Energoautomatyka

TECHNICAL REFERENCE MANUAL

CONTROLLER

Type ES-15

ES-SYSTEM

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1. APPLICABILITY

The ES-15 Controller represents an element of the ***ES-System***. It is a general purpose microprocessor-based controller intended for close/open loop control functions where control algorithms are given by application routines loaded into its memory. The controller has the following set of inputs and outputs: 8 analogue inputs, 16 binary inputs, 3 pulse inputs, 6 analogue outputs, 12 binary outputs, two RS channels and ETHERNET IEEE802.3 data link. The Controller may, via RS channel exchange information, at process level, with other controllers or data hubs.

A standard PC is used to download application routine, to modify the routine and settings and also to preview current controller operation via a serial link or a communication network.

The Controller provides analogue and binary variables in two communication networks, COM1 and COM2 (RS-485 or RS-422). The data are accessible in MODBUS-RTU standard.

2. DELIVERY KIT

The controller is delivered together with:
- Guarantee Card
- Quality Control Certificate

Each shipment of controllers comes with:
- Technical Reference Manual of ES-15 Controller
- Service Cable, RS-232

3. TECHNICAL DESCRIPTION

3.1. SPECIFICATIONS

3.1.1. Power Supply	21 ÷ 27 V_{DC} / 0.2A max
3.1.2. Analogue Inputs, XA	
- number of inputs	4 or 8
- nominal range of input signals	4 ÷ 20 mA
- A/C conversion resolution	12 bits
- input processing accuracy	0.1 %
- additional processing errors (including that resulting from ambient temperature variations)	+/- 0.1 % of span
- max. voltage drop in input circuit	3 V
- galvanic separation between inputs and with respect to central part of controller :	
- - electric strength	500 V / 50 Hz / 1min.
- - insulation resistance	≥ 20 MΩ
3.1.3. Binary inputs XB	
- number of inputs	16
- power supply (external) for initiators	19 ÷ 30 V
- current in closed initiator circuit	4 ÷ 7 mA
- galvanic separation between 8-input groups and from central part of controller	
- - electric strength	500 V / 50Hz / 1min.
- - insulation resistance	≥ 20 MΩ
3.1.4. Pulse inputs XBI	
- number of inputs	3
- type of inputs (preset with jumpers as ordered)	current or voltage type

- voltage signal specification
- - high level > 15 V
- - low level < 4,5 V
- current signal specification
- - high level > 12 mA
- - low level < 7 mA
- galvanic separation between inputs and from central part of controller:
- - electric strength 500 V / 50 Hz / 1min.
- - insulation resistance ≥ 20 MΩ

3.1.5. Binary outputs YB

- number of outputs 12
- type of outputs universal AC/DC
- output signal levels
- - resistance at switching-on ≤ 24 Ω
- - max. output voltage at switching-off 300 V
- - current-carrying capacity of outputs ≤ 100 mA
- galvanic separation between outputs and from central part of controller:
- - electric strength 500 V / 50 Hz / 1min.
- - insulation resistance ≥ 20 MΩ

3.1.6. Analogue outputs YA

- number of outputs 3 or 6
- nominal range of output signals 0 ÷ 2.5 V
- resolution of C/A conversion 12 bits
- processing accuracy for outputs 0.1 %
- additional processing errors (including that resulting from ambient temperature variations) +/- 0.1 % of span
- max. load of each output 500 Ω
- galvanic separation from central part of controller:
- - electric strength 500 V / 50 Hz / 1min.
- - insulation resistance ≥ 20 MΩ

3.1.7. Network link ETH:

network transmission channel - ETHERNET IEEE 802.3 10BASE-T

- network processor CS8900A by CIRRUS LOGIC
- - transmission speed 10 Mbits/s
- galvanic separation from central part of controller:
- - electric strength 2000 V (RMS)
- - insulation resistance ≥ 20 MΩ

3.1.8. Serial links COM1, COM2:

- number of serial links 2
- link type: RS 422, RS-485 or RS-232, simultaneous transmission and reception is impossible,
- max. transmission speed 115,200 bits/s (BPS)
- character length 8 bits
- parity control parity
- galvanic separation between links and from other controller's circuits
- - electric strength 500 V / 50 Hz / 1min
- - insulation resistance ≥ 20 MΩ
- communication protocols:

COM1 - MODBUS-RTU –SLAVE and special protocol with tool software
COM2 - MODBUS-RTU – MASTER or MODBUS-RTU-SLAVE and special protocol with tool software

3.1.9. Software specification

- application routines graphical structure
- folder of procedures acc. to „ES15.LIB – Library of procedures"
- program cycle time depending on application program length
- execution time for 100 test procedures 5 ms approx.
- max. length of application program (c. 1000 procedures) 8 KB

3.1.10. Operating conditions

- ambient temperature	0 ÷ 50 °C
- relative humidity	≤ 75 %
- sinusoidal vibrations	10 ÷ 55 Hz / 0.15 mm
- disturbance level	level N

3.1.11. Dimensions [height * width * depth] 160 * 90 * 58 mm

3.1.12. Weight 0.5 kg approx.

3.2. DESCRIPTION OF OPERATION

The ES-15 is based on ultra-low-power microcontrollers, series MSP430, manufactured by Texas Instruments. It includes two microcontrollers, type MSP430F1611; one acquires external information and processes it according to the algorithm included in loaded-in application routine, and also supports serial transmission channels; the other microcontroller handles network communication via Ethernet controller. The microcontrollers are interconnected with high-efficiency parallel bus arranged on microcontrollers' ports. The microprocessors are 16-bit processors with RISC type architecture including internal memories, types RAM and Flash, and expanded set of peripherals like: 12-bit A/C converter, two (2) 16-bit counters with built-in high-speed input control (HSI) and high-speed output control (HSO) circuits, two (2) serial channels, type USART, and forty-eight (48) programmable input/output ports. Furthermore, the microcontroller provides watchdog program control, power-on restart and special JTAG interface to program the Flash memory of the microcontroller. Communication with external environment is provided via galvanically separated interfaces.

The interfaces of the controller are as follows:

- analogue inputs - 8 inputs
- binary inputs - 16 inputs
- binary outputs - 12 outputs
- pulse inputs - 3 inputs
- analogue outputs - 6 outputs
- two (2) serial interfaces - type RS
- network channel - ETHERNET IEEE 802.3 10BASE-T

Analogue inputs are separated each other with line transoptors and the primary circuits are powered from input signals, thus an easy separation between channels is ensured. Gains of input channels are determined during factory-made tuning; the values of these gains are saved in permanent memory.

Pulse inputs, galvanically separated each other and with respect to the CPU, are fed to microcontroller's inputs allowing to measure time between to changes at inputs. For example, when **SPDM** procedure is used, rotational speed of rotary machine may be measured (three-channel measurement with 2-out-of-3 selection). Pulse inputs could also be, as required by the user, applied in another way (e.g. to acquire pulse signals from energy or heat counters).

Binary outputs are represented by separated electronic relays which can switch on DC and AC circuits.

Serial interfaces are in RS-422 standard (Fig. 1); they can be connected to RS-485 standard using a special cable which comes together with concentrator.

3.3. DESIGN

The ES-15 is provided with closed enclosure intended for installation on standard mounting rails, type T-35, where it occupies 160 mm approximately. External circuits are connectable via 6 multiple connectors, each with 12 spring terminals. The multiple connectors may be disconnected from the controller without necessity to disconnect field conductors. Two 9-pin sockets for serial transmission channels (COM1 and COM2) and RJ-45 connector for Ethernet (ETH) are provided on the front panel of the controller. Furthermore, the front panel includes also four indicating LEDs: red for "CPU Stop", green for "CPU Run" referring to the basic part of controller, and also green for "ETHRun" and yellow for "ETH Line" related to network communication. Indication codes are summarized in Table 2.

4. APPLICATION SOFTWARE

The controller processes analogue an binary signals. They may represent constants or variables, the latter divide into internal and external ones, i.e. the inputs and outputs of the controller. The variables have their unique names. The names are composed from characters included in hexadecimal numbers only **(0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F)**.

The following names are assigned to **external variables**:

- binary inputs	**XB1 ÷ XB16**	names	**BB00 ÷ BB0F**
- pulse inputs	**XBI1 ÷ XBI3**	names	**BB10 ÷ BB12**
- binary outputs	**YB1 ÷ YB12**	names	**BC00 ÷ BC0B**
- analogue inputs	**XA1 ÷ XA8**	names	**AE00 ÷ AE07**
- analogue outputs	**YA1 ÷ YA6**	names	**AC00 ÷ AC05**

The following names are assigned to **internal variables**:

analogue variables	**A000 ÷ A1FF**	**- 512 variables**
binary variables	**B000 ÷ B7FF**	**- 2048 variables**

Binary variables, **B7B0-B7FF**, are used by operating system to generate information that may be applied in an application routine (they could not be used as outputs of procedures).

Currently the following variables are used:

binary variables B7B0 – B7CF are intended to MODBUS-MASTER communication; they monitor proper connection with network numbers 1 through 32 – when communication is in operation, respective binary variables are set, and when communication is interrupted, they are reset**.**

binary variables B7D0 –B7EF describe the status of elements in Ethernet with the numbers 1 through 32, and the controller sets these binary variables as ordered by network processor,

binary variable B7F0 of the condition „communication with network processor is on" ("1")

binary variable B7FC – start cycles of routine (5 cycles after restart) („1" – start cycles are on)

The source „application routine" is created in a form of graphical diagram composed of graphical functional modules interconnected each other. The structure components include: modules of declarations and procedures, interconnections between procedures, external connections and names of connections. Graphical modules corresponding to procedures and declaration of the programming language are included in the **ES15.LIB** library set. Inputs and outputs of procedures are connected to the algorithm.

The „application routine" is run successively to the numbering assigned to declarations and procedures. A number of a procedure or declaration is represented by a combination of letters and digits. The order of execution is determined by the letter order in alphabet and then by the number. The routine must include the **"Start"** declaration with the lowest number and the **"End"** declaration with the highest number. All terminations of procedures should be interconnected, i.e. they must be assigned to a variable or a constant of proper type – an analogue name for analogue terminal and a binary name to binary terminal.

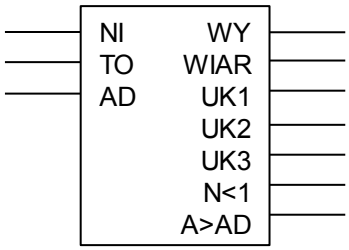
The „application routine" in such notation subjects to compilation by the **ESTool** tool program. As a result of such compilation, a batch routine is composed having the name identical to the graphical structure and extension "bin". Using the tool program, the batch routine should be loaded into the controller (RAM memory) and then, the command "write to Flash memory" shall be issued. During writing operation, the routine is interpreted into the "executable" form and saved in Flash permanent memory.

4.1. ROTATIONAL SPEED MEASUREMENTS

Rotational speed of rotary machines is measured by applying pulse waveforms from rotary sensors to pulse inputs **XBI**. Both current and voltage types of signals may be applied to pulse inputs. The type of

input is established by means of jumpers in one controller's board according to the order placed. The type of input may be easily modified by the user by removal or addition of jumper(s).

Measurement of rotational speed requires for the **"SPDM"** procedure in the application routine. Graphical representation of this procedure is given in the diagram below.



Graphical symbol of SPDM procedure

The procedure has 3 inputs and 7 outputs. The inputs are:

- **NI** – number of pulses per one turn, - e.g. for 30 pulses/turn, the entry shall be CD30
- **TO** – nominal time of one turn (in seconds), - e.g. for 20 ms/turn, the entry shall be C020
- **AD** – control threshold for rotation acceleration (in % x 0.01 / s^2) – e.g. for 3%, the number C030 shall be entered.

The measurement is based on measuring the time of one turn of the machine shaft; more accurately, the time between leading edges of pulses over the spacing equal to the number of pulses per one turn. The microcontroller is configured so as pulse inputs are fed to 3-channel "fast inputs" programmable unit which, in cooperation with 1 μs resolution counter, saves the counter status at specified change at the input. This allows to measure the times of one turn at 3 inputs with theoretical resolution of 1 μs per one turn. The time for one turn is calculated in relative rotational speed according to declared nominal speed. For nominal rotational speed, the **WY** output generates the number 0.800.

The procedure operates according to the „selection 2-out-of-3" algorithm. The output measurement signal is generated to the following rule: at firs, the discrepancy between times of one turn for three inputs is verified; if the discrepancy between at least two (out of three) input signals is less than admissible value, the output takes the average value of these signals and the signal different from the two others is indicated as false. If the discrepancy between all signals exceeds the admissible value, the output signal becomes equal to the highest speed and all the measuring paths are indicated as damaged.

The outputs of the procedure are the following signals:

- **WY** – relative rotational speed; 0.800 when the time of one turn equals to the nominal value,
- **WIAR** – the reliable measurement, „1" when the results was calculated from measurements differing each other less than the admissible value,
- **UK1, UK2, UK3** – damage to the measuring path 1, 2, 3, respectively – „1" when the path is damaged;
- **N<1** – „1" when the speed is < 1 turn/min.
- **A>AD** – violation of speed acceleration declared at input **AD,** „1" when the acceleration measured is higher than **AD**.

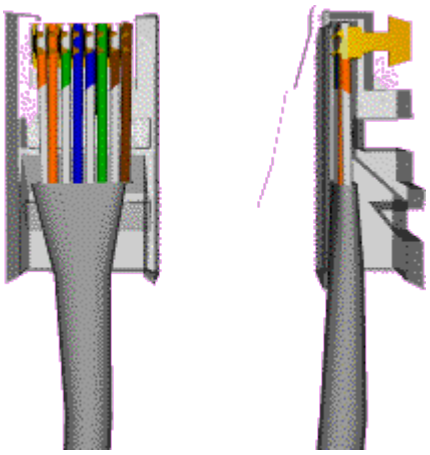
5. INSTALLATION AND START-UP

The Controller, ES-15, is to be installed on T-35 mounting rail. It is provided with six(6) multiple connectors, each with 12 spring-loaded terminals. Multiple connectors allow for simple installation/disconnection of the controller without a need to disconnect field cables. The multiple connectors are provided with "coding keys" which enable to plug in the multiple connector into the proper socket only. Multiple connectors are designed to receive connectors with cross-section area from 0.08 to 1.5 mm^2. Terminals may be "made open" with a special tool delivered by the manufacturer of terminals (WAGO Company) or with a flat screwdriver 2.5 mm wide.

How to prepare the RJ-45 plug.
In order to connect the ES-15 with mains switch, a so called *straight-through* cable is used. It is recommended to use standard wiring arrangement (acc. to the Standard *EIA/TIA-568B*). Below, please find the structure of so called straight-through cable.

Table 1. Table of connection in straight-through cable.

Pin No.	*Terminal No.1 of cable, conductor colour*	*Terminal No.2 of cable, conductor colour*	*Pin No.*
1	white/orange	white/orange	***1***
2	orange	orange	***2***
3	white/green	white/green	***3***
4	blue	blue	***4***
5	white/blue	white/blue	***5***
6	green	green	***6***
7	white/brown	white/brown	***7***
8	brown	brown	***8***



View of wired plug, type RJ-45.

If a standard PC provided with tool program **ESTool** is connected, via a standard cable and RS232C interface with the controller, it allows direct monitoring of current signal values in program structure and makes the controller start-up simple and easy.

6. SERIAL INTERFACES OF CONTROLLER

The ES-15 is provided with two serial channels, type RS, and ETHERNET IEEE802.3 network channel.

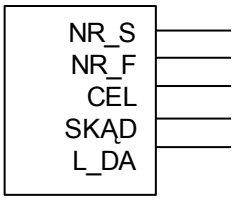
6.1. SERIAL CHANNELS - COM1 i COM2

The channels represent the RS-422 electrical standard. They may be arranged to the RS-485 standard or, with a special cable delivered by the manufacturer, they may be interconnected with RS-232 standard interface – see Fig. 1.

Both RS channels are programmed to the special standard for communication with tool routines in the **ESTool** package and in the **MODBUS-RTU-SLAVE** standard (i.e. they may be included into the MODBUS network where they react to communication initiatives controlled by MASTER component). Both channels automatically recognize whether the communication is run with the **ESTool** tool program or in **MODBUS_SLAVE** network. Both RS channel of the controller respond to the frames in MODBUS standard when the controller was assigned with a network number. The network number is assigned from the ESTool program via "TOOL" menu and "NETWORK NUMBER" command. The network numbers must be included within the range 1 through 32.

The **COM 2 channel** is also programmed to the **MODBUS-RTU-MASTER** protocol, i.e. it may be also intended to acquire information from other components within the MODBUS network. In order to cause an operation in this mode (MODBUS MASTER), the application routine of the controller need to include the **MOD-TASK** ("communication task") procedures. This procedure (its symbol is shown below) describes the task by providing on its terminal:

NR_S - network number of SLAVE component (digital number from the range CD01-CD32)
NR_F - function number (type of task); below is provided the list of functions implemented in the controller and the way of notation
CEL - destination of data transmitted (the number of the first data item)
SKAD - location from where the data are collected (the number of the first data item)
L_DA - number of data transmitter (digital number from the range CD01-CD99).



Graphical symbol of MOD_TASK" procedure

Binary variables and 16-bit registers are the information exchange elements in the MODBUS standard. In the controllers, series **ES-1x**, the information exchange elements are internal binary and analogue variables. Binary and analogue variables are directly accessible, i.e. write and read operations consist in direct indication those variable which are concerned for the transmission by specifying the names of variable on the terminals of the "Communication Task" procedure.

During data exchange, internal analogue variables subject to conversion to/from four-byte floating-point form to/from fixed point form in U2 code transmitted in MODBUS standard. **The range of analogue variables is limited to the range +/- 1.**

The application routine of ES controller may include up to 20 „MOD-TASK" procedures.

The **MODBUS** standard provides for about 20 types of functions (identified with numbers) whereas the following ones (names declared at procedure terminals are given in parenthesizes) are available in the Series **ES-1x** controllers:

NR 1 (CD01)	**read the block of output binary variables (from "SLAVE" component)**
NR 2 (CD02)	**read the block of input binary variables (from "SLAVE" component)**
NR 3 (CD03)	**read the block of output registers (from "SLAVE" component)**
NR 4 (CD04)	**read the block of input registers (from "SLAVE" component)**
NR 5 (CD05)	**set output binary variable conditionally (in "SLAVE" component)**
NR 6 (CD06)	**write the register (in "SLAVE" component)**
NR 15 (CD15)	**write the block of binary variables (in "SLAVE" component)**
NR 16 (CD16)	**write the block of registers (in "SLAVE" component)**
NR 22 (CD22)	**forward the analogue variable if it was overwritten**
NR 23 (CD23)	**forward the binary variable if it was overwritten**

Notes to the list of functions:

1 The communication protocol of Series **ES-1x** controllers makes no difference between input and output variables. All types of above frames are treated as those referring to internal variables. For example, any binary variable may be read with frame "1" or "2".

2 The frame for function No. 5 is sent (i.e. a binary variable is changed in SLAVE component) if the source binary variable has changed (in MASTER component).

3 The „22" and „23" functions were introduced using reserve number of the MODBUS standard. In ES controllers, the variables "overwritten" (modified) by external unit, i.e. by ETHERNET or MODBUS network, are each time marked out after overwriting. The „22" and „23" functions allow to transmit, after overwriting, the analogue and binary variable, respectively, to SLAVE component.

6.2. ETHERNET - ETH NETWORK INTERFACE

The ES-15 is provided with Ethernet IEEE-802.3 network port in 10BASE-T execution regarding the physical medium standard (interface to medium and network topology). The front plate of the controller has RJ-45 connector to interconnect the unit with LAN network and two LEDs indicating the interface operational status. In the software layer, the network interface makes use of TCP/IP uIP stake, the work of Adam Dunkels from Swedish Institute of Computer Science.

The standard of 10BASE-T network interface specifies the following network features:

- network topology – star,
- wiring – unshielded twisted pair (UTP) cable, type CAT3 or CAT4, size AWF22 or AWG24,
- max. length of segment – 100m
- max. length of network – 2,800 m

The start topology or the network – in its basic version – is implemented by connecting the unit to the central point which is a so called network concentrator (as an active unit of the network). In order to maintain higher network reliability, it is recommended to use a so called Ethernet Switch as the network concentrator.

Addressing the network interface.

The ES-15 has www server. The configuration of the IP address of the ES-15 network interface is made by commonly available software – the Internet browsers. The ES-15 has the following factory-set IP address of the network interface: **192.168.0.2.**

Functions of network interface.

The network interface of the ES-15 is intended to provide communication with higher levels of automation and control systems, such as SCADA systems or another automation systems. These

functions may be used by application of dedicated software placed at contact between the layer of ES-15 controllers and higher levels. These functions are included in the UDP/IP special protocol implemented in ES-15; they allow for, but are not limited to:

1. to read internal analogue variables of the controller,
2. to write internal analogue variables of the controller,
3. to read internal binary variables of the controller,
4. to write internal binary variables of the controller,
5. to send application routine to the controller and to start it,
6. to read binary events stamped with astronomic time at the controller's level with 10 ms resolution of,
7. to run synchronization with astronomic time.

Apart from the functions outlined above and requiring dedicated software, the ES-15 has www server which may be interconnected by means of commonly available software – Internet browsers. At this level we can get information about detailed statistics for network interface operation and basic information on current operation of the controllers. This information covers, but is not limited to:

1) Network address of the network interface,
2) Serial number of ES-15 Controller,
3) Name and version of system software of the controller,
4) Name and version of system software of the controller's network part,
5) Name and version of application software initiated in the controller.

The www server allows also to monitor the internal analogue and binary variables which are exported from internal controller's part.

Table 2. Indication codes of the ES-15

No.	CPU Stop red	CPU Run green	ETH Run green	ETH Line yellow	
1	○	⊗			program runs from Flash memory
2	⊗	○			error in application routine
3	⊗	⊗			no program in Flash memory
4	⊗	⊗			downloading the routine into Flash memory
5	⊗	○			application routine is too large to be downloaded into Flash memory
6	⊗	⊗			fixed part of application routine is too large to be downloaded into Flash memory
7	⊗	⊗			procedures exceed operating capacity of RAM memory
8			⊗		processor servicing Ethernet is operating
9				⊗	Ethernet connection is on

LED status symbols:

○ -- LED is off

⊗ -- LED is on

⊗ -- slow blinking, 1 Hz (MW)

⊗ -- fast blinking, 5 Hz (MS)

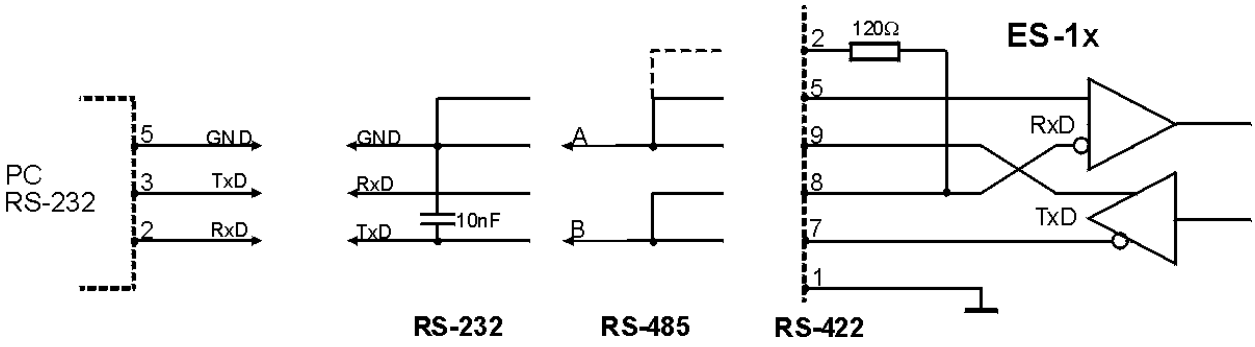


Fig. 1. Serial channels, COM1 and COM2 (RS422/RS485/RS232) of the controller

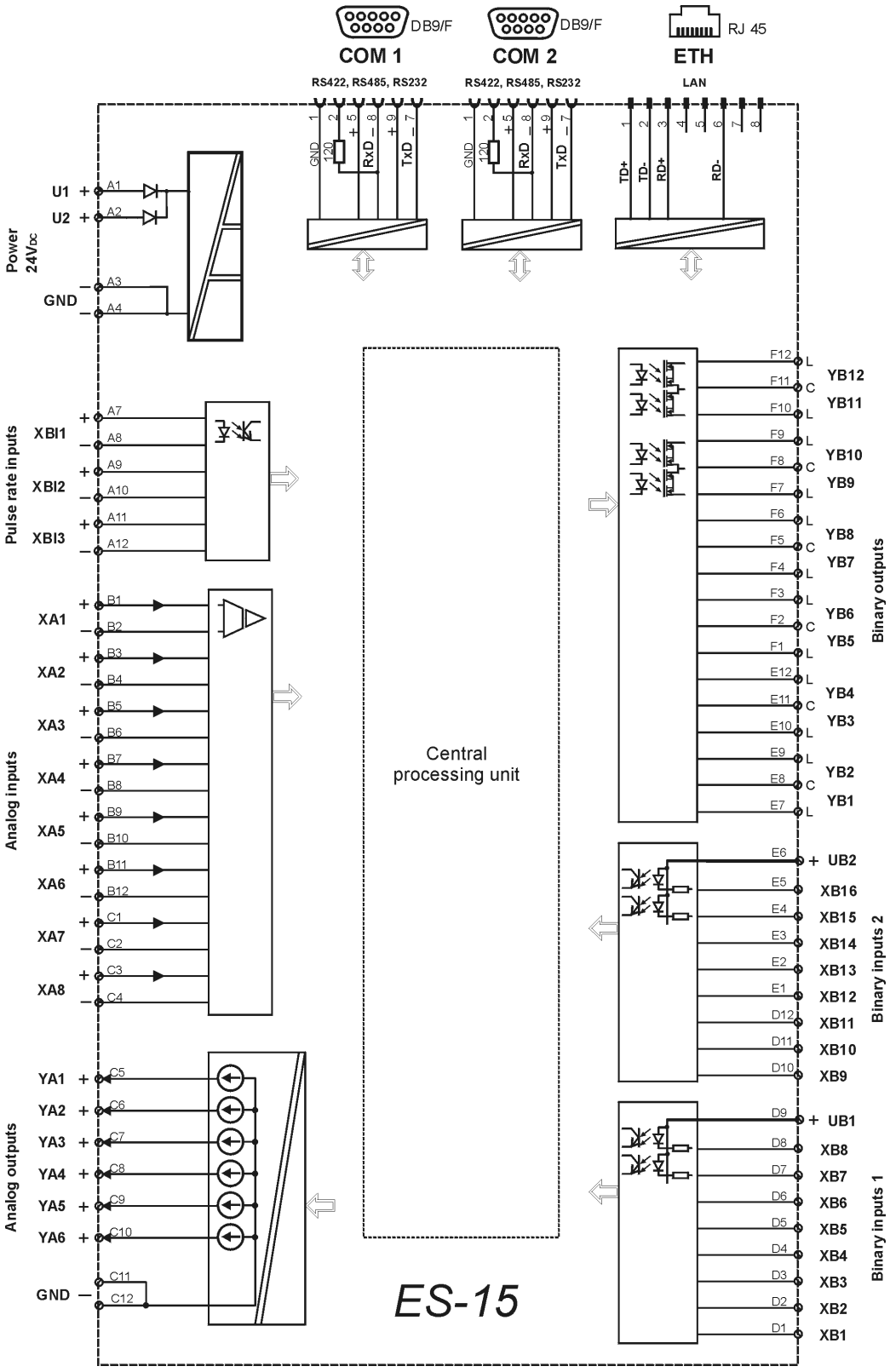


Fig. 2. Block diagram of the controller