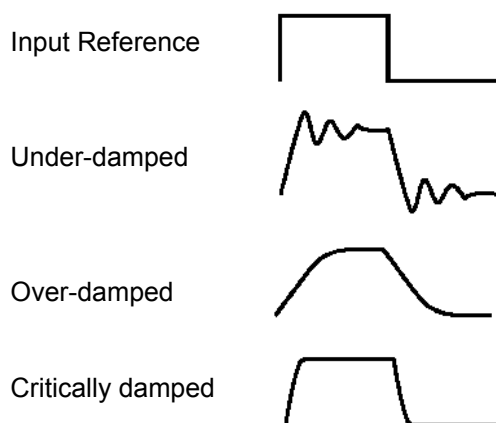


The Application Note is pertinent to the Unidrive Family

## Speed Loop Tuning

The Unidrive has built-in tuning algorithms that address the inner current loop ( the more mathematically difficult loop to adjust ). This auto-tune feature measures motor values such as stator resistance and inductance and takes other physical motor data into account such as # of poles etc to obtain a better idea of the inner motor characteristics that the current loop will be driving.

The Speed Loop must deal with the overall motor plus machine/product inertia, associated damping factors such as viscous and frictional components and hopefully little or no discontinuities such as chain slop, gearing backlash etc. Tuning criteria are often classically characterized as under-damped, over-damped and critically damped. Shown below are the 3 basic categories of tuning which result when a drive is given a step function of speed reference.

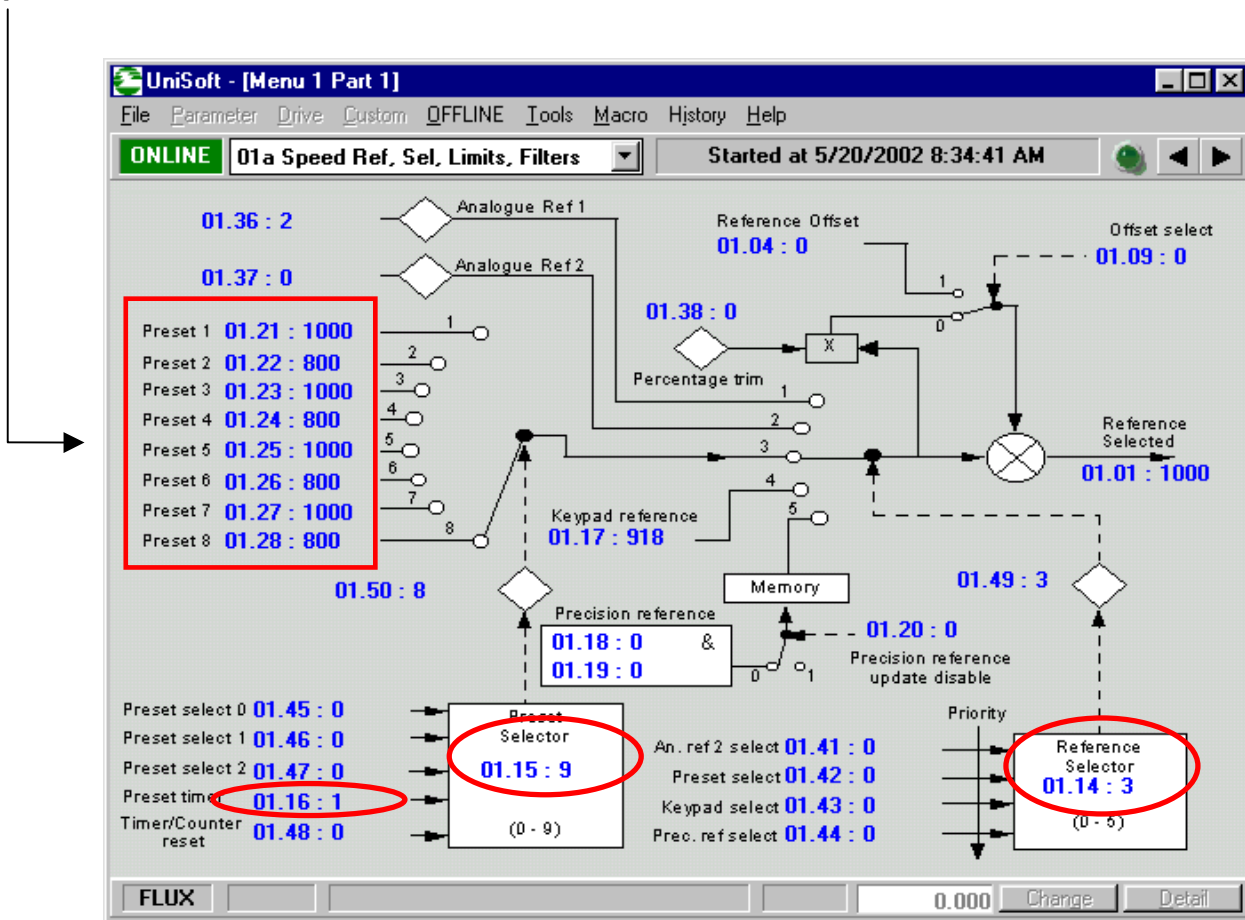


Speed Loop tuning is a rather subjective matter. Different applications may dictate a different kind of tuning. Some applications such as positioning and other forms of rapid “motion control” typically require a rather hot/crisp speed loop tuning response-perhaps a cross between critical and under-damping as shown above. Other general applications such as conveyor control, extruders and their accompanying melt pumps would require a more docile yet accurate tuning criteria-perhaps a cross between critical and over-damping as shown above. Then there are compromises that may need to be considered depending on the stiffness of the mechanical linkage that result in the best overall system performance. The primary adjustments to achieve this tuning are the Proportional, Integral and Derivative Gains of the Speed Loop. In the Unidrive these are parameters #3.10, #3.11 & #3.12 respectively.

In any case, this tuning is usually performed by the technician who is taking into account these considerations. In a steady state speed situation, performance of the speed loop may appear fine. It won't be until an external disturbance is introduced that instability will become noticeable. In order to achieve the desired speed loop tuning, it is necessary to create such disturbances but in a controlled repetitive manner so that one can make adjustments and observe the outcome. This application note will outline a simple method of using a built-in feature of the Unidrive to assist with the tuning process when operating in a closed loop mode.

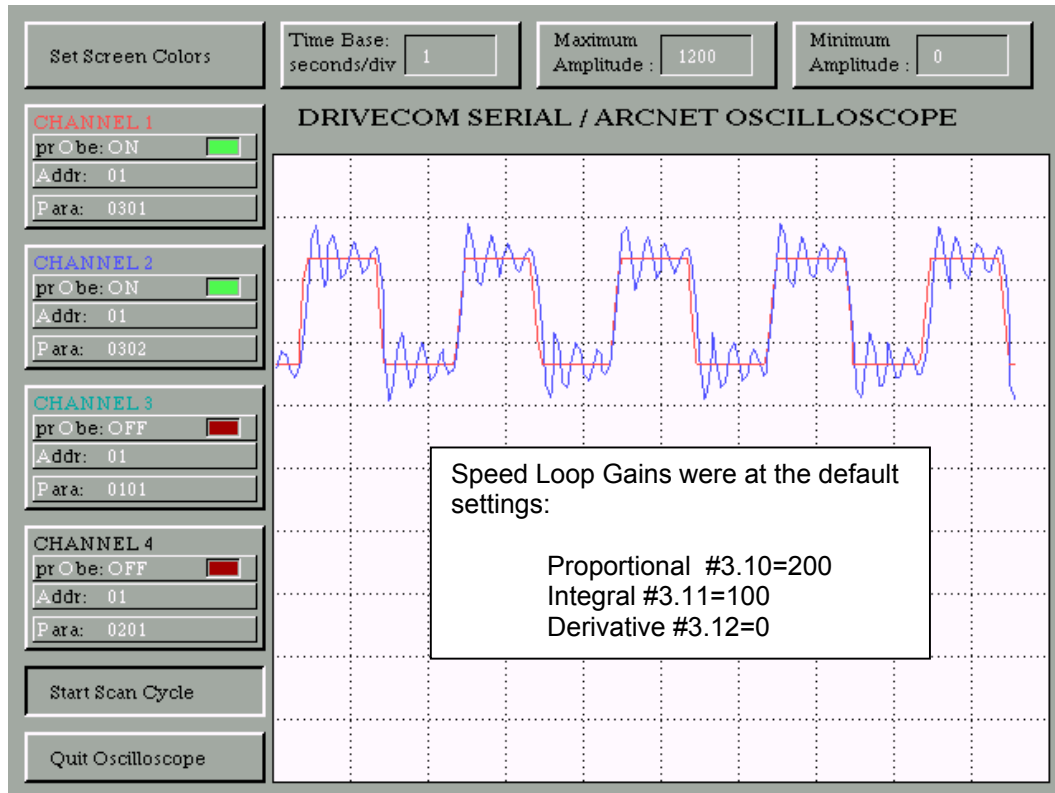
One of the easiest ways to create system disturbances is to vary the speed reference to the drive during operation. If the drive has a speed pot, one could merely ask an assistant to rotate the speed pot back and forth over a range while the technician adjusts and observes the results. This would work but can become tiresome for the assistant.

The Unidrive has a built-in feature that will step from Preset Speed 1 to 8 at regular intervals set as X.X seconds. To use this feature you would determine a modest center speed that the system can be run at. For example, if the drive has a speed pot, you would just adjust the speed to some reasonable level where you would feel comfortable to begin tuning ( top speed would not be my first choice ). For my example, I selected to modulate the Speed Reference about 200RPM – between 1000 and 800 RPM. You can place these speeds into the Preset Speed registers in an alternating fashion- see below. ( **Note- these speeds are in RPM as expected for Vector or Servo mode operation** )



In order to activate the Automatic Preset Speed interval feature, you would set the Time Interval in parameter #1.16 ( 2.0 or 2 seconds would be a good starting point ). You would also need to set #1.15=9 and #1.14=3 to allow the drive to follow these Speed Preset values. If the drive was already running by the pot at 1000 RPM for instance, these parameter changes would begin taking affect causing automatic speed changes between 1000 & 800 rpm at 2 second intervals. Keep in mind that you may need to adjust the accel and decel ( #2.11 and #2.21 respectively ) to lower values to allow more of a step or abrupt speed change.

Shown below is a screen shot of the Speed Reference ( #1.01 red trace ) vs the Speed Feedback ( #3.02 blue trace ) of a motor operating in the Vector mode. The shot below was taken using our DriveCom scope program for a PC. DriveCom is a free software available from our website.



#### Tuning the speed loop gains using an oscilloscope

Connect the oscilloscope to analog output 1 to monitor the speed feedback.

Give the drive a step change in speed reference and monitor the response of the drive on the oscilloscope.

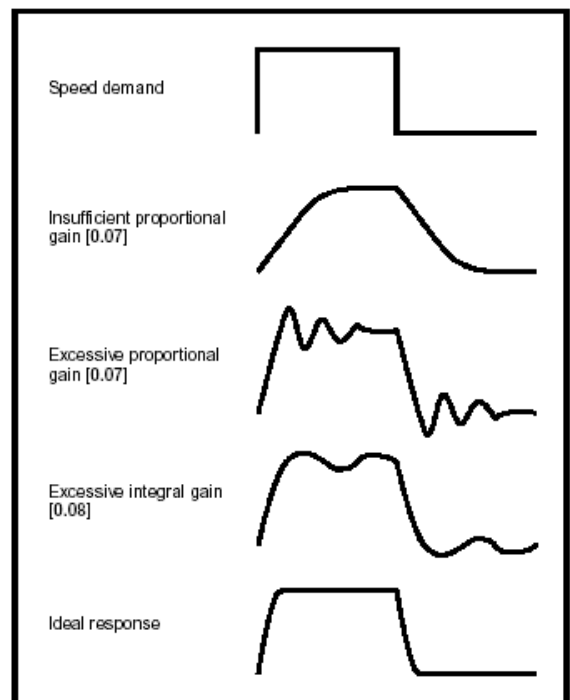
The proportional gain should be set up initially - the value should be increased up to the point where the speed overshoots and then reduced slightly.

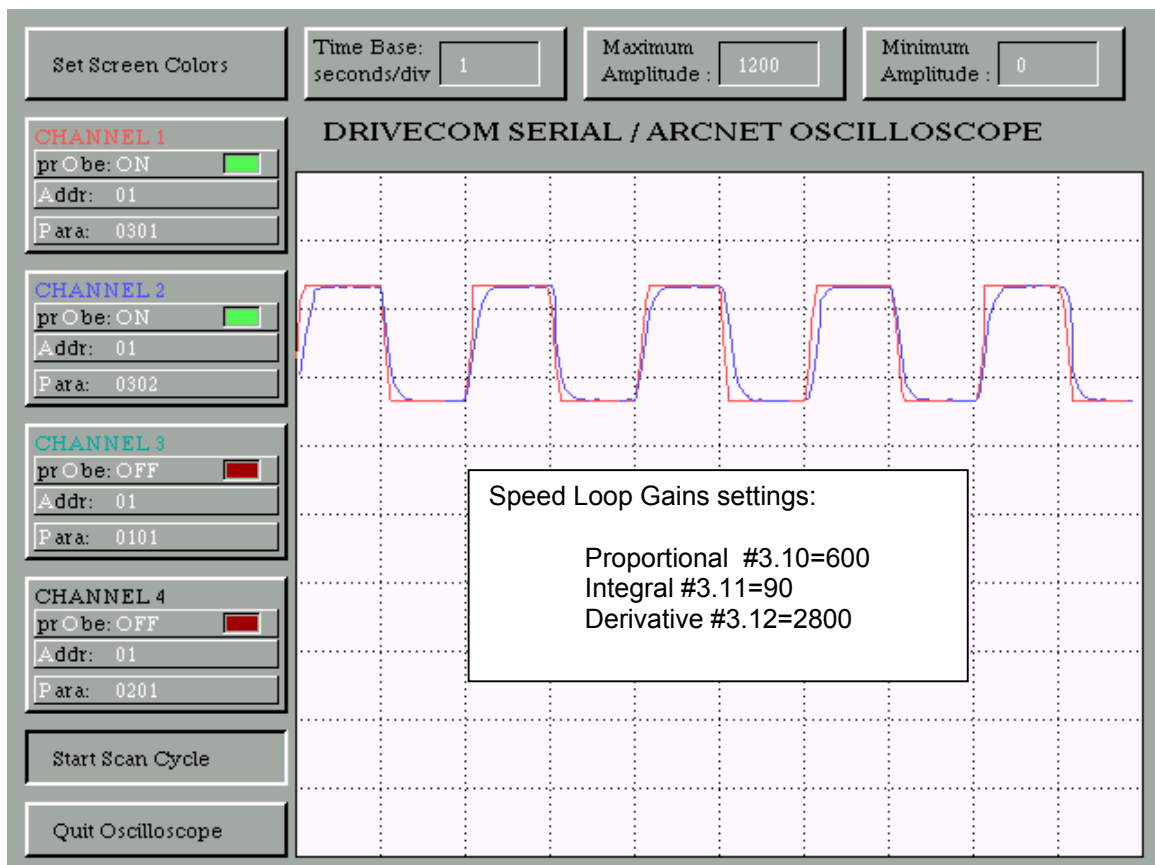
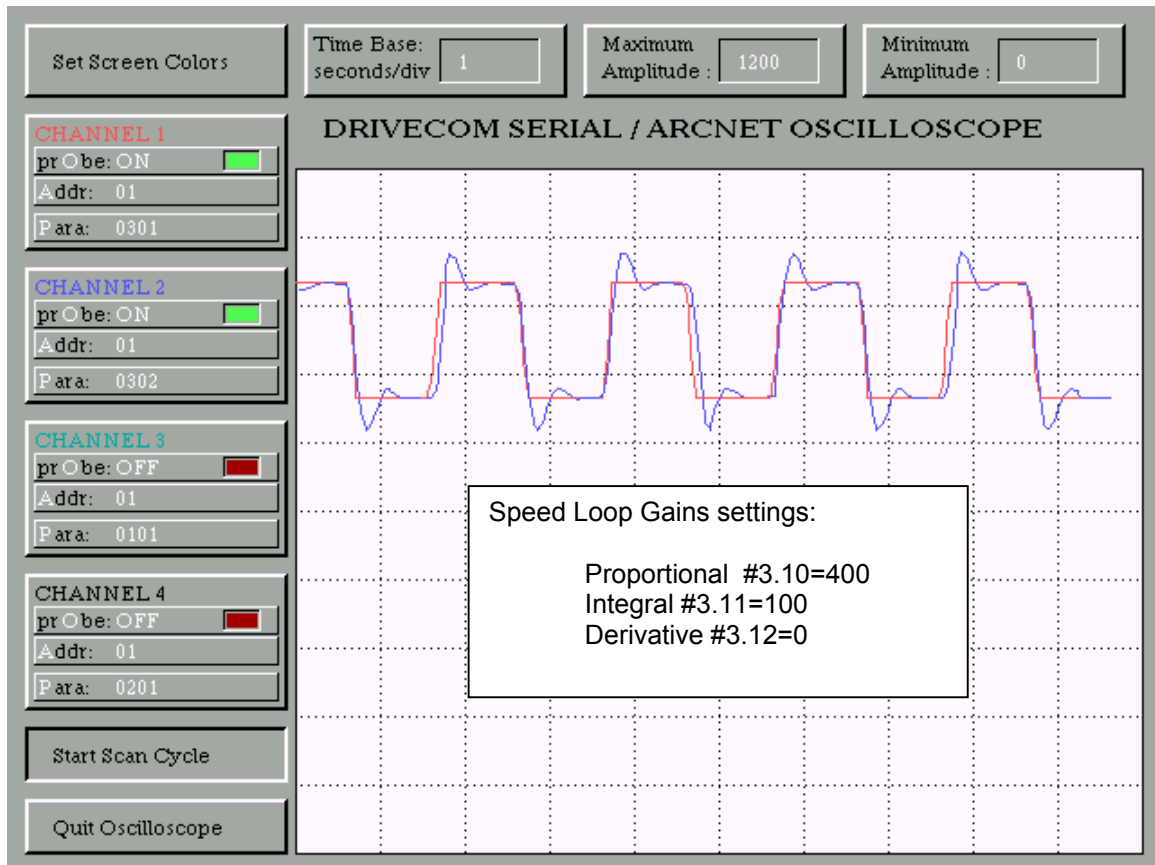
The integral term should then be increased up to the point where the speed becomes unstable and then reduced slightly.

If a derivative gain is required the value should be increased up to the point where the system response becomes unstable and then reduced slightly.

It may now be possible to increase the proportional gain to a higher value and the process should be repeated until the system response matches the ideal response shown below.

The diagram below shows the effect of incorrect P and I gain settings as well as the ideal response.

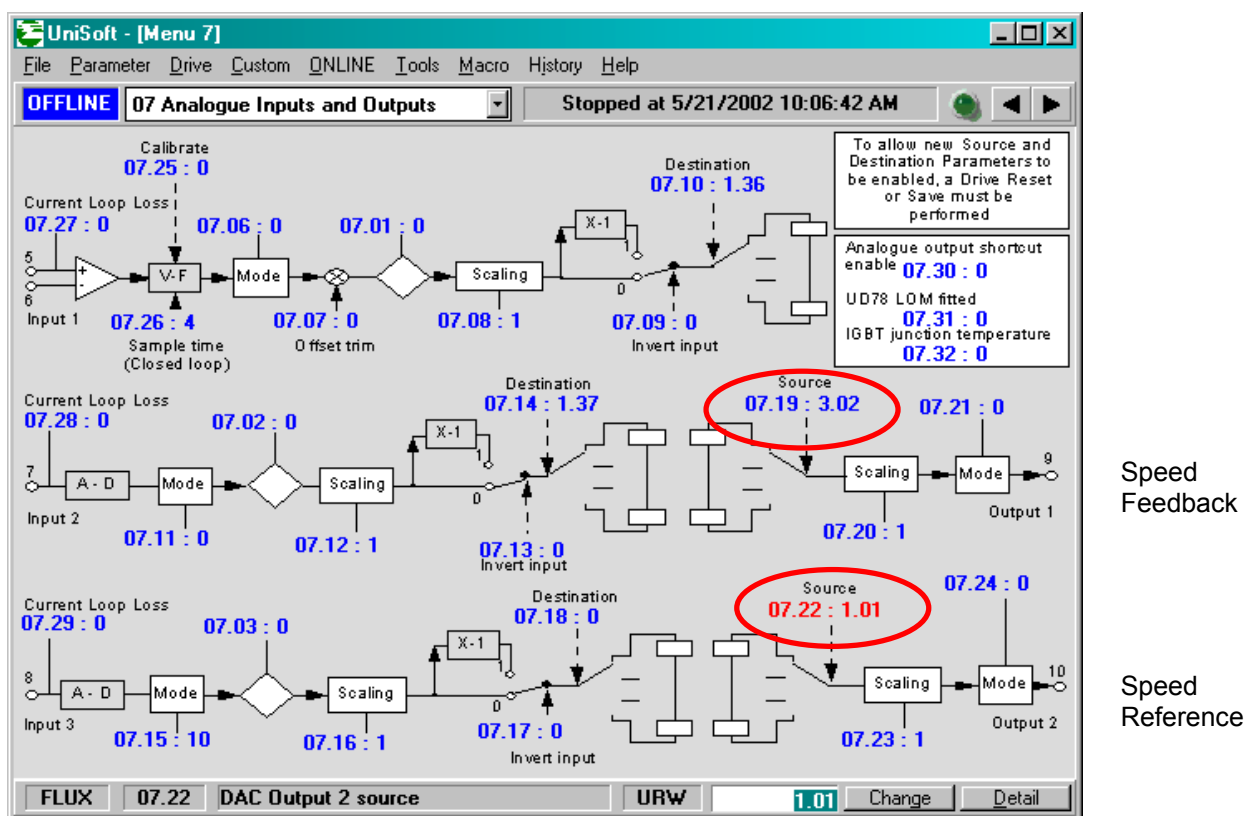




I could have continued to adjust further but this performance was more than satisfactory for my application so I was pleased with the critically damped performance of the last screen shot.

In practice one may wish to perform additional tuning at higher speeds and perhaps with larger steps and quicker interval changes. This can easily be accomplished using the Automatic Preset Speed interval feature as described previously. Once the desired tuning performance is achieved one would need to at least change #1.14 back to the original setting before performing a store so that the alternating speed presets are not in the picture any more. If the preset speeds are going to be used in the final application, these tuning speeds could be removed altogether and don't forget about #1.15.

As an alternative to observing the results using the "soft-scope", one could use an actual oscilloscope by placing at least one channel of a 2 Channel scope on pin 9 of the Unidrive. The default for this Analog output is a voltage proportional to the Speed feedback .



If it is desired to see both Reference and Feedback on a 2 Channel scope, you could change #7.22 to 1.01 in order to bring out the Speed Reference on pin 10.

**Questions ?? Ask the Author:**

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Shown below is an extract from the Unidrive Manual under Optimization and with the description of parameters #3.10-#3.12 Speed Loop PID gains.

## Dynamic performance

### Closed-loop only

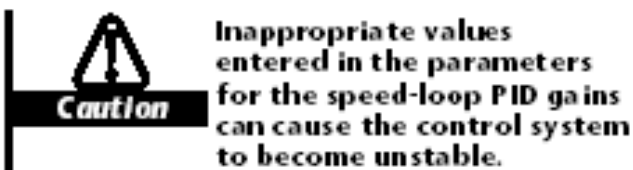
The following parameters affect the dynamic performance of the Drive when it is operating in a closed-loop mode:

**0.07** Speed-loop proportional gain

**0.08** Speed-loop integral gain

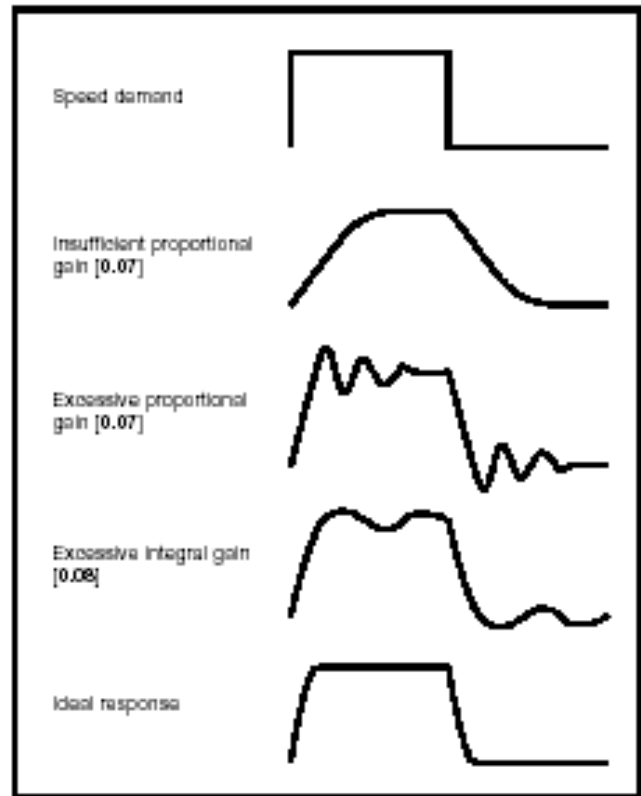
**0.09** Speed-loop derivative gain

### Procedure



The default values of the speed-loop PID gains can be used for undemanding applications. Use the following procedure when the performance is to be improved in speed or torque control:

1. Connect the load to the motor.
2. Start and stop the Drive as required.
3. Set the motor running at the required speed.
4. To increase the speed of response to a change in speed demand, or to a change in load, increase **0.07** Speed-loop proportional gain. Set **0.07** just below the value that causes the motor to vibrate. It is common for the vibration to be worse at zero speed. An excessive proportional gain can result in instability.
5. To improve the ability of the Drive to maintain a speed or torque demand under steady-state or slowly-changing conditions, increase **0.08** Speed-loop integral gain.  
A high value of **0.08** can cause the motor speed to vary sinusoidally around the speed demand. This effect can be minimized by increasing the value of **0.07** Speed-loop proportional gain.
6. To reduce overshoot when the speed demand or the load on the motor is suddenly changed, increase **0.09** Speed-loop derivative gain. Excessive derivative gain will cause noise in the motor.



**Figure 2-9** Response to a step-change in speed demand when the speed-loop PID gains are adjusted

### Default values and range

Pr	Default value	Range
<b>0.07</b>	200	0 ~ 32000
<b>0.08</b>	100	0 ~ 32000
<b>0.09</b>	0	0 ~ 32000

### Summary

The waveforms shown in Figure 2-9 represent the signals that would appear at terminal 9 of the signal connector when the speed demand applied to terminals 5 and 6 (or terminal 7) is a square-wave.

