Kyntronics
Innovation in Motion

TECHNICAL REPORT
TR-1292

INTERFACE FOR SHA USING MODBUS/TCP, SSI, & M700

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REVISION HISTORY

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1 PURPOSE

To provide guidelines for interfacing Kyntronics SmartHydraulicActuator (SHA) over ModbusTCP.
The servo drive is a Control Techniques M700 or M702. Position feedback is an SSI encoder.

2 SYSTEM OVERVIEW

The system consists of one SHA (Smart Hydraulic Actuator) with a subpanel containing controls.

The subpanel presents a user interface consisting of an STO signal and two Ethernet ports.
There is a keypad/display integral to the servo drive which may be used to inspect and modify settings.

The drive has two RJ45 Ethernet sockets, labeled 1 and 2. They are tied to a built-in Ethernet switch. Both ports support the ModbusTCP protocol. Socket 2 may be used simultaneously for Ethernet communication with a laptop for programming or monitoring the drive. IF not using a fieldbus at all, Socket 1 may be used for laptop communications.

2.1 SafeTorqueOff

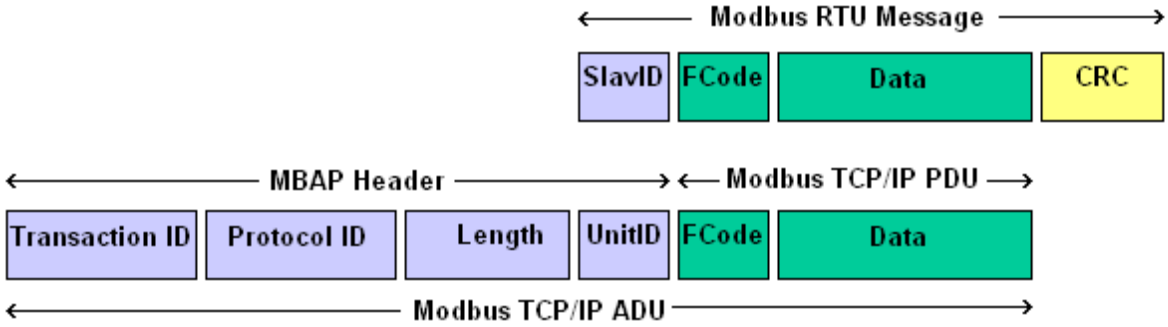
The drive controlling the EHA's hydraulic motor is equipped with an STO (Safe Torque Off) discrete input. This circuitry reliably interrupts power from the output of the drive to the motor when not satisfied. In order to allow motor motion, it requires a 24VDC signal; typically, from the machinery Emergency Stop circuitry.

Turning off the STO signal does not interfere with any logic or communications functions of the drive.

2.2 Modbus/TCP Interface

The SHA's controls are based on a servo drive with an Ethernet port supporting Modbus TCP. The ETHERNET ADDRESSING section below has instructions on changing the address and subnet.

A VB.Net sample application is provided to assist with development and commissioning. It demonstrates control of an SHA over a direct Ethernet connection. While not precluded, the use of hubs, bridges, etc. requires engineering considerations not covered in this document.



This shows how Modbus packets are incorporated into Modbus TCP.
Use standard Modbus TCP Ethernet port 502.

UnitID depends on which device you are communicating with. Use the first field in the menu address. For example, the status register block (0.20.035 thru 040) is in the drive itself, so use UnitID=0. Most other registers (3.##.###) are in the MCi200 module, so use UnitID=3.

The drive's Modbus interface only makes use of Holding Registers, via function codes FC3(Read Holding Registers) and FC16(Write Holding Registers). Coils, Inputs, and Input Registers are not used, and the associated commands will be rejected by the drive.

One aspect not implicit in the basic standard is the handling of 32-bit data. Fortunately, this has been implemented to work within the standard function codes, so any PLC supporting Modbus TCP can use it. To handle 32 bit values, set bit 14 (4000H) in the address register, and double the word count. MSW (Most Significant Word) comes first. See the example in the INPUTS section below.

2.2.1 INPUTS – Data from SHA to PLC

These are the five most popular registers for reading. They have contiguous addresses therefore may be read as a block. Reading as a 16-bit register will produce the least significant word, which will be fine for the STATUS, but leave out some info on the FAULTCODE. IF your position values never exceed 32767 you can handle them as 16 bitters. Likewise the force values.

STATUS – Bitmap. Address: 16bit=2035 32bit=18419 Keypad: 0.20.035
- Bit 0 - Ready (No faults, and the STO is satisfied. Stays on while moving.)
- Bit 1 - In Position mode
- Bit 2 - In Position ForceLimited mode
- Bit 3 - In Force mode
- Bit 5 – Faulted
- Bit 11 - STO Satisfied
- Bit 12 - Jogging

The other bits do not apply to this application but should not be assumed to be zeros.

MEASURED POSITION – Address: 16bit=2036 32bit=18420 Keypad: 0.20.036
Units are hundredths of a millimeter, measured from "zero" as covered in section 3 above.
Its validity is not influenced by SafeTorqueOff or Command or Faults. Increasing value ~ extending rod.

FAULTCODE – Address: 32bit=18421 Keypad: 0.20.037
Retains the current or last fault. Does not clear when fault goes away.
But the Faulted bit in Status word does. See Faults section below.

MEASURED FORCE – Address: 16bit=2038 32bit=18422 Keypad: 0.20.038
Units are Pounds Force. Deduced from an internal pressure sensor. Only valid when positive.
Increasing value corresponds to more compressive (extending rod) force.

FORCE PROFILE – Address: 16bit=2039 32bit=18423 Keypad: 0.20.039
This reads the force target value (setpoint) from the force profile generator.
It allows the PLC to see the effects of Force Jerk, Accel and Velocity. Units are Pounds Force.

PUMP SPEED - Address: 16bit=2040 32bit=18424 Keypad: 0.20.040
Units are RPM. Rotation which causes retract motion is negative

For example, reading the first four input registers as a block of 32-bit values works as follows:
- Function Code = 16 (Read Holding Registers)
- Address = 18419 (2035 + 4000H = 47F3H)
- Length = 8 (We are reading two 16-bit words per register.)

The eight words in your PLC are:

STATUS MSW	Always zero.
STATUS LSW	STATUS
POSITION MSW	Always zero unless position is negative.
POSITION LSW	Position in thousandths
FAULTCODE MSW	Major fault code
FAULTCODE LSW	Fault subcode

FORCE MSW	Top 16 bits of Measured Force in pounds
FORCE LSW	Bottom 16 bits of Measured Force in pounds

2.2.2 OUTPUTS – Data from PLC to SHA

These are the five most popular registers for writing. They have contiguous addresses therefore may be written as a block. Writing as a 16-bit register will populate the least significant word, which will be fine for the COMMAND. IF your position values never exceed 32767 you can handle them as 16 bitters. Likewise the force values.

COMMAND (bitmap) Address: 16bit=7101 32bit=23485 Keypad: 3.71.001

Bit 0 – Activate loop control (leave on when commanding bits 1,2, or 3)
Bit 1 – Position mode
Bit 2 – Position with Force Limiting mode
Bit 3 – Force mode
Bit 4 – Jog Extend
Bit 5 – Jog Retract
Bit 6 – Jog Enable
Bit 8 – Halt. Forces motion profile generator to ramp to zero speed using accel rate.
Bit 15 – Reset Fault. See FAULTS below.

Turning off all three mode bits will cause the drive to relax. Check valves may come into play.
Turn on Reset Fault to reset the drive. Don't leave it on. It will confuse you later.

The Jog bits are only enabled in Manual mode. Refer to the Manual Control section below.

INDEX TARGET POSITION Address: 16bit=7102 32bit=23486 Keypad: 3.71.002

Used in Position and Position ForceLimited modes.
Units are hundredths of a millimeter, measured from "zero" as covered in section 3 above.

FORCE LIMIT MAX Address: 16bit=7103 32bit=23487 Keypad: 3.71.003

Compressive (rod extending) pounds limit in Force Limited Position mode. Units are Pounds.

FORCE LIMIT MIN Address: 16bit=7104 32bit=23488 Keypad: 3.71.004

This would be the tension (rod retracting) pounds limit in in Force Limited Position mode.
But there is no retract pressure sensor, so always set this negative 500 pounds or more.

FORCE REFERENCE Address: 16bit=7105 32bit=23489 Keypad: 3.71.005

Units are Pounds. This parameter is used as the target value in Force mode.

2.2.3 MOTION PARAMETERS – Readable and writeable

There are other motion parameters which can be read and written over the Modbus TCP interface. Each is a 32bit value. All but the first three are typically set once while commissioning. But it is possible to change them on the fly. Remember when reading and writing to set the length to two words per parameter. MSW comes first.

Position related parameters are scaled in thousandths of an inch. Force in Pounds.

Addr	Name	Definition	Keypad
23385	Position Jerk	Jerk used in position profile	3.70.001
23386	Position Accel	Accel & Decel used in position profile	3.70.002
23387	Position Speed	Max velocity (unsigned) used in pos profile	3.70.003
23434	Position Kp	Position loop proportional gain	3.70.050
23435	Position Ki	Position loop integral gain	3.70.051
23454	Force Kp	Force loop proportional gain	3.70.070
23455	Force Ki	Force loop integral gain	3.70.071
23466	Pump Max RPM	Pump RPM limit extending in force mode	3.70.082
23467	Pump Min RPM	Pump RPM limit retracting in force mode. Negative!	3.70.083
23475	Force Jerk	Jerk used in force profile	3.70.091
23476	Force Accel	Accel & Decel used in force profile	3.70.092
23477	Force Velocity	Rate of change (unsigned) used in force profile	3.70.093
1005	Jog Speed*	RPM*10	0.01.005

The Force Pump RPM parameters may be used to limit top speed while in force mode.
Note that the Pump speed limits are measured in rotations per minute of the pump itself.
The pump is essentially positive displacement, so this can be converted to linear travel.
Since the piston rod is not zero diameter, it takes less fluid to move the piston in the retract direction.
Thus a given RPM produces a faster motion while retracting.

*JogSpeed is an oddball. Access it as a 16-bit word, and use UnitID=0 in your Modbus command.

3 TRANSDUCERS AND SCALING

Position of the cylinder rod is measured by a non-contact linear transducer. It senses the absolute position of the rod as soon as powered, without a homing procedure or external reference or battery.

The transducer output is digital, with a resolution of 50 steps per millimeter.
The value increases as the rod extends. The transducer has no internal adjustments.

The transducer is mounted such that its zero position is outside of the rods range of travel.
The system subtracts a constant called ZeroOffset to define a reachable position as “zero”.
ZeroOffset is at menu 18.051, and is set at the factory close to the fully retracted travel limit.
It can be adjusted with any of the methods in the Changing Drive Settings section below.

There is a pressure sensor built into the SHA manifold which monitors the pressure on the extend side of the piston. This also drives an Analog to Digital Converter. This value is scaled per the swept area of the piston, to produce force in pounds.

Note that pressure on the rod (retract) side of the piston is not sensed. Therefore, this device is incapable of measuring a force in the retract direction. This is not to say that it cannot exert force in the retract direction. It most certainly can. Use Position mode or Jogging.

The raw ADC value is viewable with the keypad, displayed scaled 0-100% at menu 0.07.001
All force parameters in this system treat tension as negative force. For example, setting the ForceLimitMin parameter to -25000 would limit *tension* to 25000 lbs.

Parameter 3.70.097 sets the full scale of the pressure sensor in engineering units. This is assumed to be Pounds, but could just as well be Newtons. All force parameters are in engineering units, thus changing this one parameter would convert the entire system.

All force parameters in this system treat tension as negative force.For example, setting the ForceLimitMin parameter to -25000 would limit *tension* to 25000 lbs.

4 CONTROL MODES

The interface supports three modes: Position, Position Force Limited, and Force.
Each is selected by raising a bit in the Command word, along with the Loop Enable bit.
There are no inherant timing restrictions on switching modes at any point.

When either position mode is selected, a motion profile will be generated based on the Jerk, Accel, and Speed parameters, starting from the current position and terminating at Index Target Position.

In Position Force Limited mode, compression force is limited by ForceLimitMax.
Tension force is limited by the ForceLimitMin parameter, which should be negative.
When either limit is encountered, the pump torque will be clamped to hold that force.

Note that the motion profile continues to run while a force limit is encountered.
Suppose for example that a brittle obstruction is encountered during extension, which reaches the force limit. A few seconds later it collapses, and force drops way below the limit. At this point the position controller will go charging forward to catch up with the motion profile. This motion will be limited only by the Pump Max RPM parameter (and the force limits if other obstructions are encountered).

When Force mode is selected, a force profile will be generated based on the Force Jerk, Accel, and Speed parameters, starting from the current force and terminating at the Force Reference parameter. The force profile generator can be essentially taken out of the system by setting Jerk, Accel, and Speed to enormous values. Force values are in pounds, and a negative value represents tension.

5 TUNING

The tuning parameters for the control loops are adjustable via the keypad, or even over Modbus although that would be a rare application. The unit ships tuned for good performance, however it can be optimized for the specific load characteristics.

Both controllers are classical Proportional/Integral (PI) feedback loops. The Position controller is active in either of the position modes. The force controller is active in Force mode and lies in wait while in Position with Force Limiting mode. The addresses are listed in section 2.2.3.

The tuning parameters are stored in non-volatile registers, which will retain their values while power is removed. It is not necessary to execute the Making Changes Permanent procedure detailed in part 6.3.

6 FAULTS

The display/keypad on the front of the drive decodes most faults to a description in English.

The red Reset button on the keypad will clear a fault unless its cause persists, such as undervoltage.

Bit 3 in the COMMAND register performs the same function as the red Reset button on the keypad.

The FAULTCODE input register in the interface holds the current or last fault code reported by the drive.
It does not go to zero when the fault is cleared. (But the Faulted bit in STATUS does.)
Its value is a composite of two fault registers within the drive.

The MSW (top 16 bits) are the Trip Value, from drive menu 10.020.
The LSW (bottom 16 bits) are the Sub-Trip Value from menu 10.070.

The Nidec/CT M700 User Guide has 35 pages of error codes. Here are the most popular trip values:

2 : OverVolts – Energy from an overhauling load or fast decel has raised the DC bus too high.
3 : Instantaneous Overcurrent – Cannot be reset for ten seconds.
6 : Pump thermostat tripped. See next paragraph.
19 : Brake R Too Hot – Energy dumped into the braking resistor during fast decels has overheated it.
20 : Motor Too Hot – This is estimated by a mathematical model; not a sensor.

The pump is supervised by a thermostat, which is closed when temperature is below the trip point.
The thermostat is monitored by drive input 6, readable at menu 08.006. It should be high (on) when OK.
If the thermostat trips, the keypad will announce this fault as “External Trip.3”.
If you see this error during startup, verify the wiring of the PUMP THERMAL cable.
If you see this error on every powerup, and the reset button clears it, see section 5.3 of this manual.

Not every SHA system incorporates the pump thermostat. Check your schematic.

7 MANUAL CONTROL

Occasionally you might need to move an SHA without a ModbusTCP host; for example, during installation. This can be done with the drive's keypad/display.

Jogging is done by running the pump at a constant speed. No position loop control is involved.
Manual jog speed is set at menu 1:005. It is scaled in pump RPM. Note that the value as shipped could be near the maximum pump speed of 2500. Reduce it before first use. 200 RPM is a nice starting point.

Jogging is armed by setting Drive menu 18.047 = "on". At power-up it *should* default to off. See below. When Menu 18.047 is on, the system will ignore most of the COMMAND word. Instead the green and blue keypad keys will jog at the speed specified in 1.005, as mentioned above.

Green → key = Jog Extend
Blue ← key = Jog Retract

Jogging can also be done via the Command register:

Command.bit 4 = Jog Extend
Command.bit 5 = Jog Retract
Command bit 6 = Jog Enable (performs the same function as setting menu 18.047).

Don't forget to set 18.047 OFF or cycle power to give control back to ModbusTCP.

IF you find that the system is powering up with Jogging enabled, someone has left 18.047 on.

8 ETHERNET ADDRESSING

Each drive uses the same Ethernet ("IP") address for ModbusTCP and for programming.
As shipped, the system's drives were given IP address starting at 192.168.1.101.
Refer to the table in SYSTEM OVERVIEW above for the specific addresses.
The address can be inspected and changed with the keypad at menu element 4.02.006.

As shipped, the drive subnet masks were set to 255.255.0.0.
This requires that for two devices to see each other, the first two bytes of their IP addresses must match. (This puts them in the same *subnet*). The mask is adjustable at menu element 4.02.007.

After changing either parameter, do the Making Changes Permanent procedure
Then cycle power to force the Ethernet port to change.

9 ETHERNET DIAGNOSTICS

A green LED is located directly (within a quarter inch) below each of the drive's Ethernet sockets. If this is not flashing, check the network connections and power to the device on the other end of the cable. There is almost no software misconfiguration which will prevent this LED from flashing. One exception may be the presence of another device with the same IP address.

The drive requires about 20 seconds after power-up before becoming active on the Ethernet.

The host computer or PLC and the SHA will only be able to communicate if they are on the same *subnet*. In most networks, the Ethernet subnet mask is set to 255.255.0.0. In this case, the first two numbers of devices address must match to be on the same subnet. For example

Drive : 192.168.1.101
PLC : 192.168.1.027 <<Same subnet as the drive. No problem.
PLC: 192.168.2.153 <<Same subnet as the drive. No problem.
PLC: 192.167.1.153 <<Different subnet from the drive. Won't work.
PLC: 193.168.1.153 <<Different subnet from the drive. Won't work.
PLC: 192.168.1.101 <<Same address as the drive! Won't work.

If the host device is unable to establish a connection with an SHA, consider connecting it to a laptop and "pinging" it. From the Windows or Linux command line, type PING 192.168.1.101 (the drive's address). It will respond with either "Reply from 192.168…" (Yay) or "Request timed out" (Boo). This tests the basic functionality of the Ethernet.

If still no response, verify the drive's IP address using the procedure in ETHERNET ADDRESSING above.

Each drive has two Ethernet ports, marked 1 and 2.
Bridging is enabled, so daisy chaining thru the drives will work.

All registers being exchanged using Ethernet can be inspected and modified with the keypad & display. This can be useful when debugging the PLC interface.
The menu elements for the parameters are itemized in MOTION PARAMETERS above.

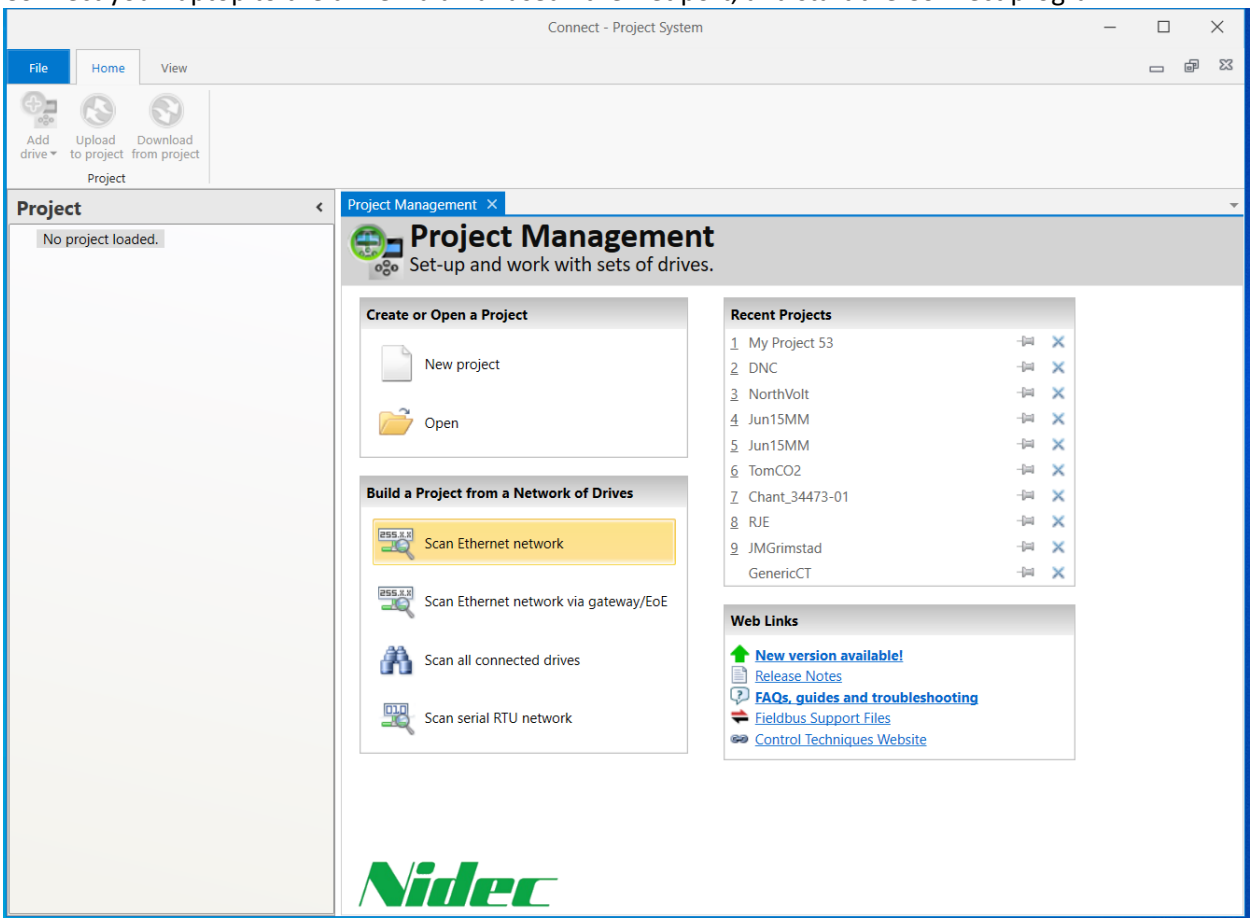
You can use the Keypad to inspect values being written by ModbusRTU and vice versa.
Sometimes you suspect that the ModbusTCP interface is constantly writing *something* to a given register but can't be sure because it never changes. Try using the keypad to temporarily write a different value. See if the ModbusTCP interface stomps on your change, reverting to the previous value.

10 CHANGING DRIVE SETTINGS

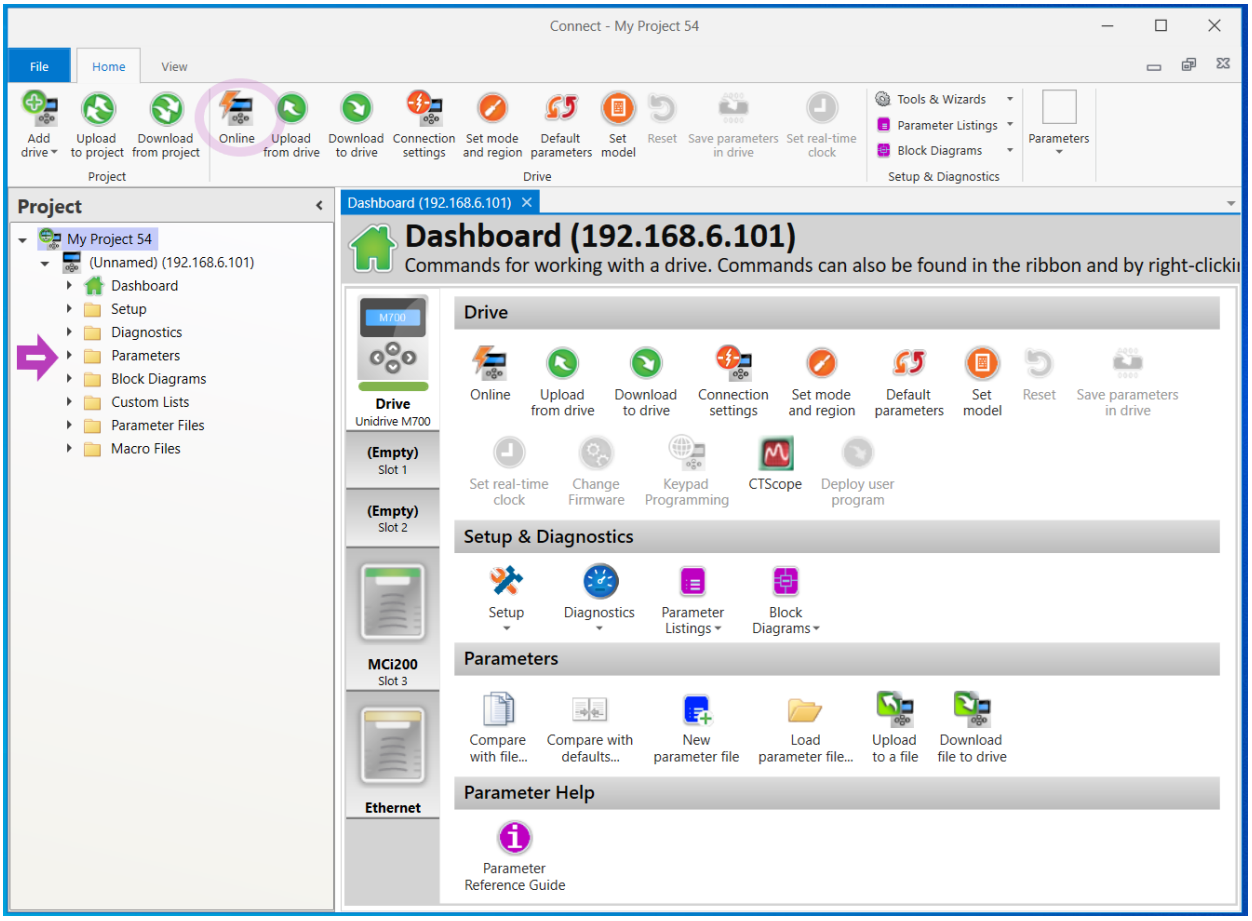
10.1 Control-Techniques “Connect” Software

The servo drive manufacturer, Nidec/Control Techniques, named its configuration software Connect.
It is a free download from the web, and requires no job-specific files or password to access the drives.

Connect your laptop to the drive via an unused Ethernet port, and start the Connect program



Click “Scan Ethernet Network” and the software will find the drive.
If there is more than one drive on the net, it will find them all.
If more than one is found, you can click “wink” and the corresponding drive will flash its red LED at you.

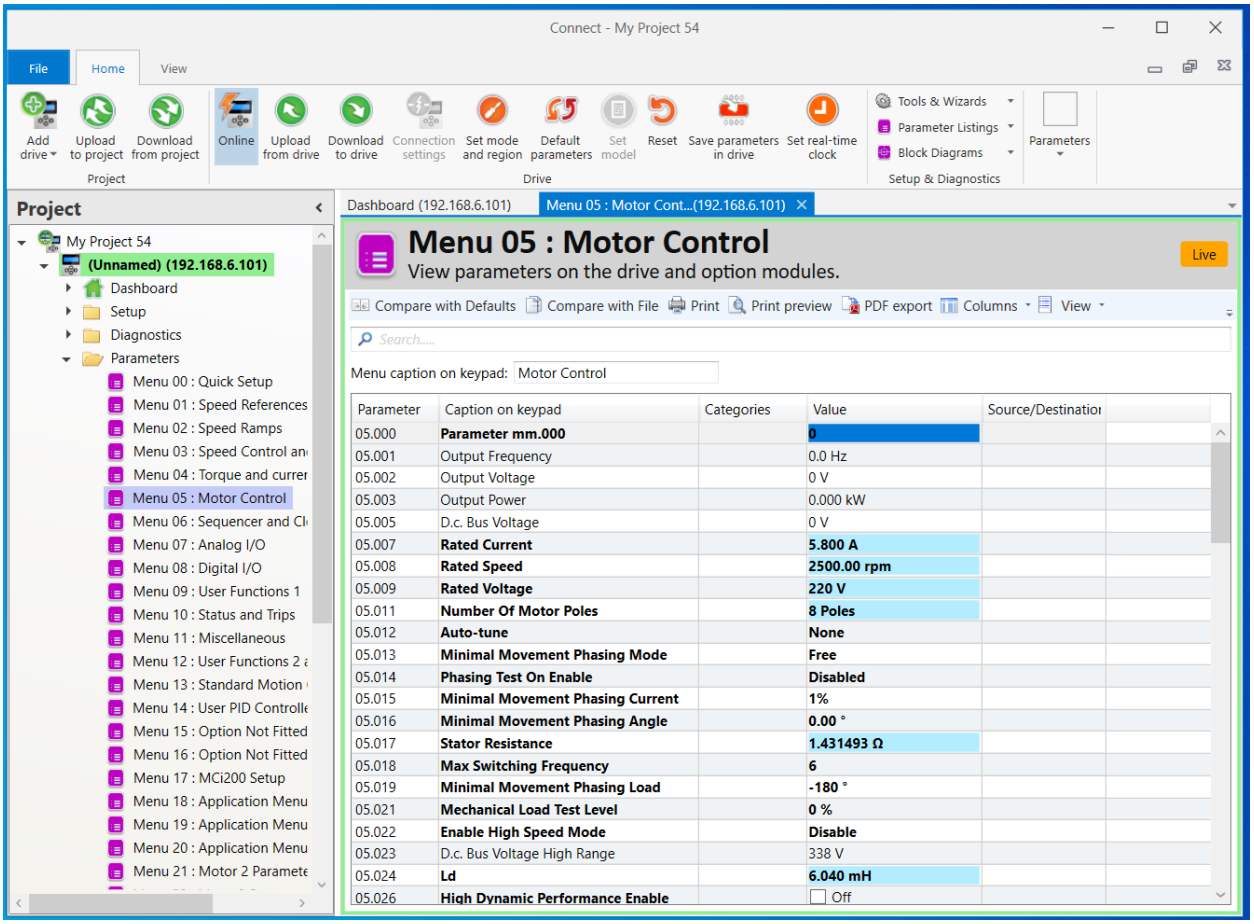


Connect has created a new file called “My Project ##”. On my machine there were already 53 others.

If you expand the tree structure at left by clicking on “Parameters” (magenta arrow) you could inspect any menu item, thinking these are the drive settings. And you would be wrong. This is one of the two gotchas in Connect. The software has fetched the drive type and filled in the option slots. (My drive happens to have an Mci200 in slot three.) But all of the menu items are populated with default values, not the ones on the drive. If you were to close Connect now, the file it saves on your laptop will NOT have the values from the drive.

Clicking “Upload from drive” will copy the drive value to your laptop. Now when you close Connect, the saved file will contain the drive settings.

Notice the Online icon at top, circled in magenta. It is not highlighted. This signifies that we are not live with the drive. Click it, and expand the Parameter tree at left.



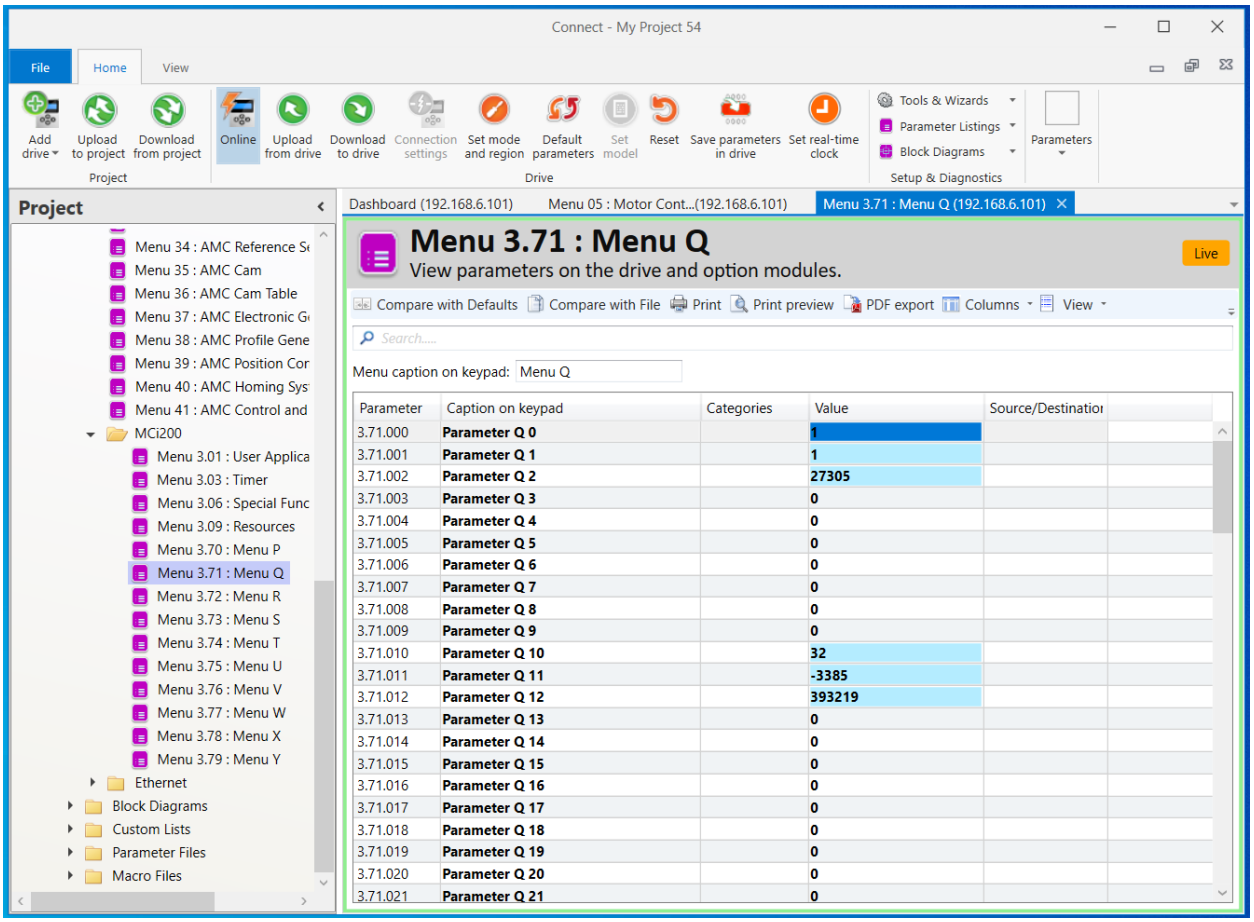
Notice how the Online icon is now highlighted; bluelighted on my machine.
This tells you that you are looking at live values on the drive. This brings me to the other gotcha: Forgetting that you are offline and making changes and wondering why they don't do anything.
It happens.

Notice that only some of the names and values are in bold. The ones not in bold are read only.
You can edit the ones in bold by clicking on the value itself. Be careful. Its live.

Notice that some values are backlighted in pale blue. These deviate from the default values.

Once you have made a flock of changes, you may want to save them on the laptop, so you click the File tab and look for "save as" and its greyed out. Don't panic. This is because you are on line. Click the Online icon to unhighlight it and then "save as" will become available. BUT WAIT! If you click it now, the settings you save will not reflect those changes you just made online. Click "Upload from drive" before saving.

All of the parameters shown in this snip are for the drive itself (device zero).
On the left hand window pane, slide the vertical scroll bar down a bit…



Here is where the non-drive menu items are hiding. All menu items have three fields, such as 3.71.003. The first field specifies the device, the second field is the menu, and the third is the specific parameter. The drive itself is device zero, and the option modules use their slot number.

All drives have an Ethernet interface which is built into the drive, but acts like an option module. M750 drives have it at slot 3. M700 drives have it at slot 4.

All Kyntronics SHA drives are equipped with either an MCi200 or MCi210 module to do the heavy computation. M750 drives have it in slot 1. M700 drives have it in slot 3.

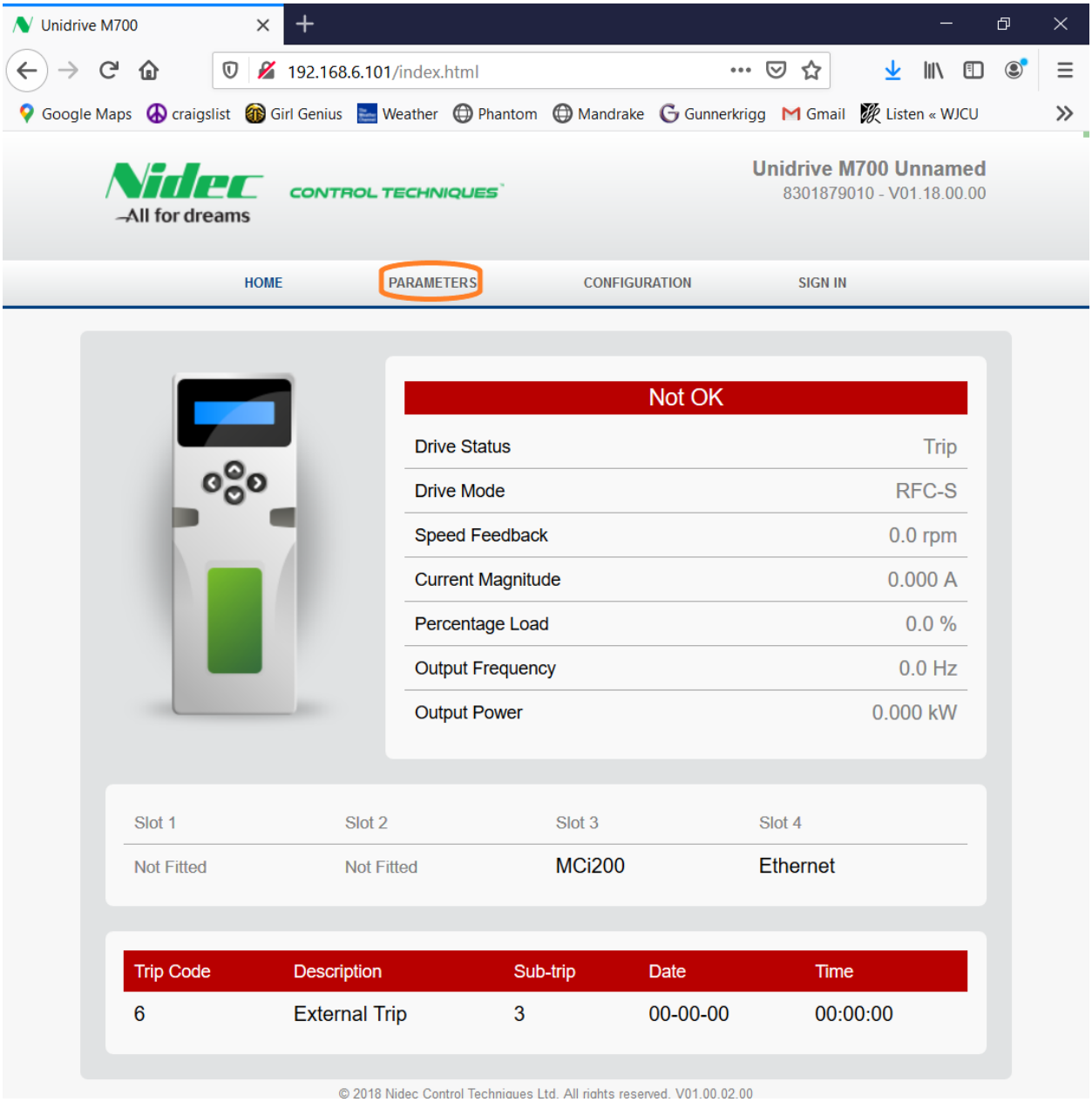
An MCi210 module also has its own Ethernet ports. If the drive is master in a master/follower system, the ports on the MCi210 should be used instead of the drives native Ethernet ports.

Should you happen to be changing an Ethernet address, be sure you are changing the ports on the device you think you are.

The MCi210 Ethernet settings on an M750 drive are at Menu 1.02.0xx.

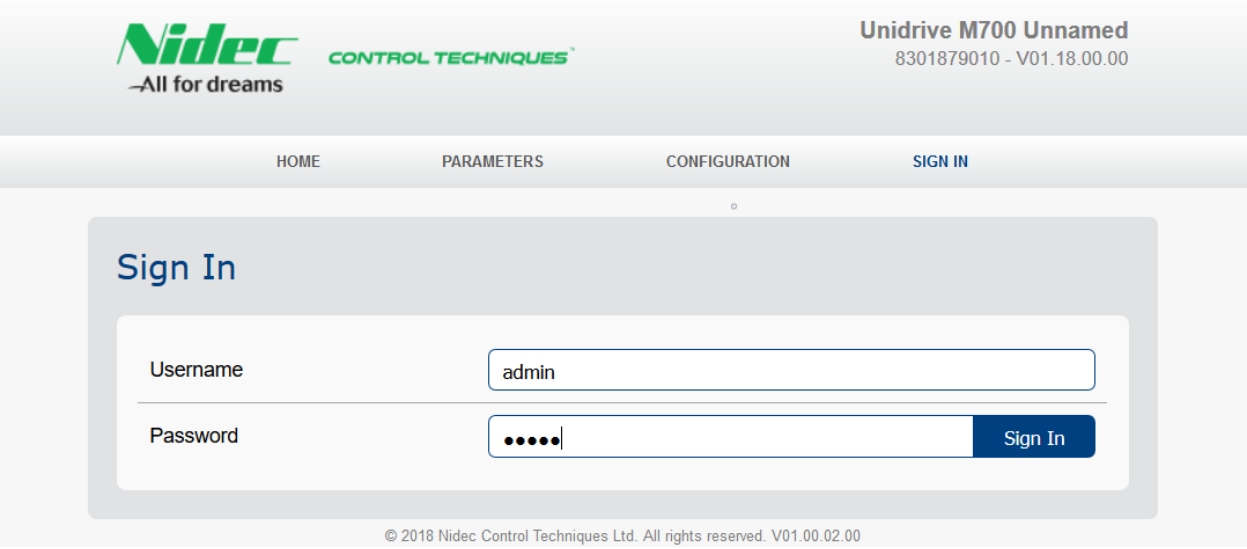
10.2 Web Browser

A laptop connected to the drive via Ethernet can view and modify any parameter, using its web server. Open your preferred web browser and enter the IP address of the drive, like so:

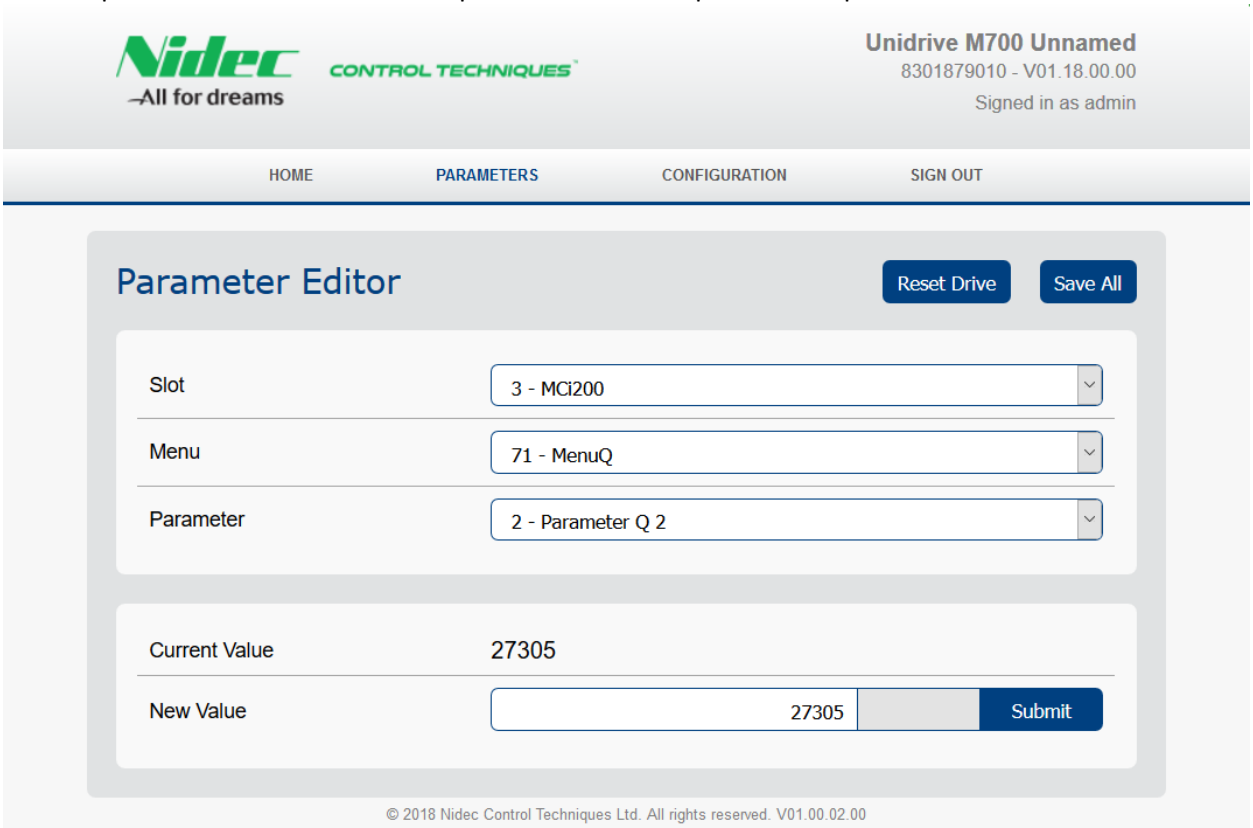


Click the PARAMETERS tab circled at top center.

Enter Username “admin” and Password “admin”. Yes really.



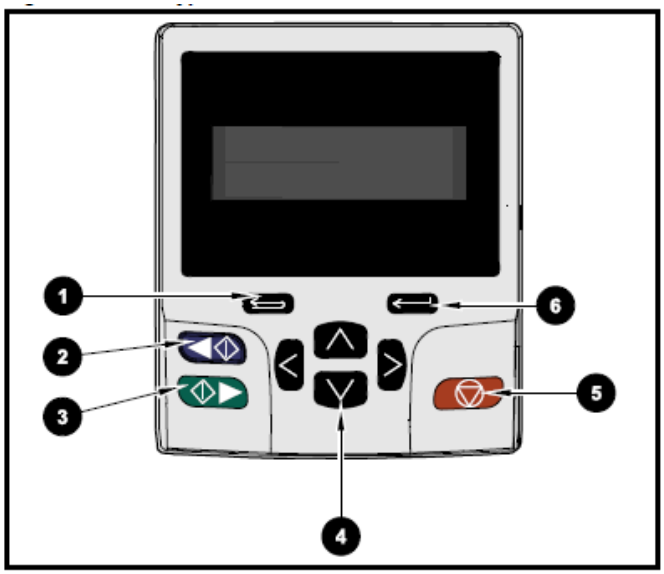
Use the pull-down boxes to select the parameter. This snapshot corresponds to menu 3.71.002.



To change a value, enter “New Value” and click “Submit”.

10.3 Optional Keypad/Display

The servo drive can be equipped with a keypad and display. This shows status and fault conditions and allows various motion parameters to be modified. It also allows Jogging of the actuator without the fieldbus host connection, which is useful for setup.
M700 drives come with the keypad/display built in.
M750 drives requires attaching a KI-Compact RS485 adapter to the drive, with wiring to the keypad.



1 = Escape. Backs out. Always safe.
2 = (blue) Jog Retract.
3 = (green) Jog Extend.
4 = Arrow keys. See text.
5 = (red) Reset. See FAULTS section.
6 = Enter. Use caution. See text.

10.3.1 Inspecting Parameters

Parameters are structured in the form: Device.Menu.Element
The left and right arrows scroll thru the Device.Menu combinations.
In this system, devices are numbered 0, 1, 2, and 3.
Some devices will not be visible until the drive has been powered for at least 20 seconds.

The keypad/display does not show the “0.” on the front of the addresses for Device zero.
For example, the address 0.18.047 is shown as 18.047.

The left and right arrows never modify anything unless you have first pressed the Enter key.

The up and down arrows scroll thru the elements of a given menu.
They stay within the menu, and do not jump to the next one when you scroll past the last element.
As soon as you select an element, its value and terse description are displayed.
Looking at a parameter will never interfere with the operation of the system.

10.3.2 Modifying Parameters

To modify a value, inspect it as detailed above, then press the Enter key.
A digit of the value will begin flashing.
While flashing, the left and right arrows select digits, and up and down arrows change them.
Pressing Enter again will accept the changed value. Think “Key on the RIGHT does a WRITE”.
Pressing Escape instead will back out, with the old value intact. Think “Key on the LEFT LEFT it alone.”

Some parameters are Boolean instead of numeric. These only accept values ON or OFF.
In these cases, the up arrow always selects ON, and the down arrow selects OFF.

Note that changes take effect instantly, even before you press Enter. Yes, really.
For example, setting menu 18.047 = ON will arm the jog keys immediately.
Using arrow keys to step thru values on the Command word can pass thru unintended commands.

10.4 Making Changes Permanent

In some cases, changes must be saved to nonvolatile memory, or they will be lost when power is removed. This is not true of any of the parameters in device 01.xx.xxx.

First, put the system in the state you want it to powerup in.
For example, turn JogEnable off if you have left it on.

Next set menu 0.10.034 to a value of 1. This prevents a spurious pump thermostat fault at powerup.

If using Connect, click the Save Parameters in Drive icon.
If using the browser interface, click the SaveAll icon.
If using the optional keypad/display:

1. Select element zero of *any* drive.menu; for example 0.07.000 or 0.18.000.
2. Press the Enter key (upper right). At this point, “no change” should start flashing.
3. Press the Up arrow, and the display should change to “save parameters”.
4. Hit Enter and then the red reset button. The display will change back to “no change”.

11 GLOSSARY

H	Hexadecimal (suffix). The attached value is expressed in base 16.
IP Address	Four-byte address used by Ethernet. Expressed in the form 192.168.001.002
MSW	Most Significant Word. The upper 16 bits of a 32-bit value.
LSW	Least Significant Word. The lower 16 bits of a 32-bit value.