Welcome to the training module, DCS800 Standard Firmware software functions.

If you need help navigating this module, please click the Help button in the top right-hand corner.
To view the presenter notes as text, please click the Notes button in the bottom right corner.
Objectives

This training module covers:

- Firmware structure overview
- Armature control circuit
  - Speed control
  - Current control
- Field control circuit
- ABB drive profile
The DCS800 firmware consists of 2 main parts:

The armature is controlled by the speed controller with inner armature current controller.

The field is controlled by the EMF controller with an inner field current controller.

The speed reference can be selected from several sources and is then processed by the ramp.

The speed actual can be read from several sources and is then sent to the speed summation point.

The speed controller uses the speed error between speed reference and speed actual to calculate a torque reference.

With the help of the torque selector, it is possible to choose between the torque reference from the speed controller and external torque reference. In the first example, the drive is speed controlled, in the second example the drive is torque controlled. Torque control is for example used for winders or followers in a master follower application.

The torque reference is recalculated to a current reference by means of the motor flux. The actual current is measured by the drive and the current controller uses the error between reference current and actual current to calculate the proper firing angle alpha.

The EMF reference can be selected from several sources.

The actual EMF is measured and calculated by the drive and the EMF controller uses the error between EMF reference and EMF actual to calculate a flux reference.

The relationship between flux and field current is not linear. Small field currents lead to a relatively high flux, but due to magnetic saturation in the motor an always increasing amount of field current is needed to generate the same amount of flux. Thus the flux linearization is a feed forward for the EMF controller to speed
up the relatively slow EMF controller and provides a field current reference.

The actual field current is measured by the field exciter and the field current controller uses the error between field current reference and field current actual to control the field exciter.
• Signals can be identified by the oval shape around their numbers. They are in groups 1 to 9.

• Parameters can be identified by the rectangular shape around their numbers. They are in groups 10 to 99.

• Parameters which are usually written by Adaptive Program, application program or overriding control can be identified by the gray rectangular shape.

Signals can be identified by the oval shape around their numbers. Signals are measured and calculated actual values of the drive. This includes the control-, status-, limit-, fault- and alarm words. The drive’s signals can be found in groups 1 to 9. None of the values inside these groups is stored in the flash and thus volatile.

Parameters can be identified by the rectangular shape around their numbers. Parameters adapt the drives firmware function to the connected application. The drive’s parameters can be found in groups 10 to 99.

Parameters, which are usually written by Adaptive Program, application program or overriding control, can be identified by the gray rectangular shape around their numbers.
Firmware functions
Speed reference selection

- Speed reference can be selected from several sources
- First speed reference is shown in signal 2.30 SpeedRefExt1
- Second speed reference is shown in signal 2.31 SpeedRefExt2
- Parameter 10.02 allows to change the direction of rotation by negating the speed reference
- If the drive is controlled locally by DCS800 control panel, DriveWindow or DriveWindow Light the local speed reference is connected to input “Local”

- The speed reference can be selected from several sources and is then sent to the speed ramp.
- The first speed reference is shown in signal (2.30) and can be selected with parameter (11.03) from different sources. These sources are analog inputs - see signal (5.03) to (5.08) - or parameters like (23.01). With Adaptive Program, application program or overriding control, it is possible to write speed reference values directly into the parameter (23.01).
- The second speed reference is shown in signal (2.31) and can be selected with parameter (11.06) from different sources. The sources are the same as those described for the first speed reference.
- Parameter (10.02) allows the changing of direction of rotation by negating the speed reference.
- If the drive is controlled locally by the DCS800 Control Panel, DriveWindow or DriveWindow Light the local speed reference is connected to input “local”.
The speed actual can be selected from several sources and is then sent to the speed summation point. The speed actual is selected with parameter (50.03). The speed feedback can be calculated from the EMF with or without flux compensation or measured by speed feedback devices like pulse encoder or analog tacho.

Internally all reference speeds and speed actual are scaled to a value of 20,000 speed units. The scaling factor can be found in signal (2.29). This means, that the speed value in revolutions per minute in signal (2.29) equals an internal value of 20,000 speed units.

It is possible to filter the actual speed with parameter (50.06) for example to get rid of disturbances like noise of an analog input.

All together there are three different filters for actual speed and speed error. Parameter (50.06) filters the actual speed and should be used for filter times smaller than 30 ms. Parameters (23.06) and (23.11) filter the speed error and should be used for filter times greater than 30 ms. It is recommended to set (23.06) and (23.11) to the same filter time.

The drive’s direction can be changed with bit 8 of auxiliary control word 2.
Firmware functions
Speed ramp

- The speed reference is processed by the speed ramp and is then sent to the speed summation point.
- The speed reference is limited before and after the ramp.
- Selection of two different sets for deceleration and acceleration times is available. They can be chosen by parameter (22.11).
- Balancing the ramp is possible as well as bypassing the ramp by means of forcing the ramps output to the value of its input.
- The ramps output can be held or frozen with bit 5 of used main control word. Bit 6 and 4 set the ramps input or output to zero.
- The ramps input and output are also controlled by the stop modes in parameters (21.02) to (21.04). If an active stop mode is set to ramp stop the ramps input is set to zero and the drive ramps its speed down. If an active stop mode is set to torque limit, the ramps output is set to zero and the drive stops at the torque limit.
- Jogging can be realized with parameters (10.17) and (10.18). Both parameters and the main control word used utilize one of the two fixed speeds set with parameters (23.02) or (23.03). Jog2 command overrides Jog1 command. To prevent speed steps, it is possible to set special acceleration and deceleration time only for jogging with parameters (22.12) and (22.13).
The speed controller is separated in several parts. Part one explains the speed error and acceleration compensation.

For every controller to work an input error is needed. To calculate the speed error for the speed controller the speed actual is subtracted from the speed reference. This is done by means of the speed summation point. The speed error is then sent via window control to the speed controller and displayed in signal (2.03).

Parameters (23.06) and (23.11) filter the speed error as PT-2 filter component.

The acceleration compensation is used to compensate for additional torque needed to accelerate or decelerate the motor and the connected inertia. The additional torque reference (2.07) is a feed forward into the speed controller and helps speed up the process and thus stabilizes the drive.

The acceleration compensation calculates an acceleration and deceleration torque depending on the dv/dt (2.16) and can be adapted with parameters (24.14) and (24.15).
Window control is a function implemented in speed controller.

This is used for drives working in torque control.

The idea is to block speed controller as long as speed error remains within the window set by parameters (23.08) and (23.09). This allows the external torque reference (2.08) to affect the process directly. If the speed error exceeds the programmed window, the speed controller becomes active and influences the process by its own torque reference (2.09).

To release window control set parameter (26.01) to Add and set bit 7 of (7.02) auxiliary control word 1.
Firmware functions
Speed controller, part 2

- Speed controller is a PID controller
  - Proportional portion is in 2.04
  - Integral portion is in 2.05
  - Derivative portion is in 2.06
- Torque limiters can be set
- Balancing the speed controller is possible
- Speed controller output can be held or frozen
- Droop is used in certain applications
- Speed step used for commissioning

The speed controller is based on a PID-controller and uses the speed error between speed reference and speed actual to calculate the torque reference necessary to minimize the speed error. The PID-controller generates three different torque references which are added together. It is possible to observe each torque by means of signals (2.04), (2.05) and (2.06). The proportional portion is shown in signal (2.04), the integral portion is shown in signal (2.05) and the derivative portion is shown in signal (2.06).

The torque limiter for the speed controller has its own limits which can be set with parameter (20.07) for the maximum torque limit and parameter (20.08) for the minimum torque limit. To make sure, that all other torque and current limits are taken into account, signals (2.19) and (2.20) are connected to the limiter.

Balancing the speed controller is possible with parameter (24.11) and bit 6 of auxiliary control word 1.

The speed controllers output can be held or frozen

Droop is used in certain applications to archive a speed drop depending on the load. This function may become necessary for proper load sharing between drives which are linked via material for example paper, steel or foil and running with a common speed reference. The amount of speed drop caused by the load is determined by parameter (24.02).

Parameter (23.10) speed step can be used during commissioning for manual tuning of the speed controller.
The most important parameters to set in the speed controller are the p-part or proportional gain which is set with parameter (24.03) and the i-part or integral time which is set with parameter (24.09). The d-part or derivation time shown in parameter (24.12) is seldom used.

Additionally, it is possible to adapt the p-part and the i-part depending on torque or speed. This is the load adaptive proportional gain. The adaptive proportional gain of the speed controller is used to smooth out disturbances which are caused by low loads and backlash. The load adaptation is valid for positive and negative torque.

Torque depending gain adaptation is possible by defining a minimum p-part to be set in (24.04) and p-part weakening point (24.05).

In certain applications it is useful to have the option of increasing or decreasing the proportional gain and decreasing or increasing the integral time at low speeds to improve the performance of the speed control. For example in a crop shear application a very high p-part is needed, but that leads to a vibrating motor at standstill. Simply lowering the p-part around zero speed will solve that problem. The speed adaptation is valid for positive and negative speeds.

- The linear increase or decrease of proportional gain and integral time starts at the speed set with parameter (24.18) and ends at a speed set with parameter (24.17). Parameter (24.19) determines the proportional gain at the start speed set with parameter (24.08). Parameter (24.20) determines the integral time at the start speed set with parameter (24.08).
Firmware functions
Torque selector, part 1

- DCS800 provides two different choices of torque reference
- Torque reference A can be selected with parameter 25.10
- Filter torque reference with parameter 25.02
- Torque reference B provides a torque ramp function
- Torque is limited by limiter values 20.09 and 20.10

- The DCS800 provides two different choices of torque references.
- Torque reference A can be selected with parameter (25.10). For an analog connection it is possible to choose between analog input one to analog input six. For a digital connection it is possible to write on parameter (25.01). This parameter for example is used in a master follower application or is written to by the overriding control system.
- Additionally torque reference A can be filtered with parameter (25.02). For load sharing - with for example different types of motors - parameter (25.03) should be used.
- Torque reference B can only be used for a digital connection for example via master follower or from the overriding control system it is possible to write on parameter (25.04). Additionally torque reference B is connected via a torque ramp, so that torque steps which might damage attached mechanics can be avoided.
- Torque is limited by limiter values (20.09) and (20.10). They take the smallest connected value for their maximum limit and the largest connected for their minimum limit.
The torque selector processes the torque reference from the speed controller and the external torque reference depending on its switch setting.  

- Setting zero forces the output of the torque selector to zero.  
- Setting one uses the torque reference from the speed controller. Now the drive is in speed control.  
- Setting two uses the external torque reference and thus the drive is in torque control.  
- With setting three, the minimum of the two torque references is taken, whereas setting four chooses the maximum of the two references.  
- Setting five adds both torque references and is used for window control.  

The setting of the torque selector is controlled by parameter (26.04). The setting is either fixed set by means of parameter (26.01) torque select or variable and depending on the setting of parameter (26.05). Thus it is possible to change between speed- and torque control via a digital input.  

Depending on parameter (26.03) it is possible to change the torque selector mode.
Firmware functions

Torque limiter

- Load compensation with parameter 26.02
- Gear backlash compensation for a large loose
- Torque limitation by different sources selected

The torque reference is processed by the torque limitation and is then sent to the armature current controller. For some applications it is necessary to connect an additional torque for load compensation with parameter 26.02.

If the gearbox has a large loose and the torque is changing its direction, then the gears can be damaged. To prevent this, the DCS800 provides a gear backlash compensation for smooth torque reversal.

- When the torque changes its direction, the torque limit is reduced for the time defined by parameter (26.09). After the time has elapsed, the torque limit is increased to its normal value according to the ramp time defined by parameter (26.10). Parameter (26.10) defines the time within the torque increases from zero- to motor nominal torque.

The torque limiter for the torque reference shows how the overall torque limits in parameter (20.09) for the maximum torque limit and in parameter (20.10) for the minimum torque limit are calculated. The base torque maximum and minimum torque limits are chosen with their selectors. The maximum torque limit is chosen with parameter (20.18). For analog connection it is possible to choose between analog input one to analog input six. For digital connection it is possible to write on parameter (20.05). This parameter is for example written to by the overriding control system.

- To take the current limits of the connected power part into account, the current limitation parameters (20.12) and (20.13) are looked at. In the base speed area torque and current are proportional. So, 100 % torque equals 100 % current. This is not the case anymore, when the motor speed exceeds the base speed and goes into the field weakening area. In field weakening the flux is reduced and an increased motor current is needed for the same amount of torque. This phenomenon is considered by multiplying the current limits with signal (3.24) flux of the motor.
o To be able to identify, the actual valid torque limit signal (2.26) shows the parameter number of the actual active torque limit.

o For some applications it is necessary to correct the torque reference coming from the torque limiter. The DCS800 provides parameter (26.15) for this task. Here it is possible to choose between analog inputs one to six.

o Additionally, torque reference used can be scaled with parameter (26.13).
Firmware functions
Current controller, part 1

- Torque reference has to be changed to current reference
- Current selector processes the current reference sources
- Current limit of bridge 1 and bridge 2 are important
- Speed depending current limitation for high-speed areas

- The torque reference must be changed to the current reference. Since torque and current are linear in the base speed area the torque can be directly re-scaled to current. In field weakening area the current re-scaling from the torque is dependent on the flux. Dividing the torque reference by the flux reference thus delivers the proper current reference.
  - Internally the nominal motor current is scaled to 10,000 current units. This equals 100% motor current. The nominal motor current is set with parameter (99.03).
- The current selector processes the current reference from different sources and passes the current reference to the current reference slope.
  - Setting current reference 311 is the standard setting and chooses the current reference calculated from the torque reference.
  - Setting current reference external uses an external current reference written on parameter (43.03) by means of Adaptive Program, application program or overriding control.
  - Setting analog input 1 to analog input 6 uses an analog input - see signal (5.03) to (5.08) - as current reference source.
- The direct current limitation uses parameters (20.12) and (20.13). The parameters should be set to the maximum current of the connected thyristor bridge. Bridge one is the forward bridge and bridge two is the reverse bridge. Setting one of the limits to zero disables the corresponding bridge. If only one bridge is connected, the limit for the second bridge is forced to zero.
- The speed dependent current limit is used to adapt the drive to the maximum current of the connected motor at high speeds. For this, the motor speed is read, and the speed dependent current limit is set with parameters (43.17) to (43.22).
For every controller to work an input error is needed. To calculate the current error for the current controller the current actual is subtracted from the current reference. This is done by means of the current summation point. The current error is then sent to the current controller.

The current reference is coming from the current limitation. The current actual is measured by either two or three current transformers or CTs connected on the AC side of the converter. The CT values are read and then transformed to the DC current by the armature current measurement. Now the current actual can be read in percent of the motor nominal current in signal (1.06) or in percent of the converter nominal current in signal (1.15).

The current controller is based on a PI-controller and uses the current error between current reference and current actual to calculate the firing angle necessary to minimize the current error. The p-part or proportional gain is set with parameter (43.03) and the i-part or integral time is set with parameter (43.07). The discontinuous current limit is set with parameter (43.08).

Parameter (43.01) is used to select current controller operation mode. The setting depends on the application the drive is used for. Here it is possible to choose armature control or field control if the drive is used as a field exciter.

The limitation of the firing angle alpha has its own limits which can be set with parameter (20.14) for the maximum alpha limit and parameter (20.15) for the minimum alpha limit.

- The firing angle alpha shown in signal (3.13) is sent from the limiter to the firing unit. The bridge reversal can be delayed with parameter (43.14).
- The firing angle is then used to calculate firing pulses for the thyristors in the power part of the drive.
This slide explains the measurement of actual values of motor and drive.

- The firing pulses are sent from the drives electronic to the power part.
- The drive also measures the armature voltage and the converter current on the AC side which is then transformed to armature current.
- The mains voltage is measured and compared with the converters nominal incoming voltage. The converters incoming voltage depends on the hardware and is encoded in the type code.
- All major motor data can be set in the group 99 start-up data.
Firmware functions
EMF controller

- EMF controller is a voltage controller to keep motor voltage constant during field weakening operation
- EMF reference can be modified with (44.25) and (44.26)
- Controller error is calculated from EMF voltage of the motor and the EMF voltage reference (3.26)
- The output of EMF controller is limited (e.g. 10...-100%)

- The EMF controller is a voltage controller and thus controls the motor's EMF in the field weakening area - meaning speed actual is higher than base speed. If speed actual is smaller than base speed the EMF controller is disabled.
  - Setting EMF internal is the standard setting and chooses the internally calculated EMF reference.
  - Setting external 44.22 uses an external EMF reference written on parameter (44.22) by means of Adaptive Program, application program or overriding control.
  - Setting analog input 1 to analog input 6 uses an analog input - see signal (5.03) to (5.08) - as EMF reference source.

- It is possible to modify the EMF reference by means of the EMF voltage reference modification. With parameter (44.25) it is possible to increase or decrease the EMF reference. Parameter (44.26) influences the voltage reference slope.

- For every controller to work an input error is needed. To calculate the EMF error for the EMF controller the EMF actual is subtracted from the EMF reference. This is done by means of the EMF summation point. The EMF error is then sent to the flux linearization.
  - The EMF reference is coming from the EMF voltage reference modification. The EMF actual is calculated with the help of the motor resistance in parameter (43.09) and the motor inductance in parameter (43.10) from the measured armature voltage.
  - The EMF controller is based on a PI-controller and uses the EMF error between EMF reference and EMF actual to calculate the flux necessary to minimize the EMF error.
- The p-part or proportional gain is set with parameter (44.09) and the i-part or integral time is set with parameter (44.10).

- The output of the EMF controller is limited by means of parameters (44.07) and (44.08).
Firmware functions
Flux linearization

- Flux control is a feed forward for the EMF controller
- In field weakening area EMF controller is active
- Result of flux summation is in parameter (3.28)
- Relationship between flux and field current is not linear
- Also used to transform the flux reference into the field current reference

The flux control is a feed forward for the EMF controller and the flux linearization is used to linearize the relationship between flux and field current.

- If speed actual is smaller than base speed the EMF controller is disabled thus signal (3.27) is forced to zero and the flux control sets signal (3.24) to maximum flux.

In the field weakening area the EMF controller is active and writes its flux reference via signal (3.27) on the flux reference summation point. At the same time the flux control is activated and adds its feed forward value via signal (3.24) to the summation point. The flux control does not control the flux it calculates the needed flux from speed actual in signal (1.04) and the motor’s base speed in parameter (99.04). The goal is to shorten the response time of the EMF controller and to set the EMF controllers output approximately to zero.

The result after the flux reference summation point can be seen in signal (3.28).

- The relationship between flux and field current is not linear due to saturation effects in the motor. For example, with a flux of 20% it is possible to generate a 40% field current. With a flux of 50% it is possible to generate a 70% field current and with a flux of 80% it is possible to generate a 90% field current.

- The flux linearization is not only used to linearize the relationship between flux and field current it is also used to transform the flux reference into the field current reference. Thus, the response time of the field current controller is speed up.
Firmware functions
Field current controller

- Field current reference is shown in signal (3.30)
- Field current selector processes current references from different sources
- Field current actual is shown in signal (1.29) in percentage
- Field current controller is based on a PI controller

The field current reference can be selected from several sources and is then sent to the field current controller.

The field current selector processes the current reference from different sources and passes the field current reference to the field current summation point.

- The standard setting is to take the field current reference coming from the flux linearization. This is done by setting parameter (45.05) to internal.
- An external field current reference can be written on parameter (45.06) by means of Adaptive Program, application program or overriding control and has to be activated by setting parameter (45.05) to external field current reference.
- Field heating can be activated with parameter (21.18). The field heating reference is set with parameter (44.04).

The field current actual is measured directly and sent from the field exciter to the armature converter and can be read in percent of the motor nominal field current in signal (1.29).

The field current controller is based on a PI-controller and uses the field current error between field current reference and field current actual to calculate the firing angle necessary to minimize the field current error.

- The p-part or proportional gain is set with parameter (44.02) and the i-part or integral time is set with parameter (44.03). The maximum positive field voltage is limited with parameter (45.02).
Firmware functions
Measurements in field circuit

- Interface between electronics to drive and motor
- Firing pulses are sent from the field exciter to the power part
- Field current actual is measured directly and displayed in signal (1.29) and (1.30)
- The field data and the type of field exciter can be set in group 99 start-up

This is the interface to the drive and motor.
The firing pulses are sent from the field exciter to the power part.
The field current actual is measured directly and sent from the field exciter to the armature converter and can be read in percent of the motor nominal field current in signal (1.29) or in amps in signal (1.30).
The field data and the type of field exciter can be set in group 99 start-up data.
This is the ABB drive profile control.

The used main control word in signal (7.04) is a packed boolean word. Each bit has a defined function according to Profibus standard. Signal (7.04) is write protected. Thus, it can only be read and not written to.

- Bit 0 is used for On / Off
- Bit 1 is used for Coast Stop
- Bit 2 is used for Emergency Stop
- Bit 3 is used for Start / Stop
- Bits 4 to 6 control the ramp
- Bit 7 is used for Reset
- Bits 8 and 9 are used for Inching or Jogging respectively and
- Bit 10 is releasing the remote control

Both commands Coast Stop, and E-Stop are low active. That means a pending Cost Stop or E-Stop is setting its command to zero. Both commands can come from either local control or via digital inputs. The digital inputs are chosen with parameter (10.08) for Coast Stop or parameter (10.09) for E-Stop. In this way, the and-blocks make sure, that a pending Coast Stop or E-Stop is always reaching the Used Main Control Word no matter which control mode is used.

In remote control, the drive is usually controlled by an overriding control system via a serial communication e.g., Profibus. The overriding control collects all needed control signals, packs them into a word and then...
writes it on the Main Control Word (7.01).

- To enable remote control parameter (10.01) has to be set to Main Control Word. Also, the panel and all connected drive tools have to be in remote control. In that case all values from the Main Control Word (7.01) are transferred to the Used Main Control Word (7.04) and the overriding control controls the drive.

- In local I/O control the drive is usually controlled by an overriding control system via digital and analog I/O’s. The overriding control gives, for example, the On / Off or Start / Stop commands via digital I/O.

- To enable local I/O control, parameter (10.01) has to be set to Local I/O. Also, the panel and all connected drive tools have to be in remote control. In that case all commands from the overriding control system are transferred to the Used Main Control Word (7.04) and the overriding control controls the drive. This mode overrides the commands given via the Used Main Control Word.

- In local control the drive is controlled by the panel or a drive tool. The panel or drive tool has to be set to local control to take the control of the drive. Be aware, that only one device can be in local control of the drive. Local mode overrides all other modes.
Key points of this module are:

- Firmware overview
- Armature control circuit
  - Speed control
  - Current control
- Field control circuit
- ABB drive profile
Additional information

- Firmware Manual (3ADW000193)