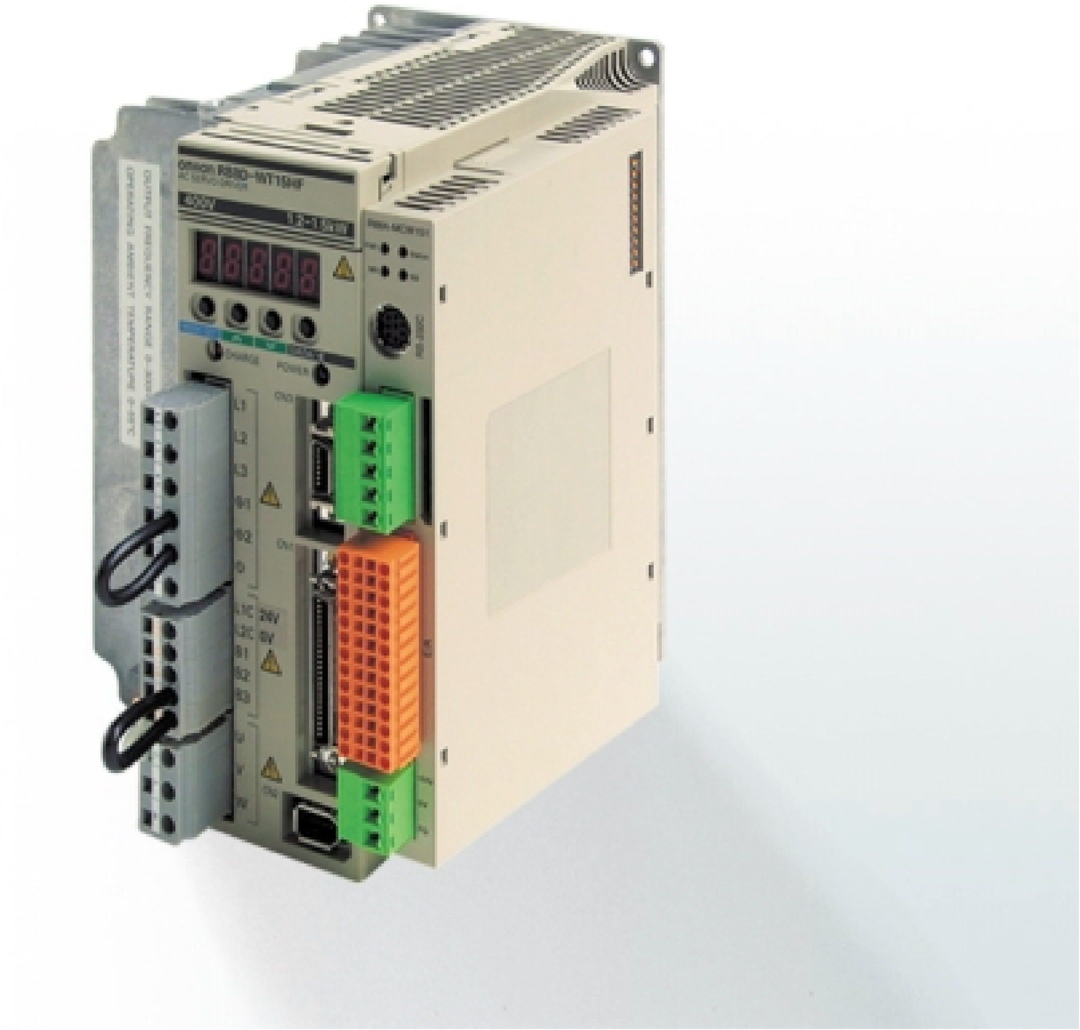
MECHATRONICS APPLICATION CENTER

TUNING THE MCW151 BOARD



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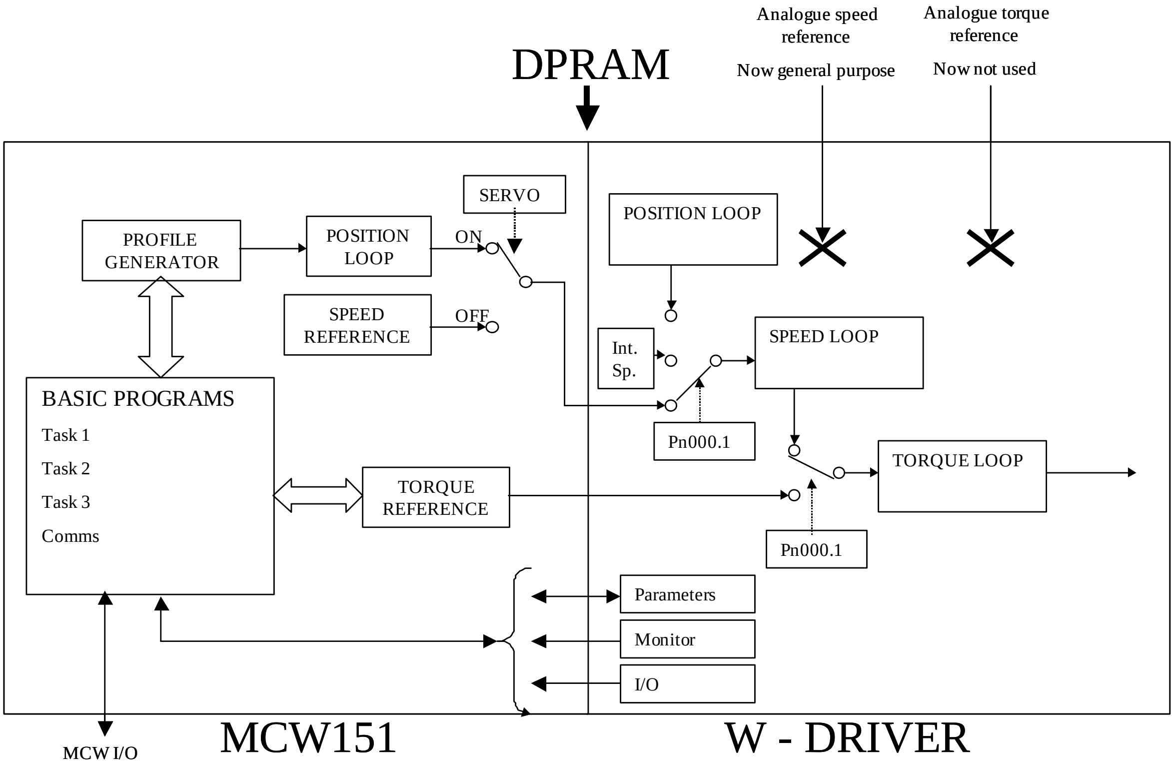
0. INTRODUCTION

This document is intended to help you tuning a MCW151 board. Before using this board you must know how to tune and use it properly. One way to learn is reading the User's manual but it can be quiet hard. For this reason we have made this document, which probably will help you to begin using and tuning this product.

Notice the MCW151 interface with W-driver. Following graph shows the relationship between driver and board through a Dual Port RAM.



We can see that MCW151 send and receive several signals from the servo driver. Mainly MCW151 board send a speed reference (from the profile generator if SERVO axis parameter is ON or dependent on DAC parameter if SERVO parameter is OFF) to the driver. And MCW151 receives a measured position from the driver (encoder). These signals are basically used to close the position loop in MC151 board.

In this document there is information about:

- Previous adjustments (Speed loop of servo driver).
- Position loop adjustments (P_GAIN and VFF_GAIN of MCW151).

1. PREVIOUS ADJUSTMENTS

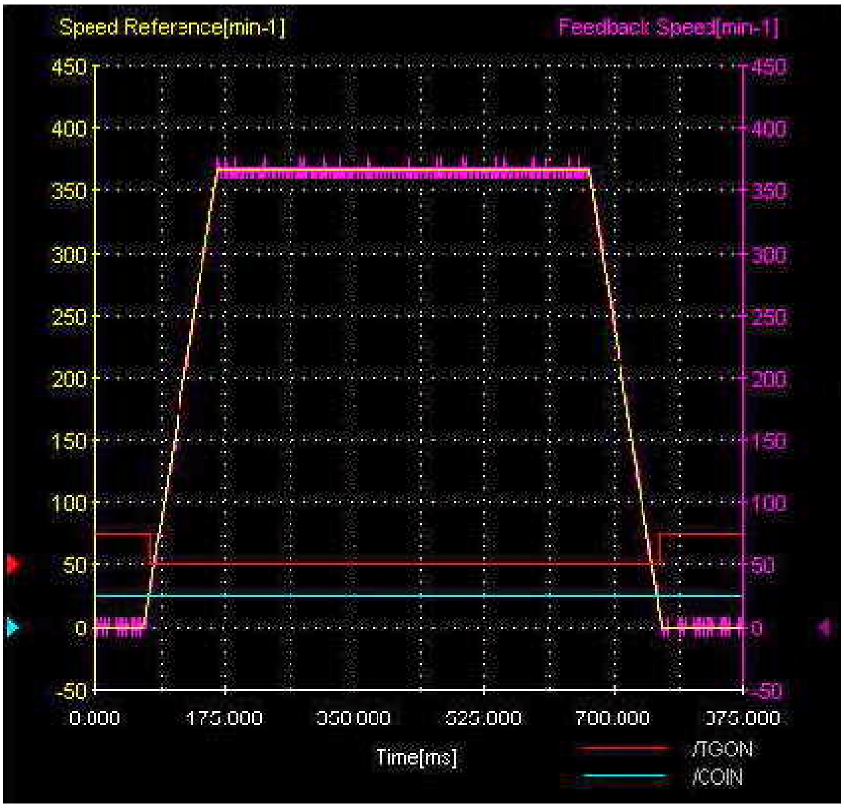
1.0. Introduction

The aim of this document is to explain how to tune MCW151 board, but there is a previous adjustment we have to do. It means adjusting W-servo driver speed loop gain.

1.1. Speed loop adjustments

If we want a good system response, before adjusting position loop in MCW151 board we have to adjust the speed loop gain of the W-servo driver. This loop has to be adjusted for faster dynamic than required to assure that the system is responding well to command. It means to adjust the two inner loops for worse conditions than they actually will work, in this way we will not worry about the response of these loops.

Picture 1 shows a good speed loop adjustment. We can see how Feedback Speed signal (in yellow) follows accurately the Speed reference.



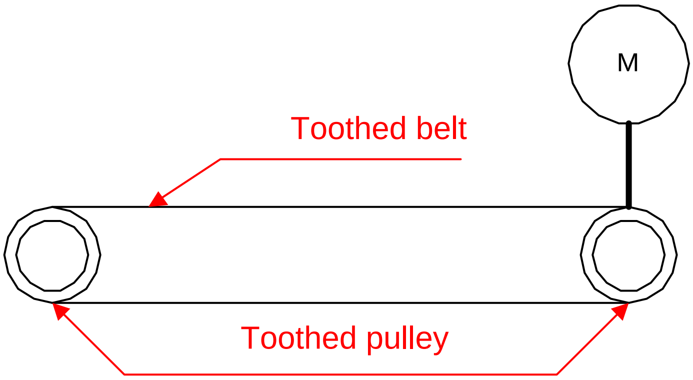
Speed and Torque loop must be transparent; it means we have to guarantee that speed reference is almost exactly the same as real motor speed.

To adjust W-servo driver read document “Tuning the W-series Servodriver”. You will find all the information you need to adjust speed loop.

Servo has to be adjusted for speed or torque control, so we must set parameter Pm000.1 to 0 or 9.

1.2. **Example**

Toothed belt:



We have adjusted the highest rigidity we can before the system oscillate because it will mean higher gains and then better responses.

In this case rigidity is set to 7, so Speed loop gain parameter (Pn100) will be 120 (Hz), speed loop integration time constant (Pn101) will be 800 (x 0,01ms) and Torque command filter time constant (Pn401) will be 30 (x 0,01ms). For 1100-rpm of speed reference with 50 milliseconds of accelerating and decelerating ramps.

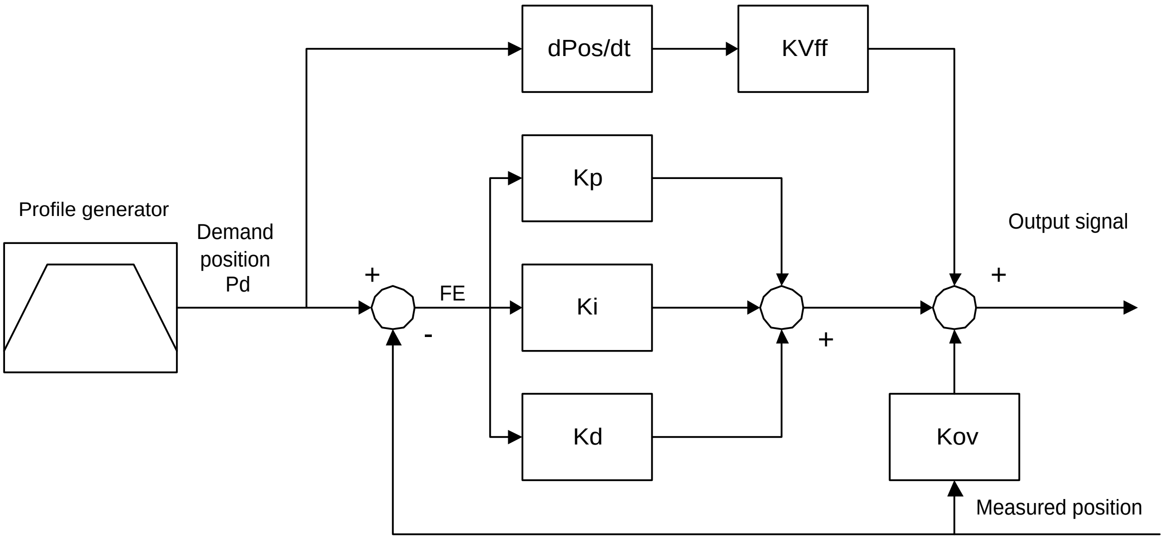
Inertia ratio adjustment is made by autotuning function (Fn001). Parameter Pn103 was set to 1200.

2. POSITION LOOP

2.0. Introduction

The servo system of the MC Unit uses a semi-closed or inferred closed loop system. This system detects actual machine movements by the rotation of the motor in relation to a target value and actual movement, and reduces the error through feedback.

The following graph shows the basic blocks of the MC Unit.

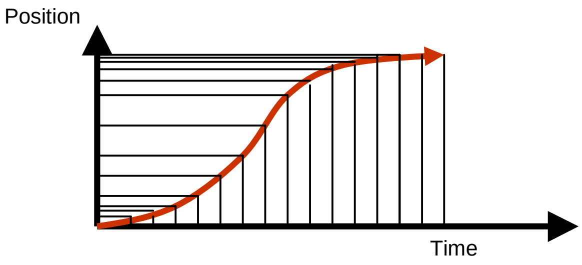


MC Board performs actual position control according to demand position. The main input of the controller is the following error (FE), which is calculated difference between the demand position and the actual measured position. Output signal is the required speed reference that has to control the rotational speed of the servomotor. Measured position is the feedback signal generated by the encoder.

2.1. Profile generator

The profile generator is a mathematical block responsible to calculate each Servo Cycle the target position (DPOS) for each axis.

The position profile is generated according to the motion instructions that are commanded via Basic Programs. Motion instructions are stored in a temporary buffer, waiting for its executing.



Cycle	DPOS
0	0
1	25
2	100
3	225
…	X

2.2. Gain descriptions

2.2.1. Proportional Gain

The proportional gain Kp creates an output that is proportional to the following error (FE). All practical systems use proportional gain. For many just using this parameter alone is sufficient. It is called P_GAIN

$$P\_GAIN = K_p \cdot FE$$

2.2.2.Integral Gain

The integral gain Ki creates an output that is proportional to the sum of the following errors (FE) that have occurred during the system operation. Integral gain can cause overshoot and so is usually used only on systems working at constant speed or with slow accelerations. It is called I_GAIN.

$$I\_GAIN = K_i \cdot \sum FE$$

2.2.3.Speed feedforward Gain

The speed feedforward gain Kvff produces an output that is proportional to the change in the demand position (Pd) and minimizes the following error at high speed. It allows reducing proportional speed error. The parameter can be set to minimize the following error at constant machine speed after other gains have been set. It is called VFF_GAIN.

$$VFF\_GAIN = K_{Vff} \cdot \Delta P_d$$

2.2.4.Derivate Gain

The derivative gain Kd produces an output that is proportional to the change in the following error (FE) and speeds up the response to changes in error while maintaining the same relative stability. It may create a smoother response. High values may lead to oscillation. The derivative gain axis is called D_GAIN

$$D\_GAIN = K_d \cdot \Delta FE$$

2.2.5.Output Speed Gain

The output speed gain Kov produces an output that is proportional to the change in measured position (Pm) and increases system damping. The parameter can be useful for smoothing motions but will generate high following errors. It is called OV_GAIN

$$OV\_GAIN = K_{ov} \cdot \Delta P_m$$

2.3. Gain adjustments

2.3.0.Introduction

A good designed system (mechanic, motor size, etc.) only needs P_GAIN and VFF_GAIN.

Other gains help to adjust systems with design problems. Applying them system will loose dynamic and/or increase following error.

2.3.1.P_GAIN adjustment

2.3.1.0. Introduction

- P_GAIN is proportional to following Error. Following formula shows this relation.

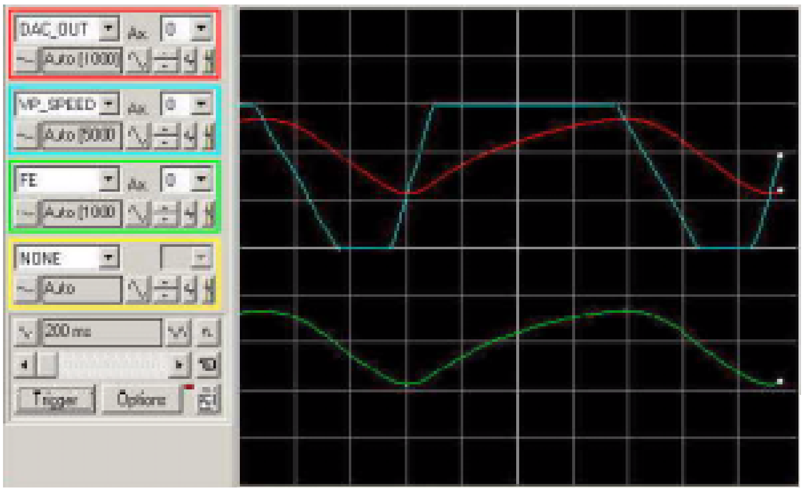
$$FE = \frac{SPEED}{S\_RATE} \cdot \frac{60}{ENC\_RESOL} \cdot P\_GAIN$$

- FE is also proportional to Speed, as shows formula above.
- Decreasing P_GAIN we loose dynamic because the more the P_GAIN the more dynamic. But Increasing P_GAIN above a limit will cause oscillations.
- The following pictures show

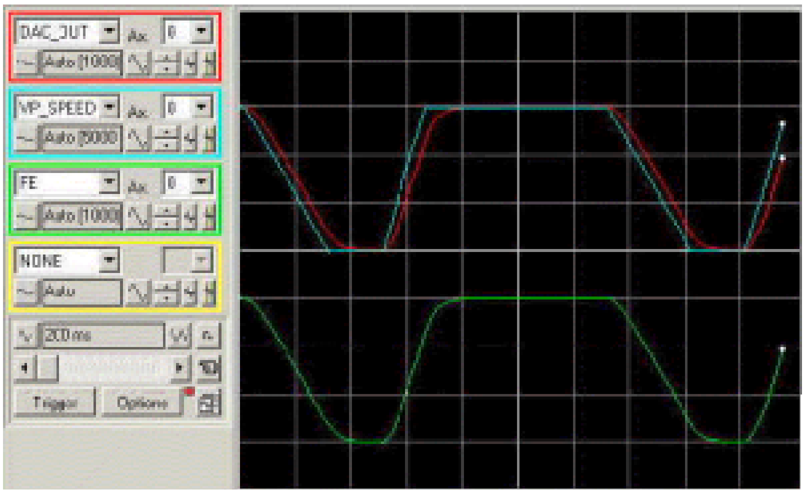
2.3.1.1. Examples

Following pictures show the response of the system with different values of P_GAIN. Best response has to be for the highest value of P_GAIN before having oscillations. In this case P_GAIN=2. Signals shown are: (red) feedback speed, (blue) speed reference and (green) following error.

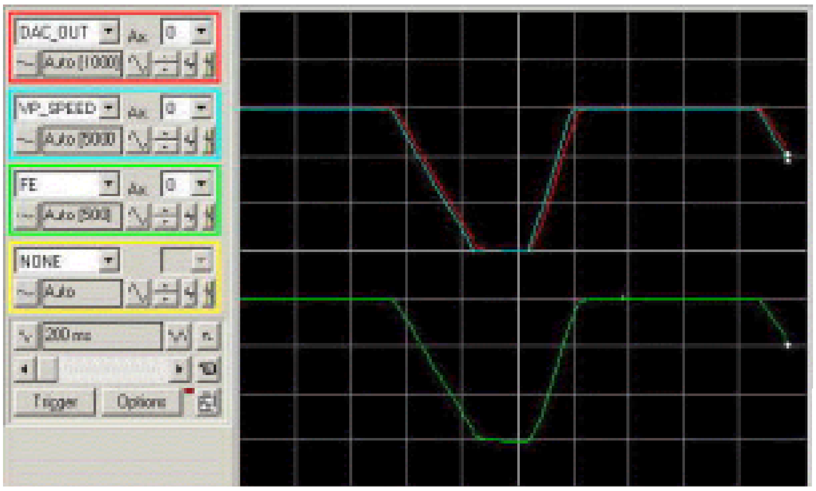
P_GAIN=0.1



P_GAIN=1

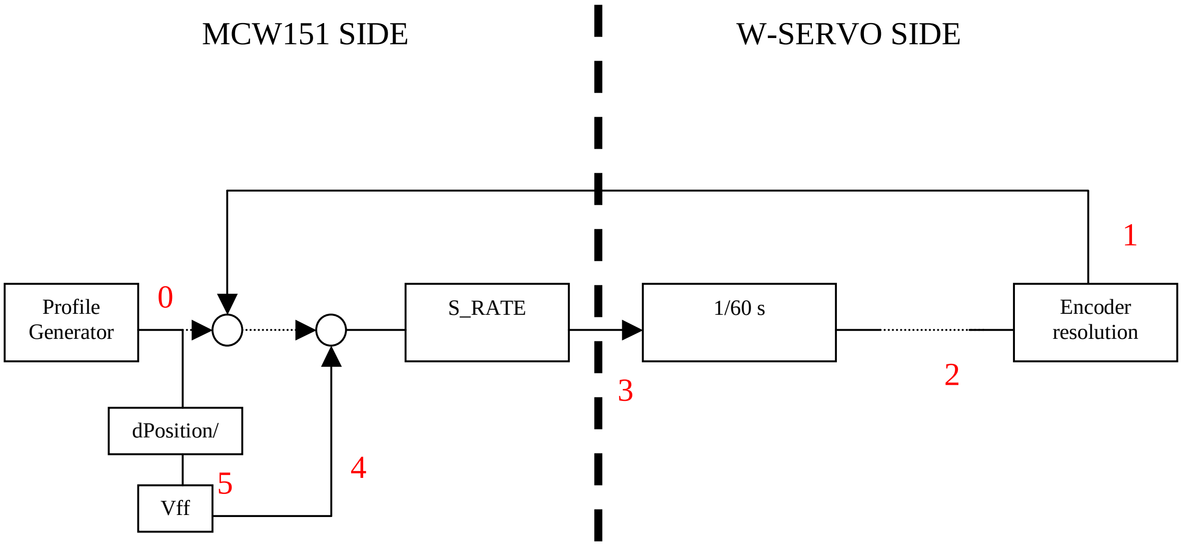


P_GAIN=2



2.3.2.VFF_GAIN adjustment

2.3.2.0. Introduction



The target is to have the rate of point ‘1’ and point ‘5’ the same. We can make the calculation in different ways. To make a numerical example, I will assume than the adjustments in the W servo are as default (for using with an inverter or with another adjustments, change the necessary values.

- We want in point 0 a profile with a speed of SPEED counts/s (the servo loop is working always in counts despite the UNITS value) and, of course we want to receive the same speed from the motor in point 1. We will see which value of V_FF gives this condition:

If in point 1 we want SPEED counts/s, in point 2, as speed reference in the Servodriver we have (in revolutions per second) and considering the encoder resolution (counts per revolution) that depends on the motor model:

$$SPEED\frac{counts}{s}\cdot\frac{1revolution}{Enc\_resolution}$$

- And in point 3, we have the speed reference in revolution per minute (rpm):

$$SPEED\frac{counts}{s}\cdot\frac{1revolution}{Enc\_resolution}\cdot\frac{60s}{1\min}$$

- In point 4 we obtain the magnitude of the position loop output. The ratio between this value and the speed reference in rpm's is depends on the motor and is determined by the S_RATE parameter:

$$SPEED\frac{counts}{s}\cdot\frac{1revolution}{Enc\_resolution\_counts}\cdot\frac{60s}{1\min}\cdot\frac{1}{S\_RATE\frac{rev}{\min}}$$

- In point 5 we have to consider the effect of the V_ff gain. This point 5 is the speed that the profile generator outputs:

$$SPEED\frac{counts}{s}\cdot\frac{1revolution}{Enc\_resolution\_counts}\cdot\frac{60s}{1\min}\cdot\frac{1}{S\_RATE\frac{rev}{\min}}\cdot\frac{1}{V\_ff}$$

- And all this has to be equal to the desired speed counts/s

$$SPEED\frac{counts}{s}\cdot\frac{1revolution}{Enc\_resolution\_counts}\cdot\frac{60s}{1\min}\cdot\frac{1}{S\_RATE\frac{rev}{\min}}\cdot\frac{1}{V\_ff}=SPEED\frac{counts}{s}$$

- Then, finally:

$$V\_ff=\frac{1revolution}{Enc\_resolution\_counts}\cdot\frac{60s}{1\min}\cdot\frac{1}{S\_RATE\frac{rev}{\min}}=\frac{60}{Enc\_resolution\cdot S\_RATE}$$

But if you try in practice which value is better you will find that the suitable value is much bigger than the calculated one. The difference comes from the SERVO_PERIOD value. We have been working in seconds all the time, and then, the value you have to apply is:

$$VFF\_GAIN=\frac{V\_ff}{SERVO\_PERIOD}\cdot 10^{6}$$

Here you can see the influence of this parameter in the calculation of this gain.

If you set this gain correctly, nearly all the corrections are following this way and the Position PID is only making very small corrections, that adjustment allows you to keep the position error small and around zero independent of the speed of the movement.

2.3.2.1. Example

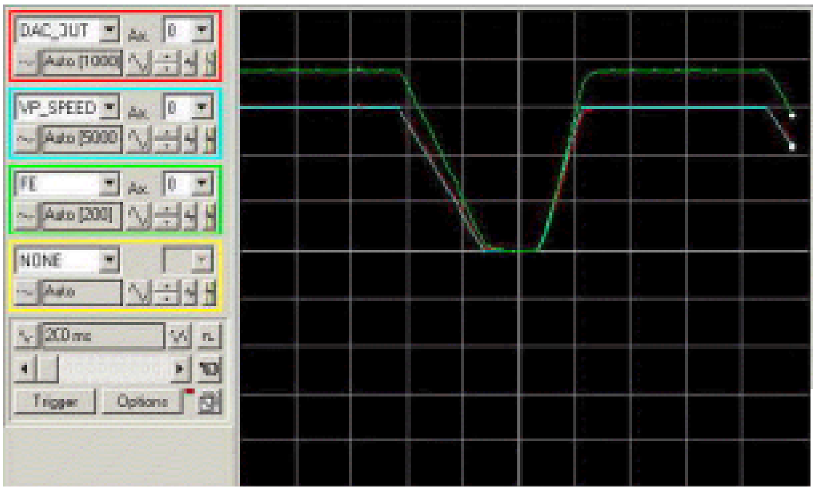
Calculation of the VFF_GAIN for a MCW151 connected to a W Servodriver with the motor: R88M-W40030T-S, it has 8192 pulses per revolution and S_RATE is 0.3667. The SERVO_PERIOD in the MCW151 set to 500 (units is µs).

We obtain that:

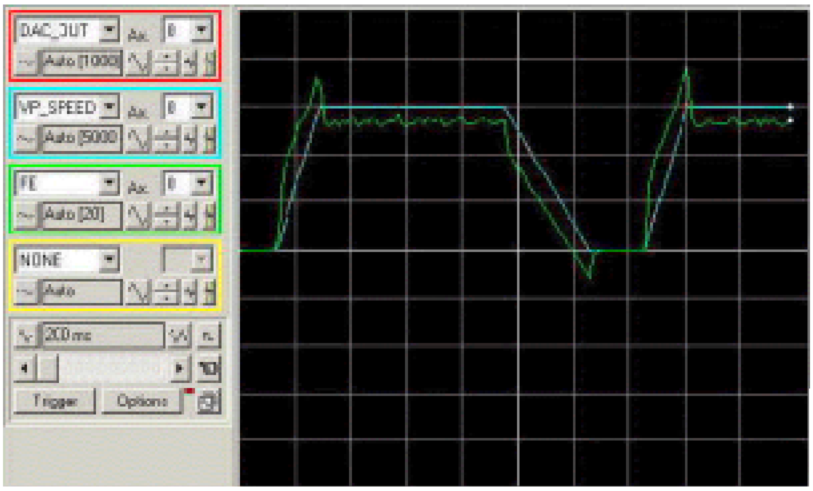
$$VFF\_GAIN = \frac{60}{8192 \cdot 0.3667} \cdot \frac{1000000}{500} \approx 39.9467$$

Following pictures show the response of the example with different values of VFF_GAIN. Best response has to be for the calculated value of VFF_GAIN=39.95. Signals shown are: (red) feedback speed, (blue) speed reference and (green) following error.

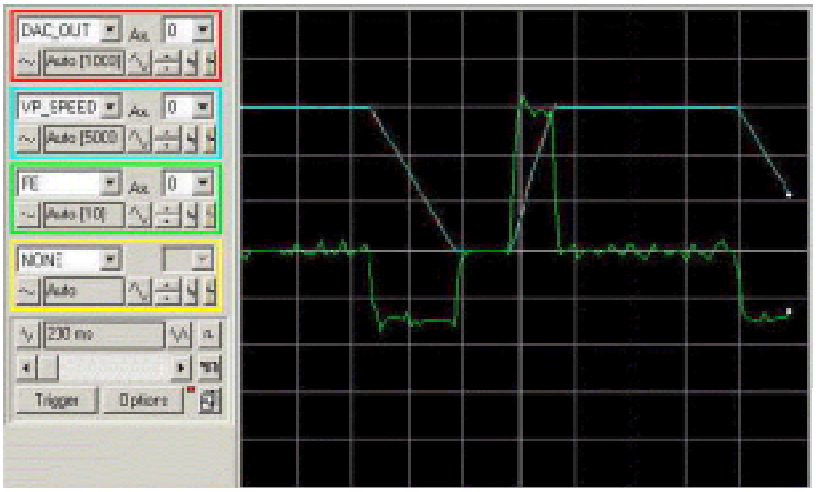
VFF_GAIN=20



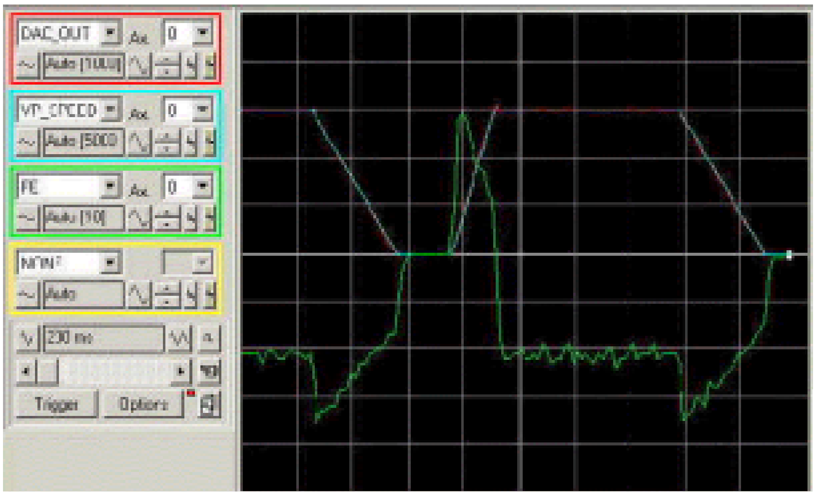
VFF_GAIN=38.5



VFF_GAIN=39.95



VFF_GAIN=40.5



2.3.3.Final adjustment

P_GAIN=2 and VFF_GAIN=39.95