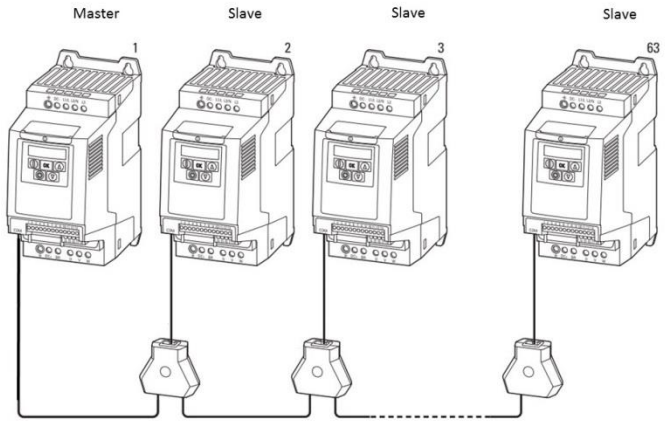
PowerXL™

DA1 Variable Frequency Drives
Master Slave Operation



Level 2	1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended

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Contents

Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Frequency inverters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters using the operating software are permitted.
- All covers and doors must be kept closed during operation.
- To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).
  – Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).
  – Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

Disclaimer

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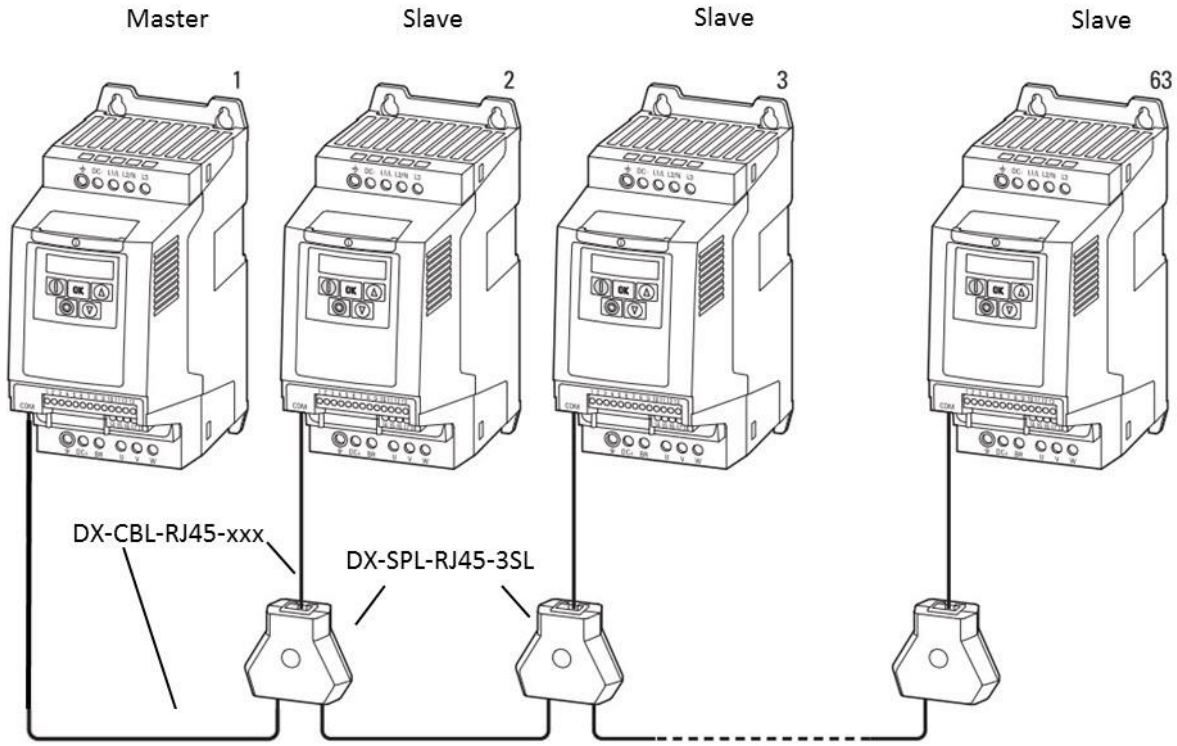
General

The master slave function is part of the standard device and doesn't need additional hardware except patch cables and splitters. The communication between the master and the slave drives uses the OP System Bus (see AP0040026EN).

The master drive as well as the slave drives have to be from the series DA1.

This Application Note describes

- the functionality of the master slave operation
- the configuration
- application examples



The functions described here, refer to an application software version 2.0 and above (see parameter P0-79).

Functionality

The master drive sends its status (Stop, operation, sense of rotation …) as well as its output frequency every 30 ms to the connected slave drives. The slave drives follow the information they received from the master drive and the output frequency of the master becomes speed reference for the slaves. Different settings of the max. frequency (f-max = P1-01) at master and slave drive are irrelevant. These values are only limits. Please note that this is a speed regulation and not a control with angular synchronism.

In this mode the speed of each slave is limited by the settings for the minimum (= f-min (P1-02)) and the maximum (= f-max (P1-01)) speed / frequency. This means for example, that in case the minimum frequency is higher than the one coming from the master, the slave runs with the speed set with P1-02, and doesn't follow the master speed as long as this value is below the one of P1-02. In those cases, where the slave has to follow the master all the time, P1-02 can remain at 0 Hz.

During acceleration and deceleration the dynamic of the slave drive is limited by its own ramp. This leads to longer acceleration and deceleration times when the ramp times are longer than those of the master drive. See also example 5.

The speed reference of each slave drive can be scaled and enables an individual adaptation (see firther below „ SlaveSpeedScalingControl (P2-28) and SlaveSpeedScalingFactor (P2-29)").

Configuration

Configuration of the network

The connection between the devices themselves is carried out via OP System Bus.

The addressing is done with P5-01. “PDP Address” of the master drive MUST be set to “1”. Further up to 62 slave drives may have an arbitrary and unique address in the range from 2 to 63.

Behavior in case of breakdown

Breakdown of the master drive:	The slave drives stop (STOP is displayed).
Breakdown of a slave drive:	The master drive continues to run.

Configuration of the master drive

The master drive doesn’t require any special configuration, but will be configured application dependent. Only condition: Parameter P1-12 may NOT be set to “5”, because this mode is exclusively for drive working as slaves.

The master drive can be controlled via terminals (P1-12 = 0), but a control via field bus is also possible. Please note that parameter P5-01 doesn’t only determine the address at the OP System Bus, but also the one at a field bus. This means that the field bus has to be configured in a way that the master drive gets the address “1”.

Configuration of the slave drive

The up to 62 devices must configured as slaves → P1-12 = 5

At each slave drive P5-01 has to be set to an arbitrary value in the range of 2 … 63. Please note that parameter P5-01 doesn’t only determine the address at the OP System Bus, but also the one at a field bus.

Hint:
During operation the reaction time of the slave drives on speed variations coming from the master is limited by the ramps. If the ramp times of the slave are longer than those of the master a speed difference will appear during transition periods. The ramps of the slave drives have to be set as short as possible, in any case shorter than those of the master, taking a possible speed scaling factor into account. See also example 5.

Terminal configuration of the slave drive

The terminal configuration can be selected with P1-13 out of predefined sets. The configuration changes depending on the setting of P1-12. For master-slave-operation it is as follows:

P1-12 = 5: Slave-Mode					
P1-13	DI1	DI2	DI3	DI4/AI1	DI5/AI2
0	User defined	User defined	User defined	User defined	User defined
1	START	INV	Select BUS REF / f-Fix	without function	Select f-Fix Bit0
2	Not allowed				
3	Not allowed				
4	START	INV	Select BUS REF / f-Fix1	without function	Select t-dec1 / t-dec2
5	START	INV	Select BUS REF / AI2 REF	without function	AI2 REF
6	START	INV	Select BUS REF / f-Fix1	without function	EXTFLT
7	Not allowed				
8	Not allowed				
9	START	INV	Select f-Fix Bit0	Select f-Fix Bit1	Select BUS REF / f-Fix
10	START	INV	without function	without function	Select BUS REF / f-Fix1
11	Select Quick-dec		Select BUS REF / f-Fix	without function	Select f-Fix Bit0
12	Not allowed				
13	Not allowed				
14	Select Quick-dec		Select BUS REF / f-Fix1	without function	Select t-dec1 / t-dec2
15	Select Quick-dec		Select BUS REF / AI2 REF	without function	AI2 REF
16	Select Quick-dec		Select BUS REF / f-Fix1	without function	EXTFLT
17	Not allowed				
18	Not allowed				
19	Select Quick-dec		Select f-Fix Bit0	Select f-Fix Bit1	Select BUS REF / f-Fix
20	Select Quick-dec		without function	without function	Select BUS REF / f-Fix1
21	Not allowed				

Function of the terminals:

<table>
<tr><td>AI2 REF</td><td>Analog input AI2 (terminal 10) is used for speed reference
P2-33: Configuration (voltage input / current input …)
P2-34: Scaling
P2-35: Offset</td></tr>
<tr><td>EXTFLT</td><td>External fault. Enables the inclusion of an external signal into the fault messages of the drive. During operation a High signal has to be present at the terminal. A Low signal leads to a trip of the drive with the message „E-tr iP“</td></tr>
<tr><td>INV</td><td>Inversion of the sense of rotation, using the ramps set inside the drive. Low = no inversion, High = inversion</td></tr>
<tr><td>Select BUS REF / AI2 REF</td><td>Selection between references. Low = Reference coming from the master drive, High = AI2</td></tr>
<tr><td>Select BUS REF / f-Fix</td><td>Selection between references. Low = Reference coming from the master drive, High = Fixed frequency. The fixed frequency itself is selected with „Select f-Fix Bit 0…2“.</td></tr>
<tr><td>Select BUS REF / f-Fix1</td><td>Selection between references. Low = Reference coming from the master drive, High = f-Fix1, set with P2-01</td></tr>
<tr><td>Select f-Fix Bit 0
Select f-Fix Bit 1</td><td>Selection of the fixed frequency with digital commands. The fixed frequencies f-Fix1 … f-Fix4 are defined by P2-01 … P2-04

<table>
<tr><td></td><td>Bit 1</td><td>Bit 0</td></tr>
<tr><td>f-Fix 1 (P2-01)</td><td>Low</td><td>Low</td></tr>
<tr><td>f-Fix 2 (P2-02)</td><td>Low</td><td>High</td></tr>
<tr><td>f-Fix 3 (P2-03)</td><td>High</td><td>Low</td></tr>
<tr><td>f-Fix 4 (P2-04)</td><td>High</td><td>High</td></tr>
</table>
</td></tr>
</table>

Select Quick-dec	Activation of a Quick Stop with the ramp, defined by P2-25. To activate a Quick Stop, a simultaneous High signal at both terminals is necessary.
Select t-dec1 / t-dec2	Selection between the deceleration ramps „t-dec“ (P1-04) and „t-dec2“ (P8-11). Low = deceleration ramp 1, High = deceleration ramp 2
START	Starts and stops the drive. In case a High signal is applied to the respective terminal, the drive accelerates with the selected ramp. When the signal is removed, the drive stops. The behavior during the stop phase depends on the setting of P1-05 (Stop Mode). At stand still the drive will be disabled. In applications with two senses of rotation, the direction is selected with “INV”.

START Signal

To operate a drive in Master-Slave-Mode it is always necessary to have a START signal coming from the master drive. The terminal configuration selected with P1-13 determines, if an additional START signal at the slave drive is necessary.

P1-13 = 1 … 10 START signal at master drive and slave drive necessary
P1-13 = 11 … 20 Only START signal at master drive necessary

In applications, in which the slave drive has to be operated without the master drive (e. g. during set up of a machine), it is necessary to start the slave drive separately. This is NOT possible with the pre-defined terminal configurations (P1-13 = 1 … 20).

With P13 = 0 the devices of the series DA1 can be configured individually. With this measure a separate START signal for the slave drive can be achieved. See example 6 “Configuration for a separate start of the slave drive”.

P1-13 = 0 Individual configuration in Menu 9 “Control” possible

SlaveSpeedScalingControl (P2-28) and SlaveSpeedScalingFactor (P2-29)

Each single slave drive can be adopted to the requirements of the application individually by

- multiplication with a factor set with P2-29
- multiplication with a factor set with P2-29 + addition of an offset, coming from AI1 (terminal 6).
- Multiplication with two factors (a digital one, set with P2-29 and an analog one, coming from AI1 (terminal 6)

See also examples 1 … 4

PNU	Parameter	Name	Range	Default
2510.0	P2-28	SlaveSpeedScalingControl	0: slave frequency = master frequency 1: slave frequency = master frequency · P-29 2: slave frequency = (master frequency · P-29) + reference at analog input AI1 (term. 6) 3: slave frequency = (master frequency · P-29) · reference at analog input AI1 (term. 6) Handling see Examples 1 … 4	0
2511.0	P2-29	SlaveSpeedScalingFactor	-500.0 % … +500.0 %	100.0 %

AI1 Signal Range (P2-30), AI1 Gain (P2-31), AI1 Offset (P2-32)

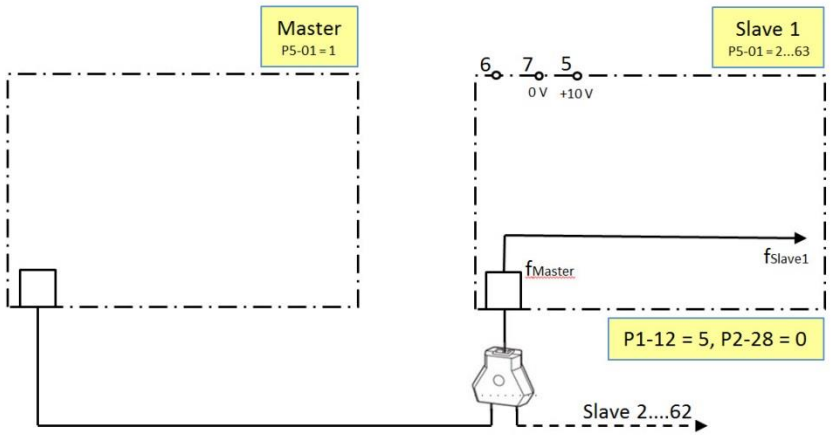
In case P2-28 is set to 2 or 3, the reference at analog input 1 (AI1 = terminal 6) impacts the speed of the slave drive. Not only the analog value itself, but also the gain (P2-31) and the offset (P2-32) are taken into account. See examples further below.

- P2-30: Selection of the kind of signal at analog input 1. The maximum value of the signal corresponds to the maximum speed / frequency set with P1-01.
- P2-31: With the gain the analog input can be scaled. The gain applies to the value at AI1 as well as for the offset.
- P2-32: Offset of the analog input 1. 100.0 % corresponds to the maximum speed / frequency set with P1-01.
    - ATTENTION: The offset is subtracted from the value at terminal 6. Means: positive values for P2-32 result in a reduction of the speed, negative ones in an increase.
    - See also examples for P2-28 = 2 resp. 3

PNU	Parameter	Name	Range	Default
260.0	P2-30	AI1 Signal Range	0: 0 … 10 V (U 0- 10) 1: 10 … 0 V (U 10-0) 2 : bipolar 0 … 10 V (- 10- 10) 3: 0 … 20 mA (A 0-20) 4: t 4 … 20 mA (trip in case of wire break) (t 4-20) 5: r 4 … 20 mA (ramps to fixed frequency 8 (P2-08) in case of wire break) (r 4-20) 6: t 20 … 4 mA (trip in case of wire break) (t 20-4) 7: r 20 … 4 mA (ramps to fixed frequency 8 (P2-08) in case of wire break) (r 20-4)	0
261.0	P2-31	AI1 Gain	0.0 … 2000.0 %	100.0 %
262.0	P2-32	AI1 Offset	-500.0 % … + 500.0 %	0.0 %

Examples for Master-Slave-Operation

Example 1: Same speeds, e.g. for conveyor belts



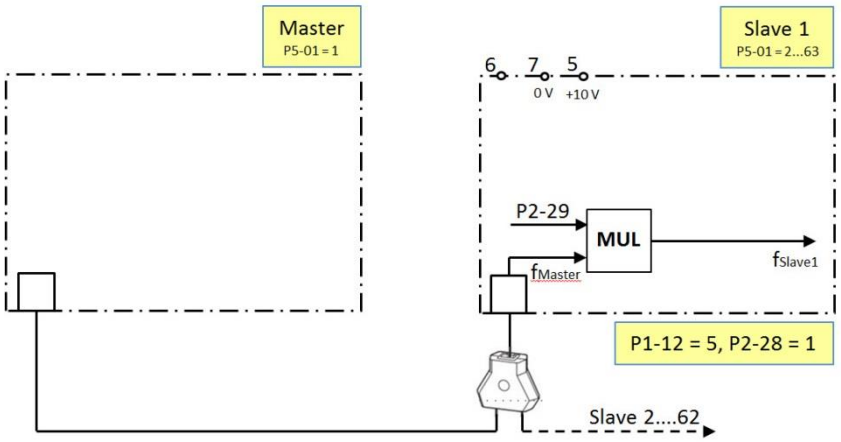
The reference for the slave drive corresponds to the speed of the master.

In applications where two or more conveyor belts shall run with the same speed, this system can be used.

Settings:

- The address of the master drive (P5-01) MUST be “1”.
- Slave drive
  - The address of each single slave drive has to be unique in the range 2 … 63.
  - P1-12 = 5 → slave mode
  - P2-28 = 0 → slave frequency = master frequency
  - P1-03 = 0.00 s → acceleration ramp (see also example 5)
  - P1-04 = 0.00 s → deceleration ramp (see also example 5)

Example 2: Speeds are associated with a factor, e.g. air handling unit



The master frequency is multiplied with a factor, determined by P2-29.

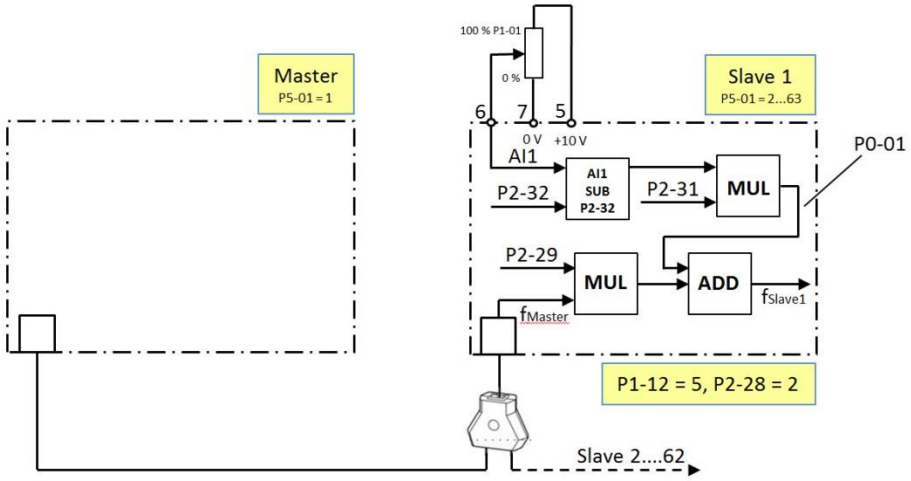
In this case, the speeds of master drive and slave drive are proportional in a certain ratio. An application example could be an air handling unit with supply and extract fans where a positive pressure is required in the room, hence the extract fan must operate slower than the supply fan, e.g. speed extract fan (slave drive) = 90 % of supply fan speed (master drive).

Settings:

- The address of the master drive (P5-01) MUST be “1”.
- Slave drive
  - The address of each single slave drive has to be unique in the range 2 … 63.
  - P1-12 = 5 → slave mode
  - P2-28 = 1 → slave frequency = master frequency · P-29
  - P1-03 = 0.00 s → acceleration ramp (see also example 5)
  - P1-04 = 0.00 s → deceleration ramp (see also example 5)
  - P2-29 = 90.0 %

The extract fan always runs with 90 % of the speed of the supply fan.

Example 3: Speeds are associated with a factor + manual adjustment (ADD)



The master frequency is multiplied with a factor, determined by P2-29. This value can be manually adjusted in both directions with a potentiometer at analog input AI1 (terminal 6). The correction is an offset and not speed dependent.

$$f_{Slave} = (f_{Master} \cdot P2\text{-}29) + P0\text{-}01$$

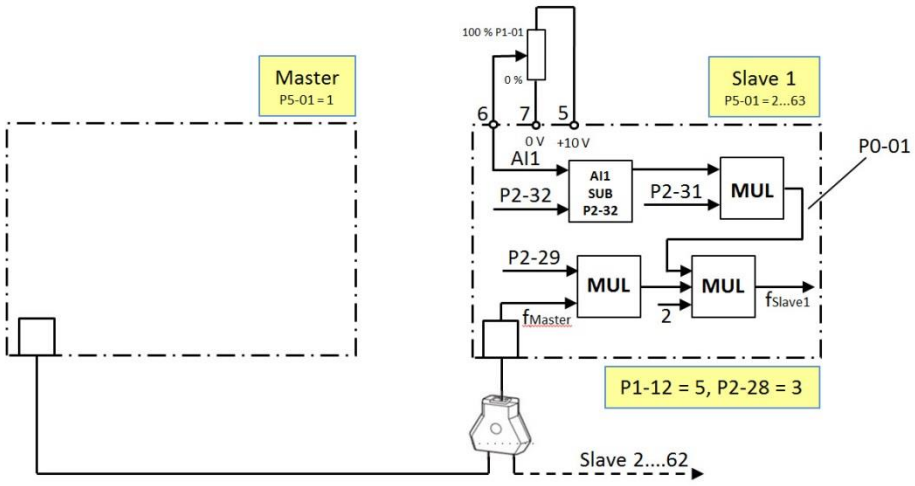
with $P0\text{-}01 = (\text{Signal an AI1 [\%]} - P2\text{-}32) \cdot P2\text{-}31$

Remark: The value of P0-01 can be at most 100 % of P1-01 (f-max). It is an internally calculated value which can be displayed but not changed manually.

Settings for a correction of ± 2 Hz:

- The address of the master drive (P5-01) MUST be “1”.
- Slave:
  - The address of each single slave drive has to be unique in the range 2 … 63.
  - P1-12 = 5 → slave mode
  - P2-28 = 2 → slave frequency = (master frequency · P-29) + reference at AI1 (term. 6)
  - P1-03 = 0.00 s → acceleration ramp (see also example 5)
  - P1-04 = 0.00 s → deceleration ramp (see also example 5)
  - Connect potentiometer to terminals 5, 6 and 7
  - The setting range of the potentiometer is determined by the parameters for gain and offset of analog input 1.
    - Because an increase as well as a reduction of the speed by the correction is required, P2-30 has to be set to 2 = „bipolar 0 … 10 V (- 10 - 10)“.
    - Calculation of P2-31 (AI1 Gain):
      - The percentages are related to the maximum output frequency of the slave drive, set with P1-01 (f-max)
      - Assumption: P1-01 = 50 Hz, range ± 2 Hz = 4 Hz band width
      - P2-31 = 4 Hz / 50 Hz = 8 %
    - P2-32 = 50 % (Offset to move zero to the middle of the scale)
- The correction value can be displayed with P0-01.

Example 4: Speeds are associated with a factor + manual adjustment (MUL)



The master frequency is multiplied with a factor, determined by P2-29. This value can be manually adjusted in both directions with a potentiometer at analog input AI1 (terminal 6). The correction is proportional to the speed.

$$f_{Slave} = f_{Master} \cdot P2\text{-}29 \cdot P0\text{-}01 \cdot 2$$

with $P0\text{-}01 = (\text{Signal at AI1 [\%]} - P2\text{-}32) \cdot P2\text{-}31$

Remark: The value of P0-01 can be at most 100 % of P1-01 (f-max). It is an internally calculated value which can be displayed but not changed manually.

Settings for the correction of +12 % … -25 %:

- The address of the master drive (P5-01) MUST be “1”
- Slave:
  - $f\text{-}max_{Slave} = f\text{-}max_{Master} \cdot 112\ \%$
  - Address
    - Die Adresse eines jeden Slave-Antriebs (P5-01) muss unterschiedlich sein im Bereich 2 bis 63.
  - Mode and scaling
    - P1-12 = 5 → slave mode
    - P2-28 = 3 → slave frequency = (master frequency · P-29) · reference at analog input AI1 (term. 6)
  - Ramps
    - P1-03 = 0.00 s → acceleration ramp (see also example 5)
    - P1-04 = 0.00 s → deceleration ramp (see also example 5)
  - SlaveSpeedScalingFactor (P2-29)
    - P2-29 = 100 % + max. Drehzahlerhöhung. (in this case: 100 % + 12 % = 112 %)
  - From this the value of P0-01 can be derived
    - With AI1 = 0 %, the output frequency should be 100 % - 25 % = 75 % of the master frequency
    - With AI1 = 100 %, the output frequency should be 100 % + 12 % of the master frequency

- Because of P2-29 = 112 %, the resulting range of P0-01 is as follows:
  - Minimum value = 75 % / 112 % = 67.0 % (Maximum one decimal place)
  - Maximum value: always 100 %

- AI1 Gain (P2-31)
  - $P2\text{-}31 = \frac{P0\text{-}01_{max} - P0\text{-}01_{min}}{2} = \frac{100\,\% - 67\,\%}{2} = 16.5\,\%$
- AI1 Offset (P2-32)
  - $P2\text{-}32 = -\frac{P0\text{-}01_{min}}{2 \cdot P2\text{-}31} = -\frac{67\,\%}{2 \cdot 16.5\,\%} = -203.0\,\%$

Hint:

- The upper limit of the output frequency / speed of the slave drive is determined by P1-01 (f-max), even when the master frequency multiplied with the factors is higher.
- Please note, that the values of P2-31 and P2-32 are limited
  - P2-31 = 0.0 … 2000.0 %
  - P2-32 = -500.0 … 500.0

Example 5: Setting the ramp times of the slave drive

A ramp at the slave drive can lead to speed differences between master and slave during acceleration and deceleration. It is important that the ramps are set to the right values.

Slave drives, always running in combination with the master drive

In this case the slave drives receive their speed reference from the master exclusively. The ramps of the slave drives have to be set to 0.00 s, to prevent additional delay.

→ P1-03 = 0.00 s
→ P1-04 = 0.00 s

Slave drives, also running individually

Depending on the selected terminal configuration with P1-13 (see “Terminal configuration of the slave drive”) slave drives can also be operated without a reference coming from the master drive. This makes sense e.g. in manual mode, where the speed reference can either be determined by the value at analog input AI2 or from a fixed frequency.

In this case it is disadvantageous when the ramp is set to zero, because this can lead to a trip at start because of overcurrent. The ramps to be set are a compromise between a good master-slave-operation during acceleration and deceleration and the prevention of overcurrent trips respectively torque shocks at sudden changes of the speed reference.

The maximum values for the acceleration and deceleration time are the ones of the master drive, taking the factor (P2-29) into account.

Maximum value for the acceleration time of the slave drive: $P1\text{-}03_{Slave} = \frac{P1\text{-}03_{Master}}{P2\text{-}29}$

Maximum value for the deceleration time of the slave drive: $P1\text{-}04_{Slave} = \frac{P1\text{-}04_{Master}}{P2\text{-}29}$

Tip: Keep ramp times as short as possible, but as long as necessary without exceeding the maximum value.

Example 6: Configuration for a separate start of the slave drive

Two motors are operated in master slave mode. During setup of the machine the slave drive has to be operated separately. The change from master slave mode to individual operation should be determined by a signal at the control terminals.

The configuration has to be defined by the user in Menu 9 “Control”.

PNU	Parameter	Name	Set value / Function
423.0	P1-13	DI Config Select	0: User defined The function of the terminals is not selected out of predefined sets, but determined individually.
400.3 421.0 400.7	P9-01 P9-03 P9-07	Enable Operation Source FWD Source FaultReset Source	1: Digital Input 1 (d in- 1) The functions Enable (P9-01), FWD (P9-03) and Reset (P9-07) are assigned to Digital Input 1 (DI1). The assignment is independent from the speed source. To operate the slave drive a High signal at Digital Input 1 (DI1) is always required.
421.3 431.0	P9-09 P9-18	LocalRemote@Startup Speed Select B0	2: Digital Input 2 (d in-2) Digital Input 2 toggles between master slave mode and terminal mode (P9-09) as well as between SpeedSource1 and SpeedSource2 (P9-18). Low = Master slave mode with SpeedSource1 High = Terminal mode with SpeedSource2
430.0	P9-10	SpeedSource1	5: Master speed (Sub-dr) SpeedSource1 is the master speed
430.1	P9-11	SpeedSource2	0: Analog Input 1 (A in- 1) SpeedSource2 is the reference at Analog Input 1 (AI1)