TB Wood´s

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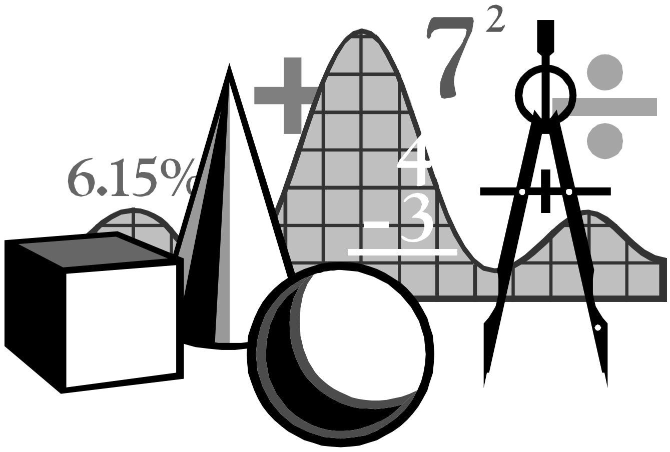
UD7000

Application "Closed-Loop Jockey Roller Position Control"

with U/f, FO, EC and SLV



As per: 19.06.99

Closed-Loop Jockey Roller Position Control

As of software version A18.05 / A17.05

Basic mechanical construction

A material enters at speed v. During this process, it is guided over a jockey roller before it is wound up in the winder. The jockey roller is arranged so that it can change height and exerts force F on the material in order to keep the material taut. There is a position sensor (potentiometer, analogue initiator etc.) on the jockey roller, and this sensor is used to detect the position. The sensor serves as the feedback element for a closed-loop position control system implemented in the inverter.

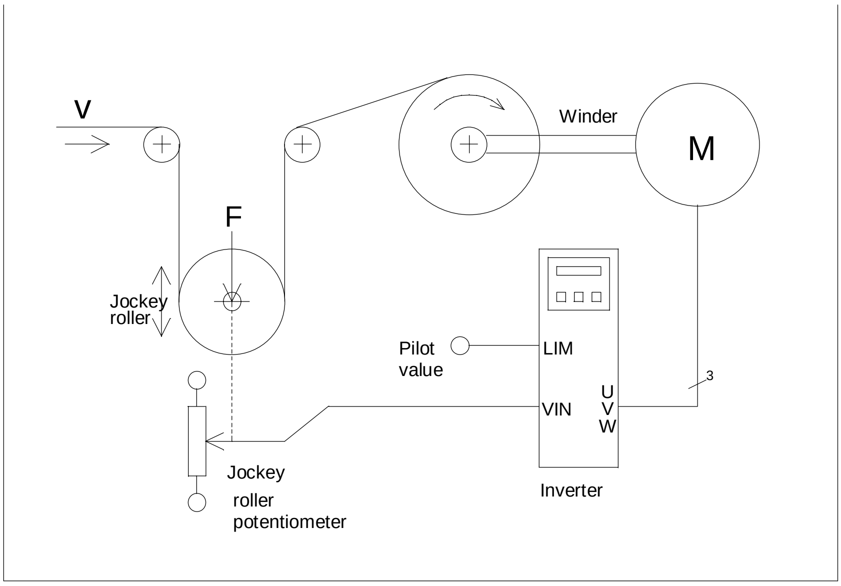


Figure 1: Mechanical system

The illustration shows a take-up winder designed as a centre winder with an additional pilot value (material speed). However, all possible applications can be implemented with the UD 7000:

- Take-up winders Unwinders Sensing-arm winders Friction winders Godet wheels Centre winders
- 2-quadrant mode 4-quadrant mode
- Jockey roller signal:
  Voltage input up to +- 10 V Current input up to +- 20 mA
- Pilot value signal:
  analogue pilot value 0..10 V digital pilot value 0..100 kHz
- Asynchronous machine with U/f control
  Asynchronous machine with SLV
  Asynchronous machine, with field-orientated control
  Synchronous machine with feedback (servo)

Controller structure in the inverter UD7000

An actual position value at terminal VIN is compared with a setpoint preset in parameter DD. This system deviation is applied to a PI controller comprising discrete elements which attempts to set the system deviation to zero. The PI controller is disabled and does not supply a signal until Drive Enable (FWD) has been issued.

Position deviations occur in the case of variations in material speed v. In order to compensate for these position deviations wherever possible, it is possible to inject via a pilot input (LIM) a "pilot value" which should be proportional to the system-preset speed v. This relieves the load on the PI controller which then needs only to make minor corrections accordingly.

The pilot value and controller output may be combined additively or multiplicatively to obtain the final frequency setpoint.

The frequency setpoint, obtained in this way, is routed via the ramp-up/ramp-down element and thus controls the drive. U/f controls, SLV, FO and EC are available as drive technologies.

The closed-loop jockey roller position control can operate in 2 or 4-quadrant mode. In 2-quadrant mode, only one direction of rotation is allowed for the connected motor. In 4-quadrant mode, both directions of rotation are enabled.

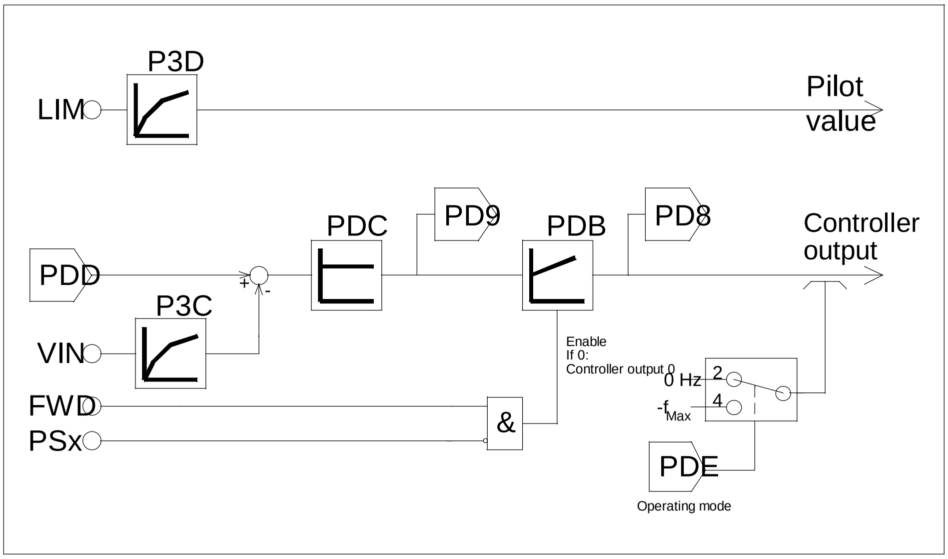


Figure 2: Controller structure

Function of the VIN/CIN input

VIN: Voltage input for jockey roller signal. A voltage range 0..10 V (parameter 31 = 0) and +-10 V (parameter 31 = 1) can be preselected.

CIN: Current input for jockey roller signal. A current range 0..20 mA (parameter 31 = 0) and +-20 mA (parameter 31 = 1) can be preselected.

The analogue signal VIN/CIN may be smoothed to varying extents via parameter 3C.

Function of the LIM input

The LIM input serves chiefly to preset the pilot value. The pilot value is intended to relieve the load on the closed-loop control system and thus reduce transient phenomena (jockey roller deflections). The analogue signal at LIM can be smoothed to varying extents via parameter 3D.

The link between pilot value and controller output is established by programming the LIM input. The LIM input has the same functions as in the standard applications, with the exception of function 3.

Additive pilot value preset (parameter 32 = 0, 3 or 4):
Incoming digital pulses are transferred as additive pilot value via function 3. Scaling is performed with parameter 36.

The analogue voltage is transferred as an additive pilot value via functions 0 and 4. Scaling is performed via parameter 34. In function 0, a voltage of 5 V forms the zero point. The zero point is 5 V in case of function 4.

With additive pilot value preset, it is possible for the inverter to adapt automatically to slowly changing winding ratios (parameter adaptation).

Multiplicative pilot value preset (frequency factor; parameter 32 = 2):
Function 2 can be used to wire the LIM input as a multiplicative factor. This may be of advantage, in particular, if it is necessary to respond quickly to changing pilot values despite a slowly adjusted controller (high diameter ratio full/empty). Parameters 38 and 39 can be used to limit the range of the LIM input.

Torque limitation (parameter 32 = 1):
The LIM input can be used for torque limitation with function 1. In order to do this, the LIM input must be defined as a torque limit value in addition to parameters 51..55. Otherwise, the LIM input does not function.

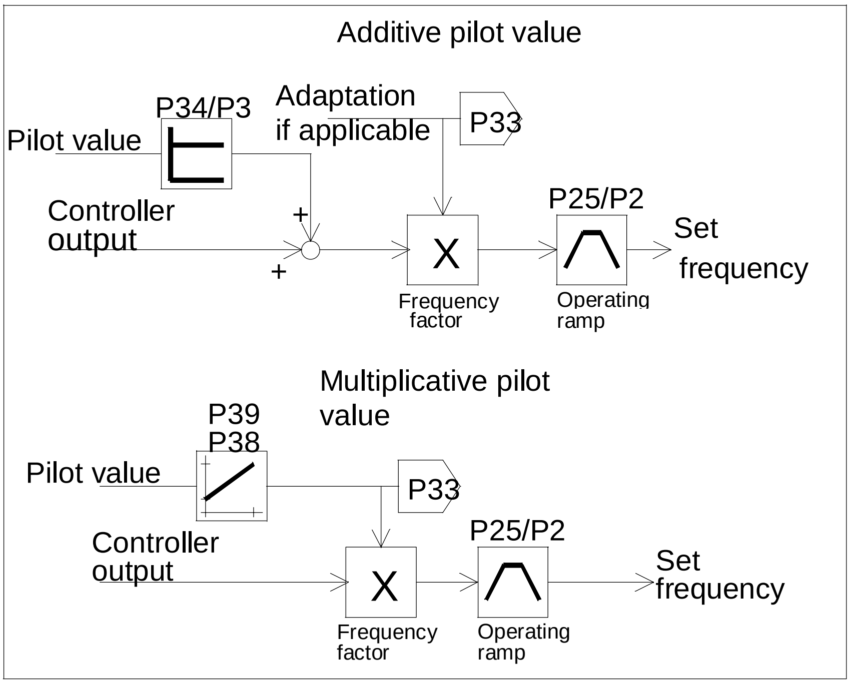


Figure 3: Linking of pilot value and controller output

2 or 4-quadrant mode

In 2-quadrant operating mode, the reverse direction of rotation is barred for closed-loop control. Both directions of rotation are permitted in Starting Aid and Parking function. Both directions are always permitted in 4-quadrant mode.

Parameter DE is used for selection:
xx2: 2-quadrant mode
xx4: 4-quadrant mode

Operation with pilot value

If an excessive jockey roller arm deflection occurs during material acceleration, it is frequently helpful use a pilot value. This can be injected additively or multiplicatively.

An additive pilot value acts in the same way as pilot control. If adjustment is correct (parameter 34 resp. 36), a clearly reduced jockey roller arm deflection can be anticipated during acceleration. Ideally, such deflections are eliminated entirely.

Limit switch function

A limit switch function is implemented by programming a binary output (parameters 92-96) with function 29. Parameter DA is used to define a window above and below the zero position of the jockey roller signal. The output is activated if the window limits are violated.

Parameter DA must be entered as a positive value.

Starting Aid, Setting mode

When the Controller Enable FWD is activated, the jockey roller arm may be well away from zero position. Under certain circumstances, this leads to major overshoot or even instability. For this reason, a Starting Aid has been implemented, and this automatically traverses the fixed frequency 1 (parameter 41) on power-up. The traverse direction is always such that the jockey roller arm is guided towards zero position. The system switches over automatically to normal closed-loop control mode when zero position is overshot.

This function ca be deactivated by programming the fixed frequency 1 (parameter 41) with value 0.0 Hz .

If the function is to be used, a value other than 0 must be programmed in parameter 41.

Parking of the jockey roller arm

If a control input is activated, the closed-loop control system resp. the Starting Aid is terminated automatically and the frequency stored in parameter 42 (fixed frequency 2) is run. When the limit switch position (parameter DA) is reached, the frequency setpoint is set to zero. The control can then cancel the Enable.

The traverse direction in this case is dependent on parameter DE (operating mode). The traverse direction in the Parking function is determined in the hundreds digit of parameter DE:

0xx:	Traverse direction in FWD direction:	typically unwinder
1xx:	Traverse direction opposite to FWD direction:	typically take-up winder

Closed-loop control mode signal

The current status is applied to a binary output by programming parameters 92..96 with value 28.

The output is deactivated during Starting Aid and in the case of jockey roller arm parking. The output is activated when closed-loop control mode is reached.

Parameter adaptation

An automatic parameter adaptation can be activated for additive pilot value preset. Parameter DE (operating mode) must be set to value x1x (tens digit = 1) for this purpose.

x0x: Adaptation deactivated
x1x: Adaptation activated

Adaptation may be activated only in the case of additive pilot value preset.

Adaptation can operate correctly only if a pilot value signal proportional to the speed v is present and only if the system is not run too slowly. For this reason, a threshold is defined, and adaptation is stopped below this threshold. Adaptation restarts when the pilot value exceeds this threshold.

Adaptation serves to compensate for varying system gain in the case of changing winding diameter so as to achieve a closed-loop control response independent of the winding diameter. At the same time, the pilot value is adapted to the changing diameter.

In the case of adaptation, parameter 33 (frequency factor) is varied so that the pilot value, on average, would result precisely in the rotational speed preset. The controller's manipulated variable thus becomes zero on average. As the winding diameter increases, the frequency factor is reduced and vice-versa. Adaptation maintains the product of winding diameter and frequency factor constant.

The correcting range for the frequency factor 33 is preset by parameters 38 and 39. These limits correspond to the winding diameters "full" and "empty".

During the Starting Aid and in the case of parking of the jockey roller arm, no adaptation is performed. A value found in parameter 33 by adaptation nevertheless influences the frequencies stored in parameters 41 and 42 for operating modes Starting Aid and Jockey roller arm parking.

Production interruption without roller change:
If the FWD terminal is disconnected, the value of the frequency factor last found by the adaptation function is retained. When the FWD terminal is reconnected, further adaptation is performed starting from this value. However, the value is stored in volatile memory and is no longer available on the next power-up.

Roller change - Setting start values for adaptation:
For this purpose, the binary inputs PS1 and PS2 must be programmed for function 12 (motor potentiometer - increment / decrement frequency factor). If the binary inputs are activated, the frequency factor changes in the period defined by parameter 7B resp. 7C to the upper resp. lower end value (minimum 0.1 s for 100% variation).

Roller change in the case of take-up winder application:
Roller change is always performed from "full" to "empty". For this purpose, the frequency factor must be set by the control to the maximum value (parameter 39). This is performed with function "Motor potentiometer increment" (PS1, P99 = 12, P7B =0.1s).

Roller change in the case of unwinder application:
Roller change is always performed from "empty" to "full". For this purpose, the frequency factor must be set by the control to the minimum value (parameter 38). This is performed with function "Motor potentiometer decrement“ (PS2, P9A = 12, P7C = 0.1s).

Output of the frequency factor:
Parameter E3 is an image of the frequency factor. This can be displayed on the standard display 2 and thus be displayed analogue via the MET outputs.

Forward/Reverse operation

Normally, the entire jockey roller application is operated in forward run. Control input FWD must be activated for this purpose. This is adequate for most applications.

However, in the case of unwinders on packaging machines, the following problem is sometimes encountered: It is necessary to bear printing in mind and, thus, the roller must be inserted winding both from the "top" and from the "bottom". This means that the roller must be operated both clockwise and counter-clockwise.

This can be implemented by ***assigned*** use of FWD and REV.

If the commissioning steps described below are implemented with roller installation "winding from the top", this assignment must always be retained, i.e. enabling must occur with FWD in the case of "winding from the top" and enabling must occur with REV in the case of "winding from the bottom".

If this rule is violated, positive feedback occurs and the drive "races".

If this assignment is complied with, it is easily possible to preset the pilot value, the Starting Aid, the Parking Aid and also parameter adaptation.

Input and output assignment

LIM: Input pilot value (digital pulses or analogue voltage)
VIN: Analogue input jockey roller signal 0..10 V or +-10 V
CIN: Analogue input jockey roller signal 0..20 mA or +- 20 mA
FWD: Binary input Drive Enable
PSx/R-J binary input (function 8) select jockey arm parking
PS1/PS2 binary input for setting the adaptation start values
STx- outputs: Output of the status of the closed-loop control system (Setting resp. Closed-loop control mode). Value 28 must be programmed in parameters 92..95 for this purpose.

Parameters

P23: fmax
P25: Ramp-up time
P26: Ramp-down time
P2C: Application 300, 310, 320 or 350: Closed-loop jockey roller control with: Standard inverter, EC, FO or SLV
P31: Setpoint selection; used here only as voltage range jockey roller signal:,
- 0: 0...10 V for jockey roller signal at VIN
- 1: +- 10 V for jockey roller signal at VIN

P32: Function LIM input
- 1: Torque limit if enabled in group 5
- 2: Input frequency factor; acts as multiplicative analogue pilot value. Scaling via P38, P39
- 3: Digital pilot value; acts as additive pilot value. Scaling via P36
- 4: Additive setpoint; acts as additive analogue pilot value. Scaling via P34
- 5: Reserved

P33: Frequency factor
P34: Influence of pilot value in the case of additive pilot value preset (analogue signal at LIM)
P36: Influence of pilot value in the case of additive pilot value preset (digital pulses at LIM)
P38, P39: Lower limit, upper limit of the frequency factor
P3C: Smoothing time constant for VIN input
P3D: Smoothing time constant for LIM input
P41: Fixed frequency 1: Set-up frequency

P42: Fixed frequency 2: Parking frequency
P43: Fixed frequency 3: Frequency threshold adaptation
P92..P95: Programming of the binary outputs
P98..P9B:R/J/PS1,2,3: Function 8: Parking jockey roller arm
PD8: Display of manipulated variable (share of the setpoint generated by the controller)
PD9: Display of closed-loop control error
PDA: Limit switch position
PDB: Integral-action time (I component) [ms]
PDC: Gain zero position (P component) [1/256]
PDD: Zero position (setpoint referred to VIN), can be considered as position setpoint
PDE: Operating mode:

Units digit: 2 or 4-quadrant.
Tens digit: Enable adaptation
Hundreds digit: Inversion of the direction of rotation in the case of jockey roller parking

Commissioning, programming

1. Operate the motor as standard inverter, EC, FO or SLV (parameter reset, choose application, switch mains off and back on again, enter motor data, test run etc.) and then set test mode to 0.
2. Connect the motor so that the motor turns in the correct direction (operating direction) in the case of FWD. This is absolutely essential in order for the closed-loop control system to operate correctly. If the direction of rotation is incorrect, reverse two motor supply leads and start the commissioning procedure again at point 1.
3. Select jockey roller position application 300, 310, 320 or 350 , switch mains off and back on again.
4. Set parameter 31 to 0 (0..10 V) or 1 (± 10 V) depending on jockey roller power supply.
5. Parameter DC = 256 (gain jockey roller controller = 1.0)
6. Parameter 23 = 10% .. 30% higher than theoretically required (maximum frequency)
   Parameter 32 = 1 (LIM input)
   Parameter 33 = 100,00% (Frequency factor)
   Parameter 34 = 0,0% (Factor LIM input)
   Parameter 36 = 16384 (Pulse count LIM input)
   Parameter DB = 1000 (Integral-action time jockey roller controller: Long integral-action time, low I component)
   Parameter DD = 0 (Zero position, jockey roller arm)
   Parameter DE = 2 or 4 (Operating mode, initially only quadrants)
   Parameter 41 = 0.1 approx. 5.0 Hz (starting frequency)
   Parameter 42 = 0.1 approx. 5.0 Hz (lowering frequency)
   Parameter 43 = 0.0 Hz (frequency threshold adaptation)
7. Adjust zero position:
   Move the jockey roller arm by hand to the required mechanical zero position. Parameter D9 closed-loop control error now indicates a numerical value corresponding to the inverted zero position. This must be transferred to parameter DD zero position with opposite sign. This entry means that parameter D9 closed-loop control error assumes the value zero. In this case, the jockey roller signal should be at the mid-point of the available range wherever possible.
8. Check the direction of corrective action:
   Move the jockey roller arm by hand in the direction in which it would run owing to an FWD command (this would be upwards in the sketch). Parameter D9 (closed-loop control error) must run in the negative direction in this case.
   If parameter D9 becomes more negative: Continue at Point 10 or 11.
   If parameter D9 becomes more positive: Continue at Point 9 - Inverting the direction of corrective action.

9. Inverting the direction of corrective action (if necessary):
   either: Parameter DC = -256 (negative gain), continue at Point 10.
   or : Connect the jockey roller potentiometer the other way around, back to Point 6.
10. Setting limit switch function (if necessary):
    Move the jockey roller arm by hand to the required position at which the limit switch is to be fitted. Parameter D9 (closed-loop control error) now indicates a signed numerical value corresponding to this position. The *magnitude* of this numerical value can be entered in parameter DA - limit switch. Any binary output (parameters 92-96) must be programmed with function 29.
11. Set parameter DC gain (P component) to a low value +10 resp -10. Always retain the sign!
12. Insert the material and enable the controller (FWD terminal). There should initially be no material movement. The jockey roller must approach to zero position at the start-up frequency and then stabilise around the zero point.
13. The closed-loop control system can be tested by material movement (synchronism or changing material speed). You can attempt to optimise by changing parameters 25, 26 (ramp slope), the P component and I component (parameters DC and DB) and the smoothing functions (parameters 3C, 3D). The sign of parameter DC gain (P component) must always be retained!

If you wish to run with pilot value (LIM input):

1. The LIM input must be enabled with parameter 32. You can use setting 0, 3 or 4 for this.
2. The material is run at the normal speed v. Vary parameter 34 resp. 36 until the manipulated variable of the closed-loop jockey roller controller (parameter D8) stabilises around zero. Work with as low an acceleration / deceleration as possible during the test phase.

The jockey roller arm can be parked as follows in the case of production interruptions (no material tearing!):

1. Program parameter 42 (fixed frequency 2) to a low rotational speed
2. Program a binary input for function 8 (deactivation closed-loop position controller) (wherever possible R/J or PS3).
3. Do not disconnect the FWD terminal
4. Activate binary input. Inverter traverses fixed-frequency 2 until limit switch position is reached. Setpoint 0 is then traversed and, if necessary, a limit switch signal is issued.
5. If the traverse direction is incorrect, the hundreds digit of parameter DE (operating mode) must be changed.
6. Disconnect the FWD terminal.

Substantial winding diameter changes with parameter adaptation (pilot value required)

1. Set the tens digits in parameter DE (12, 14, 112 or 114)
2. Set both the frequency factor (P33) and upper limit frequency factor (P39) to 100%
3. With the winder empty wherever possible, adjust parameter 34 resp. 36 so that the controller output (parameter D8) stabilises around zero.
4. Set the lower limit frequency factor (P38) to the following value: $P38 = P39 * D_{Empty} / D_{Full}$
5. Parameters 7B / 7C = 0.1s (Rate of change motor potentiometer)
   Parameters 99 / 9A = 12 (Input function motor potentiometer)
6. Take-up winder:
   Fit an empty reel, activate PS1 for 0.2 seconds and start the system up. The frequency factor must decrease with increasing reel diameter.
   Unwinder:

Fit a full reel, activate PS2 for 0.2 seconds and start the system up. The frequency factor must increase with decreasing reel diameter.

The closed-loop control system should operate stably over the entire range and the controller output (manipulated variable, parameter D8) should stabilise around zero.

7. Define threshold for adaptation:
   With the winder empty wherever possible (i.e. P33 near to 100%) and at normal web speed v, read off the frequency setpoint from the standard display 1 and enter 10% of this value in parameter 43. As a check, observe parameter 33 at changing web speeds.

Substantial winding diameter changes with multiplicative pilot value

1. Program the LIM input (parameter 32) to function 2 (multiplicative pilot value). This allows controller optimisation for the large winding diameter D (which means a stable control with small diameter d) and, nevertheless, it is possible to respond quickly to changes in the pilot value with small winding diameter d.
   For this purpose, the LIM input should be gated with the frequency factor (parameter 33) in such a way that a frequency factor of 10 % to 100 % is assigned to an LIM voltage of 0..10 V. (Setting via parameters 38, 39). A frequency factor of zero would correspond to opening of the closed-loop jockey roller control circuit and should thus be avoided.