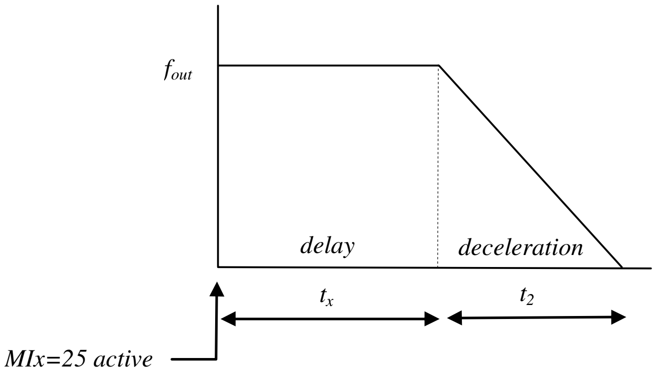
VFD-E SIMPLE POSITIONING

CONTENTS:

1 GENERAL

1.1 Simple positioning function: principle

Its purpose is, with the aid of delays, to rotate the motor a fixed number of revolutions to standstill.



The number of revolutions during deceleration t_2 from a certain frequency f_{out} to 0Hz depends on the deceleration time t_D and the frequency f_{out}.
By setting the delay t_x the number of revolutions during the delay can be set.

The delays are set at 0Hz, 10Hz, etc. in Pr01-20 to Pr01-25. For frequencies in-between the actual delay is calculated by interpolation.
In this way it is possible to set and calculate the delays and subsequently set the number of revolutions from a given frequency to standstill.
By multiplying the number of revolutions with 2πr, the distance can be calculated.

The delay and deceleration at the actual f_{out} is started when MIx=25 is active

Remarks:

- This function cannot be used for output frequencies >60Hz (see 2.1).
- For output frequencies close to 0Hz, the actual delays are inaccurate and would become very long (at 0Hz the delay would be ∞). In practice 5~10Hz is considered to be the minimum.
- It is recommended to use this function with a gearbox connected to the motor shaft.

1.2 Formulas

1.2.1 Shaft frequency f_{shaft}

The motor shaft frequency f_{shaft} in rev/s is:

Equation 1 $$f_{shaft} = \frac{2 \bullet f_{out}}{p} \quad \text{[rev/s]}$$

1.2.2 Number of revolutions S_D during deceleration

The average shaft frequency during deceleration is:

Equation 2 $$\frac{1}{2} \bullet f_{shaft} \quad \text{[rev/s]}$$

The actual deceleration time t_2 from f_{out} to 0Hz is:

Equation 3 $$t_2 = \frac{f_{out}}{f_{MAX}} \bullet t_D \quad \text{[s]}$$

So the number of revolutions S_D during deceleration is:

Equation 4

$$S_D = \frac{1}{2} \bullet f_{shaft} \bullet \frac{f_{out}}{f_{MAX}} \bullet t_D = \frac{f_{out}^{2} \bullet t_D}{p \bullet f_{MAX}} \qquad [\text{rev}]$$

1.2.3 Number of revolutions S_T during delay t_x

The number of revolutions S_T during a delay t_x is:

Equation 5

$$S_T = f_{shaft} \bullet t_x = \frac{2 \bullet f_{out}}{p} \bullet t_x \qquad [\text{rev}]$$

1.2.4 Delay t_x to give the number of revolutions S_T

For a number of revolutions S_T , the delay t_x is:

Equation 6

$$t_x = \frac{S_T \bullet p}{2 \bullet f_{out}} \qquad [\text{s}]$$

1.2.5 Total number of revolutions S

The total number of revolutions S is:

Equation 7

$$S = S_T + S_D = f_{shaft} \bullet \left(t_x + \frac{1}{2} \bullet t_2 \right) \qquad [\text{rev}]$$

or

Equation 8

$$S = \frac{2 \bullet f_{out} \bullet t_x}{p} + \frac{f_{out}^{2} \bullet t_D}{p \bullet f_{MAX}} = \frac{f_{out}}{p} \bullet \left(2 \bullet t_x + \frac{f_{out} \bullet t_D}{f_{MAX}} \right) \qquad [\text{rev}]$$

2 DELAYS

2.1 Delay for f_{out}>60Hz

Above 60Hz no delay is defined, it means this function cannot be used for f_{out}>60Hz!

2.2 Delay for 50Hz≤f_{out}≤60Hz

At 60Hz the delay is always 0s.
At 50Hz the delay is set in Pr01-25.

Interpolation:
At f_{out} the delay t_x is calculated as follows:

Equation 9
$$t_x = [\mathrm{Pr}\,01-25] - \frac{(f_{out}-50) \bullet [\mathrm{Pr}\,01-25]}{10} \quad [\mathrm{s}]$$

2.3 Delay for 40Hz≤f_{out}<50Hz

At 50Hz the delay is set in Pr01-25.
At 40Hz the delay is set in Pr01-24.

Interpolation:
At f_{out} the delay t_x is calculated as follows:

Equation 10
$$t_x = [\mathrm{Pr}\,01-24] - \frac{(f_{out}-40) \bullet ([\mathrm{Pr}\,01-24]-[\mathrm{Pr}\,01-25])}{10} \quad [\mathrm{s}]$$

2.4 Delay for 30Hz≤f_{out}<40Hz

At 40Hz the delay is set in Pr01-24.
At 30Hz the delay is set in Pr01-23.

Interpolation:
At f_{out} the delay t_x is calculated as follows:

Equation 11
$$t_x = [\mathrm{Pr}\,01-23] - \frac{(f_{out}-30) \bullet ([\mathrm{Pr}\,01-23]-[\mathrm{Pr}\,01-24])}{10} \quad [\mathrm{s}]$$

2.5 Delay for 20Hz≤f_{out}<30Hz

At 30Hz the delay is set in Pr01-23.
At 20Hz the delay is set in Pr01-22.

Interpolation:
At f_{out} the delay t_x is calculated as follows:

Equation 12
$$t_x = [\mathrm{Pr}\,01-22] - \frac{(f_{out}-20) \bullet ([\mathrm{Pr}\,01-22]-[\mathrm{Pr}\,01-23])}{10} \quad [\mathrm{s}]$$

2.6 Delay for 10Hz≤f_{out}<20Hz

At 20Hz the delay is set in Pr01-22.
At 10Hz the delay is set in Pr01-21.

Interpolation:
At f_{out} the delay t_x is calculated as follows:

Equation 13
$$t_x = [\mathrm{Pr}\,01-21] - \frac{(f_{out}-10) \bullet ([\mathrm{Pr}\,01-21]-[\mathrm{Pr}\,01-22])}{10} \quad [\mathrm{s}]$$

2.7 Delay for 0Hz≤f_{out}<10Hz

At 10Hz the delay is set in Pr01-21.
At 0Hz the delay is set in Pr01-20.

Interpolation:
At f_{out} the delay t_x is calculated as follows:

Equation 14

$$t_x = [\mathrm{Pr}\,01-20] - \frac{f_{out} \bullet ([\mathrm{Pr}\,01-20]-[\mathrm{Pr}\,01-21])}{10} \qquad [\mathrm{s}]$$

3 CALCULATION STEPS

1. Establish the maximum frequency $f_{out,max}$ from which you want to come to a standstill. Its value must be $\leq f_{MAX}$ in Pr01-00 and it must be ≤60Hz in any case.
2. Set the maximum frequency f_{MAX} in Pr01-00.
3. Set the deceleration time t_D in Pr01-10.
4. Take the number of motor poles p (normally p=4).
5. Establish the number of revolutions S to standstill and check at $f_{out,max}$ if it is not lower than given by *Equation 7* and *Equation 8* .
6. Calculate the delay at the next lower decade frequency (e.g. if $f_{out,max}$=34Hz, calculate the delay at 30Hz) acc. to Chapter 2.
7. Calculate the delays for the lower decades acc. to Chapter 2.
8. Calculate the delays for the higher decades acc. to Chapter 2. (The delays for the decades above $f_{out,max}$ can be set to 0).
9. Set all calculated delays in Pr01-20 to 01-25.
10. Set a digital input to MIx=25.
11. After MIx=25 is activated, the drive will rotate the calculated number of revolutions to standstill.

4 EXAMPLES

4.1 Standstill from 50Hz

The drive needs to come to a standstill from 50Hz in the lowest number of revolutions. From all other frequencies it needs to come to a standstill with the same number of revolutions.

4.1.1 Parameter settings

Pr01-00=50Hz (maximum frequency F_{MAX})
Pr01-10=1s (deceleration time t_D)
Pr01-20=7.50s
Pr01-21=2.40s
Pr01-22=1.05s
Pr01-23=0.53s
Pr01-24=0.23s
Pr01-25=0s

The number of poles p is 4.

4.1.2 Calculation

Assume the deceleration time Pr01-10=1s.

Delay at 50Hz

The number of revolutions from 50Hz to standstill is (*Equation 4*) is $\frac{50^2 \bullet 1}{4 \bullet 50} = 12.5$ revs

To have the lowest number of revolutions set Pr01-25=0 (no delay).
Only the deceleration time is taken into account.

Delay at 40Hz

From 40Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{40^2 \bullet 1}{4 \bullet 50} = 8$ revs

The delay must give 12.5-8=4.5 revs.

Acc. to *Equation 6* the delay $t_x = \frac{4.5 \bullet 4}{2 \bullet 40} = 0.225s$.

Rounded Pr01-24=0.23s.

Delay at 30Hz

From 30Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{30^2 \bullet 1}{4 \bullet 50} = 4.5$ revs

The delay must give 12.5-4.5=8 revs.

Acc. to *Equation 6* the delay $t_x = \frac{8 \bullet 4}{2 \bullet 30} = 0.533s$.

Rounded Pr01-23=0.53s.

Delay at 20Hz

From 20Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{20^2 \bullet 1}{4 \bullet 50} = 2$ revs

The delay must give 12.5-2=10.5 revs.

Acc. to *Equation 6* the delay $t_x = \frac{10.5 \bullet 4}{2 \bullet 20} = 1.05s$.

Pr01-22=1.05s.

Delay at 10Hz

From 10Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{10^2 \bullet 1}{4 \bullet 50} = 0.5$ revs

The delay must give 12.5-0.5=12 revs.

Acc. to *Equation 6* the delay $t_x = \frac{12 \bullet 4}{2 \bullet 10} = 2.40s$.

Pr01-21=2.40s.

Delay at 5Hz

From 5Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{5^2 \bullet 1}{4 \bullet 50} = 0.125$ revs

The delay must give 12.5-0.125=12.375 revs.

Acc. to *Equation 6* the delay $t_x = \frac{12.375 \bullet 4}{2 \bullet 5} = 4.95s$.

With a delay of 4.95s, Pr01-20 can be calculated with help of *Equation 14*:

$$4.95 = [\text{Pr}\,01-20] - \frac{5 \bullet ([\text{Pr}\,01-20] - 2.4)}{10}$$

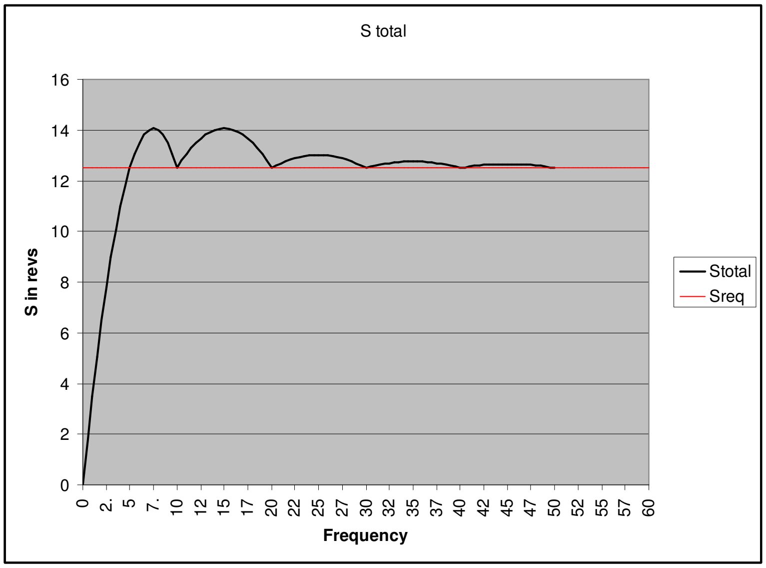
Therefore Pr01-20=7.50s.

4.1.3 Result and chart

The result is the following chart, giving the number of revolutions from the output frequency to standstill.

At low frequencies the inaccuracy becomes higher due to linear interpolation and the quadratic dependence of the number of revolutions during deceleration.

At very low frequencies (in this case <5Hz) the result is not useful, therefore the recommendation is not to use this function at frequencies lower than 5~10Hz.



4.2 Standstill from 27Hz

The drive needs to come to a standstill from 27Hz in 25 revolutions. From all other frequencies it needs to come to a standstill with the same number of revolutions.

4.2.1 Parameter settings

Pr01-00=60Hz (maximum frequency F_{MAX})
Pr01-10=5s (deceleration time t_D)
Pr01-20=15.00s
Pr01-21=4.58s
Pr01-22=1.67s
Pr01-23=0.32s
Pr01-24=0s
Pr01-25=0s

The number of poles p is 4.

4.2.2 Calculation

Assume the deceleration time Pr01-10=5s.
With this, the maximum f_{out} that gives 25 revolutions can be calculated from *Equation 4*:

$$f_{out} = \sqrt{\frac{S_D \bullet p \bullet f_{MAX}}{t_D}} = \sqrt{\frac{25 \bullet 4 \bullet 60}{5}} = 34.641 Hz$$

For frequencies >34.641Hz, the number of revolutions to standstill will be higher.

Delay at 20Hz

From 20Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{20^2 \bullet 5}{4 \bullet 60} = 8.33$ revs

The delay must give 25-8.33=16.67 revs.

Acc. to *Equation 6* the delay $t_x = \frac{16.67 \bullet 4}{2 \bullet 20} = 1.667 s$.

Rounded Pr01-22=1.67s.

Delay at 27Hz

From 27Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{27^2 \bullet 5}{4 \bullet 60} = 15.1875$ revs

The delay t_x must give 25-15.1875=9.8125 revs.

Acc. to *Equation 6* at 27Hz the delay $t_x = \frac{9.8125 \bullet 4}{2 \bullet 27} = 0.727 s$.

Delay at 30Hz

Equation 12 is to be used to calculate the delay Pr01-23 at 30Hz, when the delay Pr01-22 at 20Hz is known.

$$t_x = [\Pr 01-22] - \frac{(f_{out} - 20) \bullet ([\Pr 01-22] - [\Pr 01-23])}{10}$$

$0.727 = 1.667 - \frac{(27-20) \bullet (1.667 - [\Pr 01-23])}{10}$, therefore Pr01-23=0.324s

Rounded Pr01-23=0.32s.

Delay at 10Hz

From 10Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{10^2 \bullet 5}{4 \bullet 60} = 2.083$ revs

The delay must give 25-2.083=22.917 revs.

Acc. to *Equation 6* the delay $t_x = \frac{22.917 \bullet 4}{2 \bullet 10} = 4.583s$.

Rounded Pr01-21=4.58s.

Delay at 5Hz

From 5Hz the number of revolutions is during deceleration (*Equation 4*) is $\frac{5^2 \bullet 5}{4 \bullet 60} = 0.521$ revs

The delay must give 25-0.521=24.479 revs.

Acc. to *Equation 6* the delay $t_x = \frac{24.479 \bullet 4}{2 \bullet 5} = 9.792s$.

With a delay of 9.792s, Pr01-20 can be calculated with help of *Equation 14*:

$$9.792 = [\mathrm{Pr}\,01-20] - \frac{5 \bullet ([\mathrm{Pr}\,01-20] - 4.583)}{10}$$

Therefore rounded Pr01-20=15.00s.

Delay at 60Hz

The number of revolutions from 60Hz to standstill will be >25 because even with no delay (always 0) the number of revolutions is (*Equation 4*) is $\frac{60^2 \bullet 5}{4 \bullet 60} = 75$ revs.

Delay at 50Hz

The number of revolutions from 50Hz to standstill will be >25 because even with no delay, Pr01-25=0, the number of revolutions is (*Equation 4*) is $\frac{50^2 \bullet 5}{4 \bullet 60} = 52.083$ revs.

Delay at 40Hz

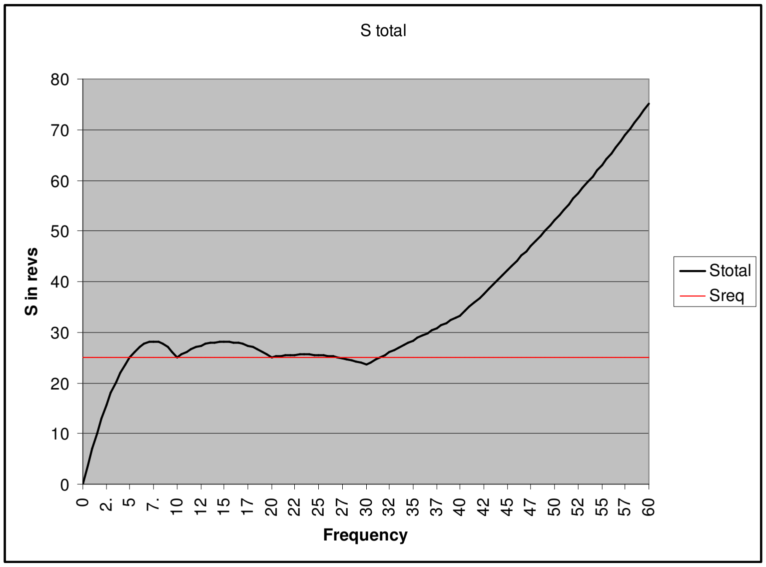
The number of revolutions from 40Hz to standstill will be >25 because even with no delay, Pr01-24=0, the number of revolutions is (*Equation 4*) is $\frac{40^2 \bullet 5}{4 \bullet 60} = 33.333$ revs.

4.2.3 Result and chart

The result is the following chart, giving the number of revolutions from the output frequency to standstill.

At low frequencies the inaccuracy becomes higher due to linear interpolation and the quadratic dependence of the number of revolutions during deceleration.

At very low frequencies (in this case <5Hz) the result is not useful, therefore the recommendation is not to use this function at frequencies lower than 5~10Hz.



5 TERMS SUMMARY

5.1 Terms

f_{shaft}	Motor shaft frequency in rev/s
f_{out}	Output frequency in Hz
f_{MAX}	Maximum frequency (Pr01-00) in Hz
S	Total number of revolutions to standstill
S_D	Number of revolutions during deceleration
S_T	Number of revolutions during delay
t_x	Delay time in s
t_D	Deceleration time (Pr01-10) from f_{MAX} to 0Hz
t_2	Actual deceleration time from f_{out} to 0Hz
p	Number of poles

6 CALCULATION IN EXCEL

To assist in calculating, you can use the Excel program “VFD-E Simple positioning.xls”.

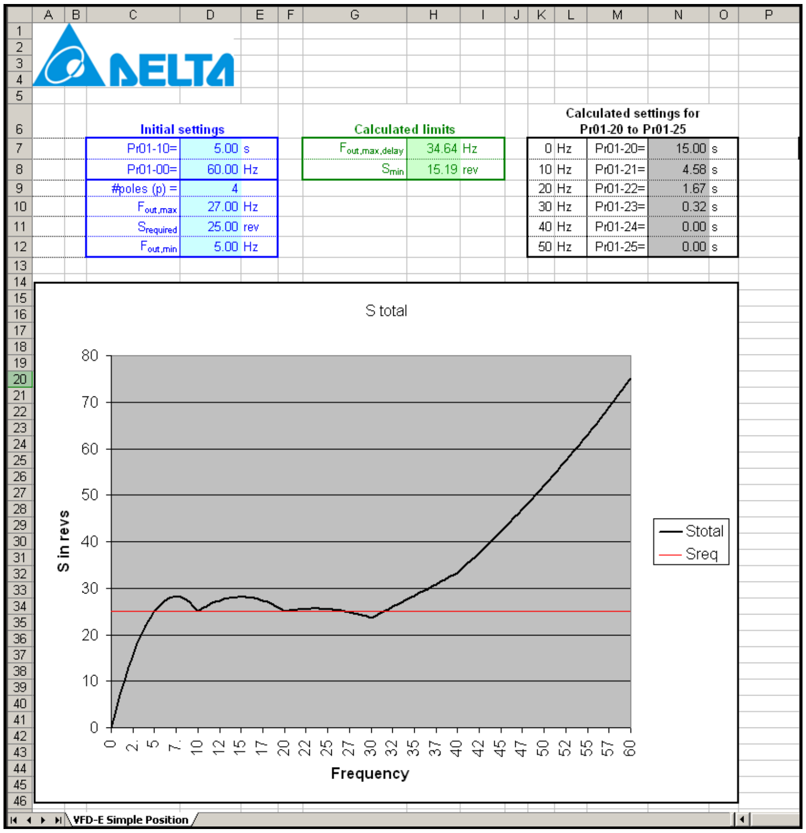
<u>Enter the following data in the blue cells:</u>

- The deceleration time in Pr01-10.
- The maximum frequency in Pr01-00.
- The number of motor poles.
- $F_{out,max}$. This is the maximum output frequency for which you want the required number of revolutions $S_{required}$ to standstill.
- $S_{required}$. The required number of revolutions to standstill.
- Fout,min. The minimum output frequency for which you want the required number of revolutions $S_{required}$ to standstill. The lower the value, the more inaccurate the result is.

<u>Green cells:</u>

- $F_{out,max,delay}$ shows the highest calculated output frequency for which $S_{required}$ can be achieved. As a warning it becomes red when it is lower than $F_{out,max}$. In that case increase $S_{required}$ or Pr01-10.
- S_{min} shows the minimum number of revolutions that can be achieved with Pr01-10 and $F_{out,max}$. It becomes red when it is higher than $S_{required}$. In that case increase $S_{required}$, Pr01-10, or $F_{out,max}$.

In the grey cells the calculated values for Pr01-20 to Pr 01-25 are given. They can be entered into the drive. The chart show the resulting #revs as function of the actual output frequency.



Initial settings

Pr01-10=	5.00	s
Pr01-00=	60.00	Hz
#poles (p) =	4	
$F_{out,max}$	27.00	Hz
$S_{required}$	25.00	rev
$F_{out,min}$	5.00	Hz

Calculated limits

$F_{out,max,delay}$	34.64	Hz
S_{min}	15.19	rev

Calculated settings for Pr01-20 to Pr01-25

0	Hz	Pr01-20=	15.00	s
10	Hz	Pr01-21=	4.58	s
20	Hz	Pr01-22=	1.67	s
30	Hz	Pr01-23=	0.32	s
40	Hz	Pr01-24=	0.00	s
50	Hz	Pr01-25=	0.00	s