, fine' as follows:

$$V_2 = 2{,}5\ \text{mV} \cdot \text{Gain}_{\text{total}}$$

Attention: Zero adjustment must have been completed prior to the above. This means that V_2 is approximately 0 V if the calibration button ’Cal‘ is not pushed.

(The gain can be adjusted with the calibration button, if, in case of an exchange of the unit, no calibration weight is available. Execute steps 1 to 4 of the above procedure. Afterwards keep calibration button "Cal" pressed in order to adjust V_2 to its original values with the calibration pots "coarse and fine". This voltage can be determined after the calibration of the system (after step 6) by pressing calibration button "Cal" and noting the voltage V_2.)

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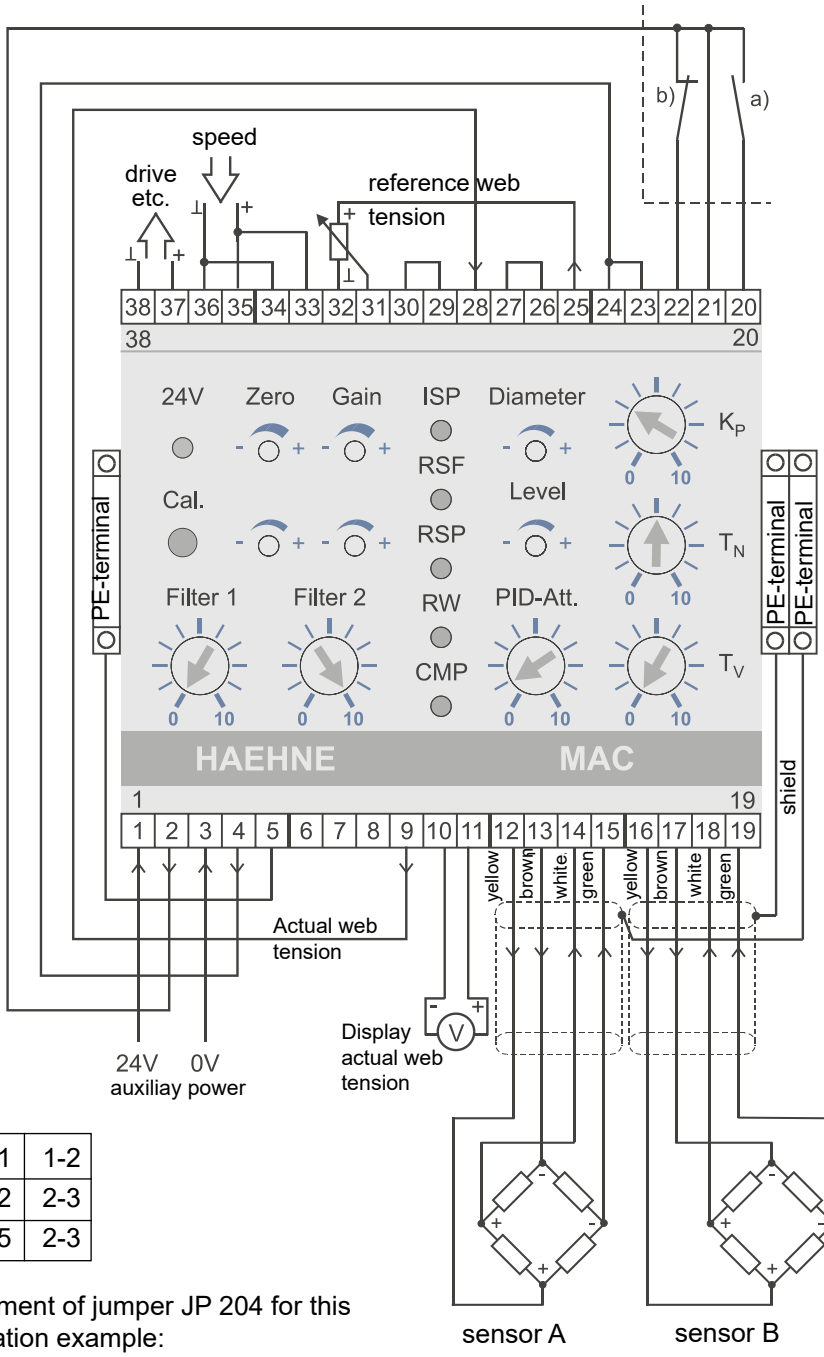
Application Examples

Amplifier-Controller-Combination MAC4.0

Operation Mode **A** (see : "Controller Operation Mode MAC4.0")

- **Reference signal of web tension adjusted with external pot**
- **Control inputs connected to PLC**
- **Control signal is speed dependant**



external contacts
(e. g. PLC)

a) ISP
I-portion only after release

b) RSP
Controller disabled
Quick stop

JP 151	1-2
JP 152	2-3
JP 205	2-3

Adjustment of jumper JP 204 for this application example:
Guide signal V_{13} on adder 2 and basic adjustment of PID-signals on adder 1

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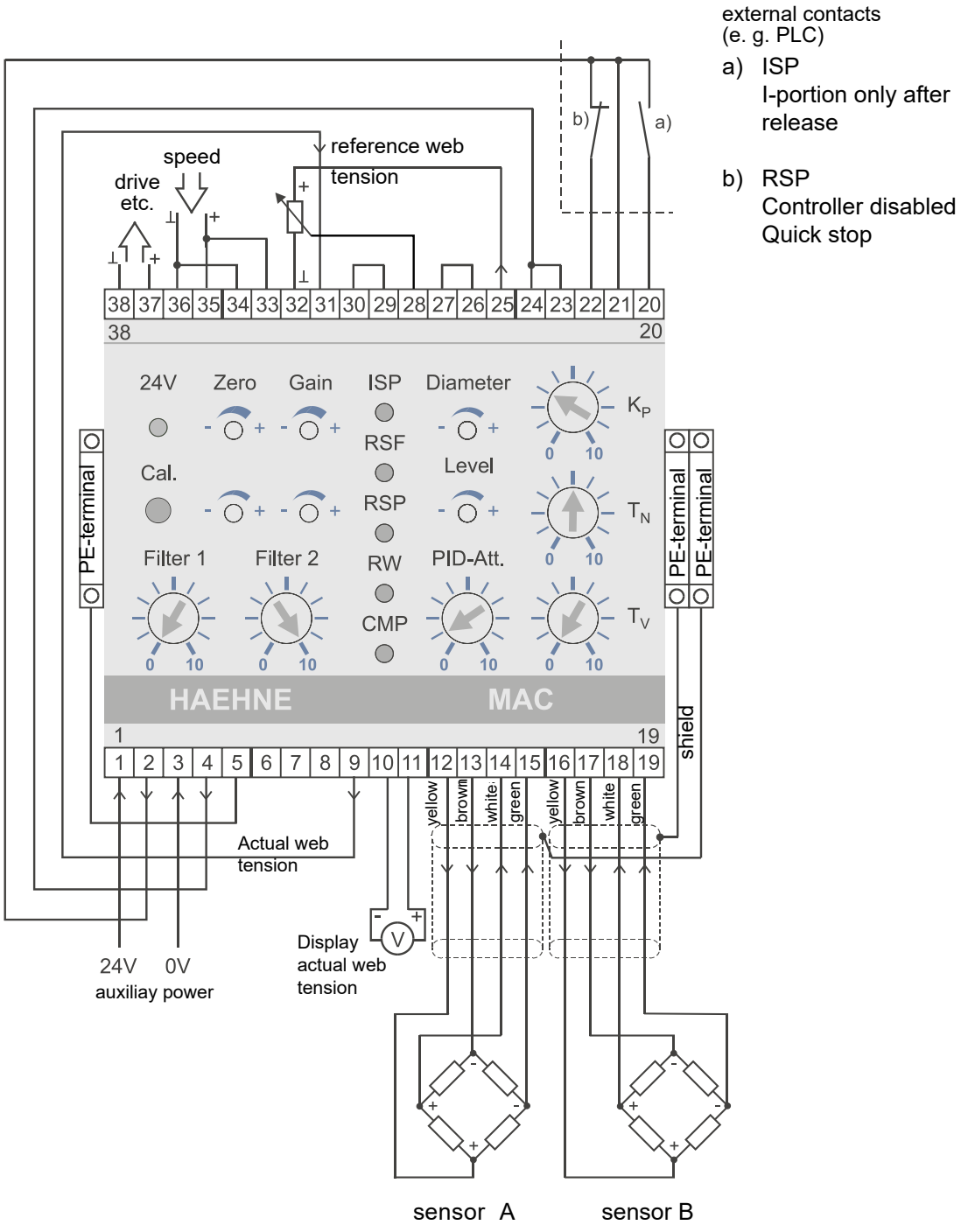
Operation Mode B

(see : "Controller Operation Mode MAC4.0")

- **Reference signal of web tension adjusted with external pot**
- **Control inputs connected to PLC**
- **Control signal is speed dependant**



JP 151	1-2
JP 152	2-3
JP 205	2-3

Adjustment of jumper JP 204 for this application example:
Guide signal V_{13} on adder 2 and basic adjustment of PID-signals on adder 1

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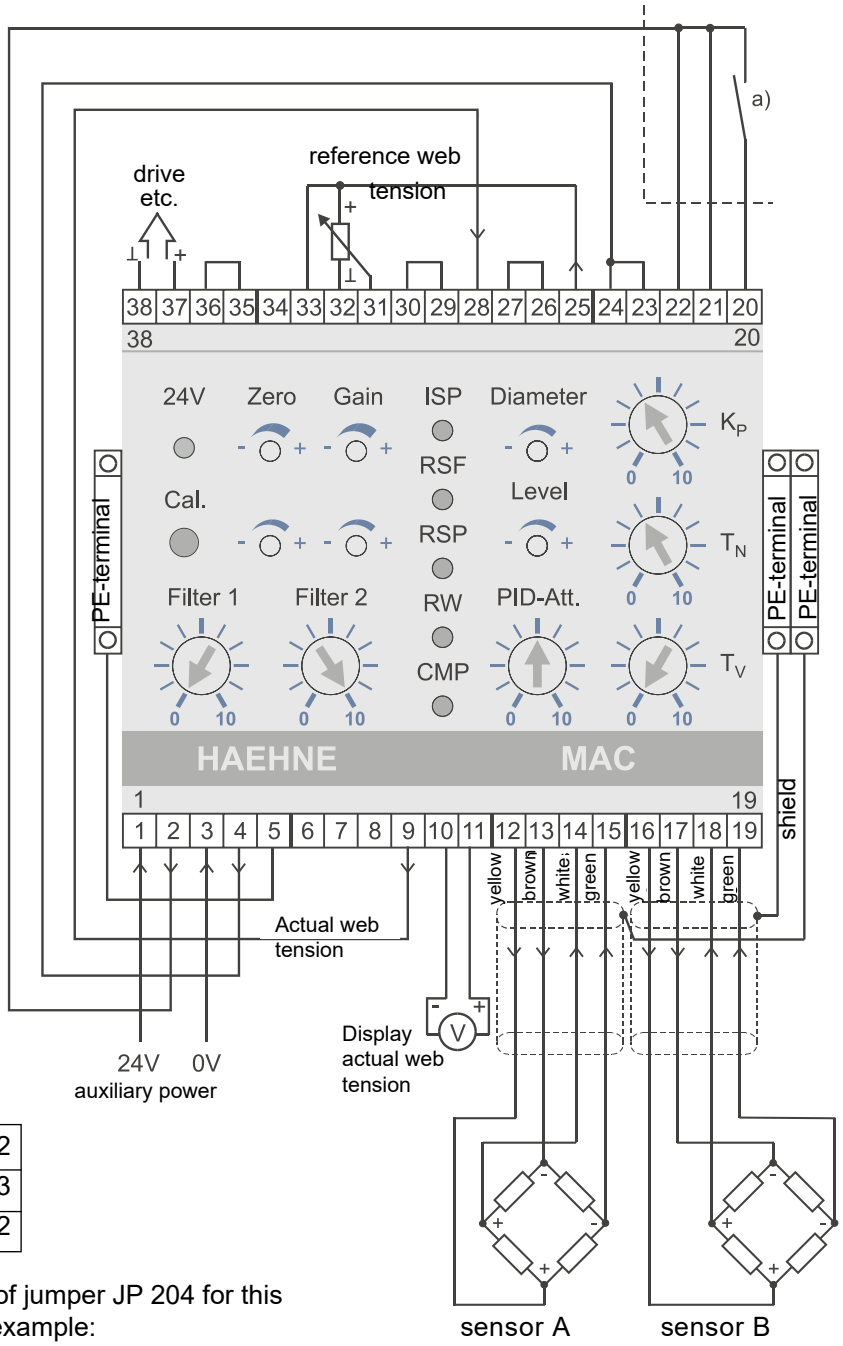
Application Examples

Amplifier-Controller-Combination MAC4.0

Operation Mode **C** (see : "Controller Operation Mode MAC4.0")

- Reference signal of web tension adjusted with external pot

- Control inputs connected to PLC



JP 151	1-2
JP 152	2-3
JP 205	1-2

Adjustment of jumper JP 204 for this application example:
Guide signal V_{13} on adder 1

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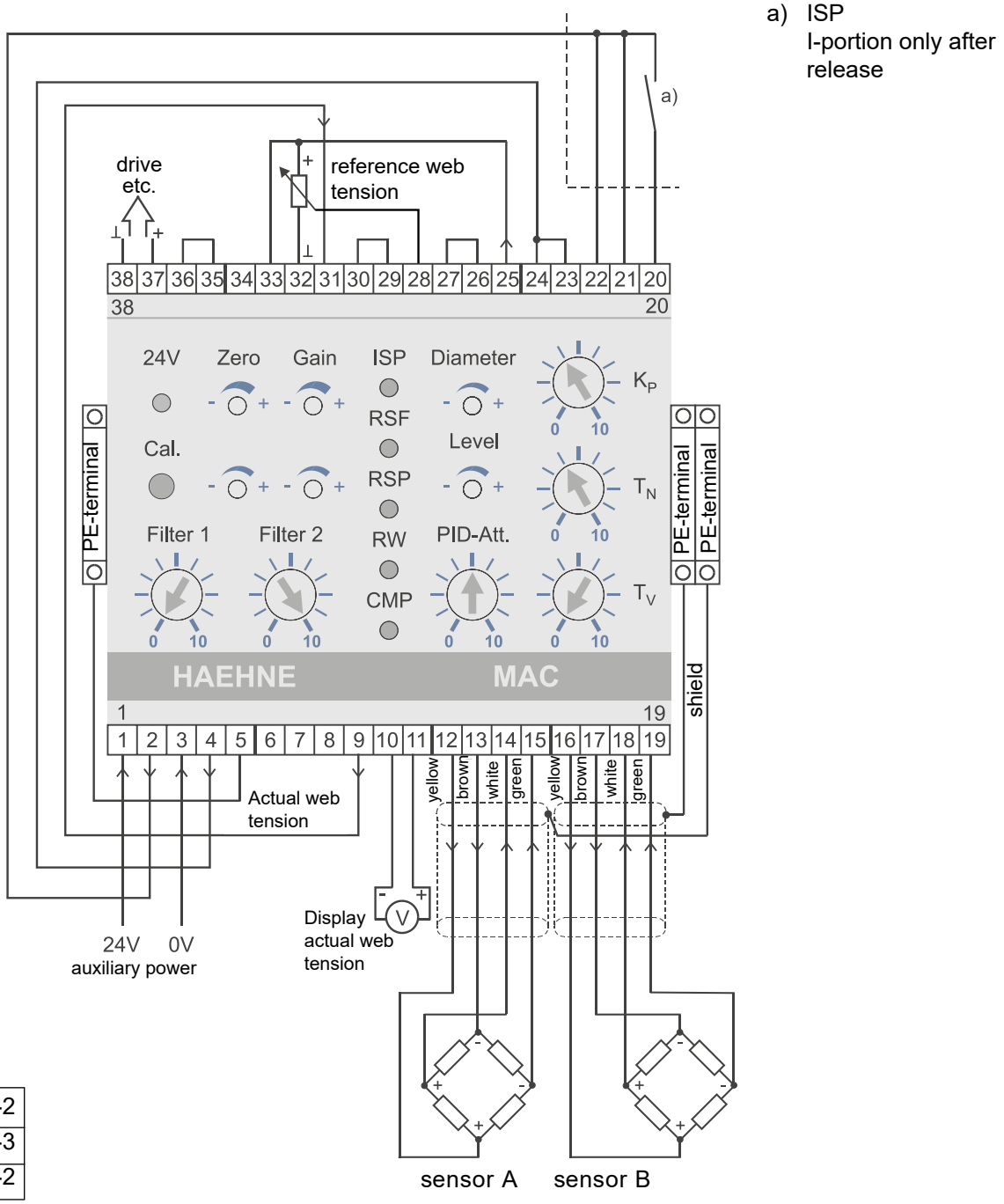
Operation Mode D

(see : "Controller Operation Mode MAC4.0")

- Reference signal of web tension adjusted with external pot

- Control inputs connected to PLC



JP 151	1-2
JP 152	2-3
JP 205	1-2

Adjustment of jumper JP 204 for this application example:
Guide signal V_{13} on adder 1

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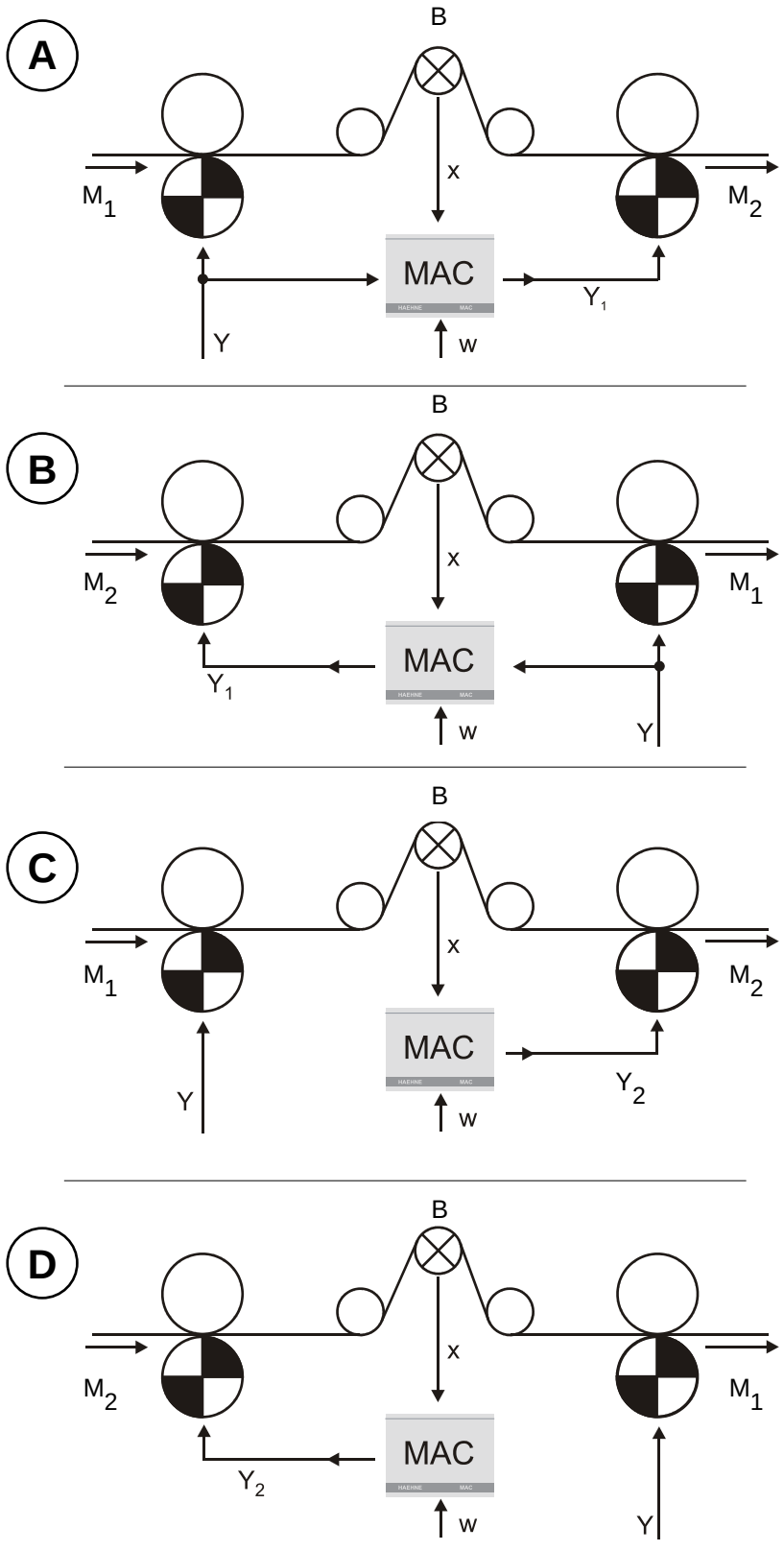
Controller Operation Mode

Amplifier-Controller-Combination MAC4.0



Main features of all operating modes:
The main drive is determined by the process and independent of the web tension

Operation mode A and B:
The guidance signal of the machine (Y) is corrected independently of the web tension (Y_1).

Operation mode C and D:
The web tension control loop is independent.

Operation mode A and C:
In the process the measuring roll is acting before the controlled drive,

M_1:	Main drive
M_2:	Controlled drive
B:	Mesasuring roll
w:	Reference signal of web tension
x:	Actual signal of web tension
y:	Reference rotational speed
y_1:	Revised rotational speed - reference value
y_2:	Calculated rotational speed - reference value

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