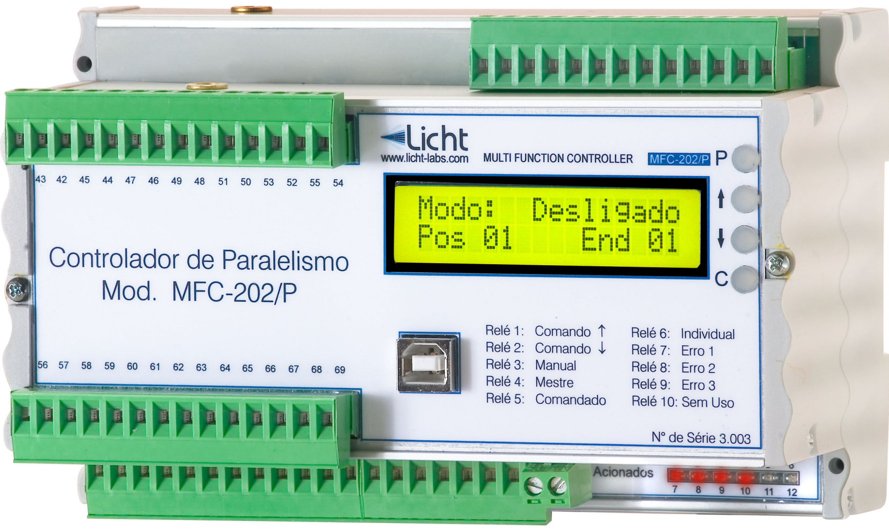
Parallelism Controller model MFC-202/P



Technical Manual

Licht

Contents

1 Introduction

The MFC-202/P controller was developed by Licht for the paralellism supervision and control of 3-phase power transformers and 3-phase groups of monophase transformers. The MFC-202/P features 10 relays for electromechanic logic, one RS485 interface for supervision and control and one optional current output for position retransmission.

The parallelism control is implemented according to the master-follower principle, under which all tap changer positions are kept synchronized. For parallel control to be successful under this scenario, we admit that all involved transformers have identical nominal currents, number of taps and voltage delta per tap. Each tap changer's position is read directly from its potentiometric sensor or indirectly either via a current loop (typically 4-20 mA) or BCD contacts, according to the client's specifications. During parallel control, the Master tap changer's position is compared to its Followers', and tap changer pulses are issued to the Follower tap changers whose positions don't match their Master's.

In the MFC-202/P architecture, each controller is responsible for a 3-phase transformer or a monophase transformer, and is interconnected with other MFC-202/P using a RS485 bus arrangement. MODBUS or DNP3 functionality is provided on a second dedicated RS485 port, which does not require additional hardware.

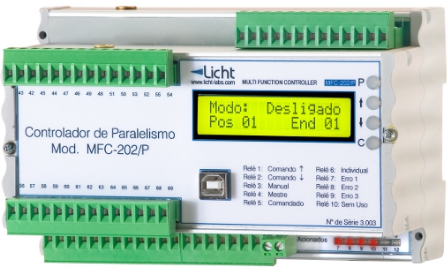


Figure 1.1 MFC-202/P controller

2 Operating principle

General Case

The operation of transformers in parallel can be motivated by expansion, redundancy or convenience. For it to be practical, the transformers involved must have their secondary voltages as similar as possible at all times. Otherwise, transformers with lower outputs become loads to the others, creating circulation currents.

The MFC-202/P is designed for power transformers with on-load tap changers. These can adjust their tranformation relation as their loads change, guaranteeing adequate regulation. The Master-Follower principle supposes that the involved transformers have tap changers with the same number of taps, and that each tap corresponds to the same output voltage. Circulation currents are minimized by operating transformers on identical positions.

In the Master-Follower principle, a transformer which we denote the Master is chosen as the reference. The others, denoted Followers, have their positions automatically updated in order to match the Master. Parallel control is synchronous, because all transformers – irrespective of being the Master or the Follower – receive simultaneous commands. Transformers can be removed from parallel control if configured as Individual, and completely ignored if configured as Disabled.

Some exceptional scenarios are detected and treated. These can vary from tap changer failures (for example, when a Follower transformer doesn't respond to commands and fails to match its Master) to configuration errors (for example, configuring a Master without Followers or Followers without a Master).

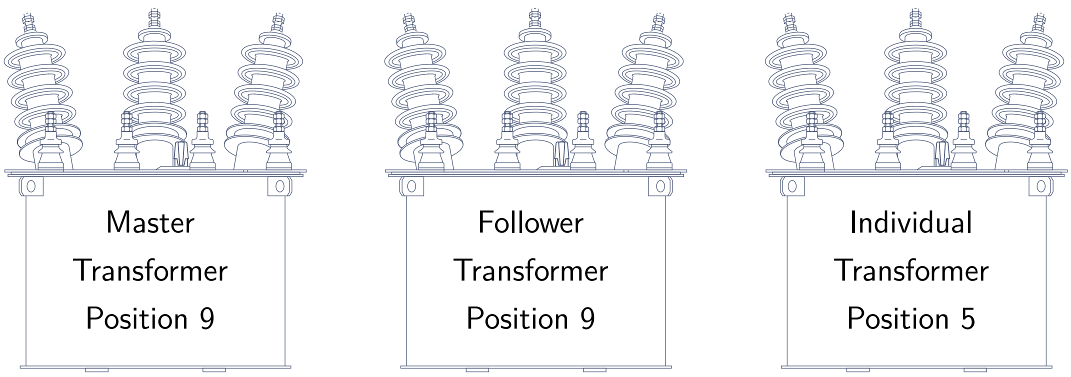


Figure 2.1 3-phase Transformer Parallelism

Manual Commands

Transformers configured as Master or Individual can be manually commanded by an operator. This command may be local (issued on the controller's keyboard) or remote (with digital dry contact inputs).

If a Follower transformer fails to respond to tap change commands, the MFC-202/P will ignore subsequent commands and signal the error condition. In this scenario, the operator must reconfigure the transformer as Individual and manually manage the system's parallelism until a solution can be found.

3 Operation

3.1 Front panel indication

Under normal operation, the MFC-202/P indicates its channel's position, operation mode (Master, Follower, Individual, Disabled) and, if applicable, the raise (↑) or lower (↓) command indications. **Figure 3.1** presents a front panel indication example.

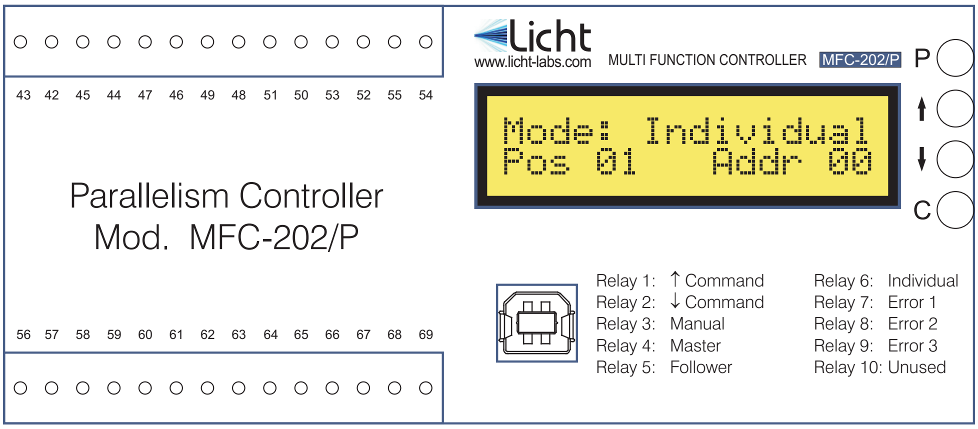


Figure 3.1 Front Panel

In alarm situations, the display alternates between an error message and the channel's indication, regardless of the device's configuration.

3.2 Manual commands

Transformers configured as Master or Individual can be directly commanded by the MFC-202/P with a manual command. Whenever the transformer is configured as Follower or Disabled, the command is ignored. Manual commands are only accepted if there's no synchronism error between all tap changers.

To perform a manual command, press **P**, choose the "Manual Command" option, press **P** again to confirm and then issue a raise or lower command with the ↑ or ↓ key.

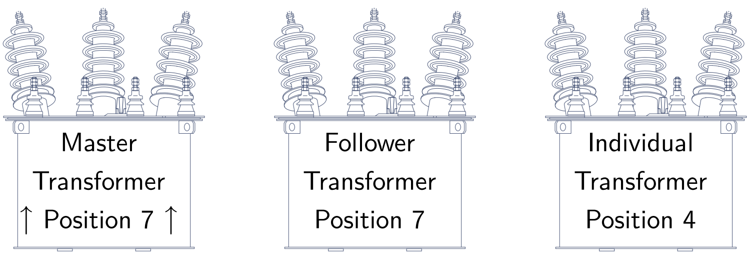


Figure 3.2 Raise Command Example (Before)

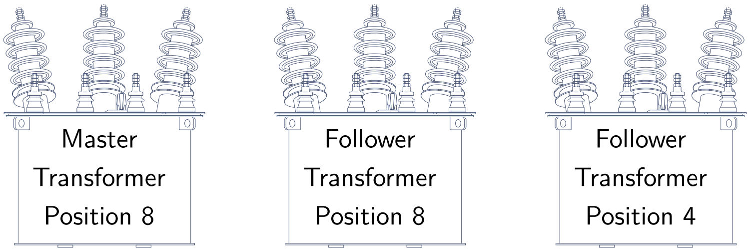


Figure 3.3 Raise Command Example (After)

3.3 Configuration

The MFC-202/P features 4 keys to access its functions. The procedure to configure any parameter is as follows:

1. Press the **P** key to enter the parameters menu.
2. Using the ↑ and ↓ keys, choose the desired parameter.
3. Press **P** to confirm the parameter's selection.
4. Choose the desired value with the ↑ and ↓ keys.
5. Confirm pressing **P**.

The configuration sequence can be cancelled at any time by pressing **C**.

3.4 Parameter reset

The MFC-202/P can be reset to factory settings. This procedure also resets its password to `AAAA`. To do so, power on the device while pressing **C**.

4 Programmable parameters

The MFC-202/P was developed to provide the user with the greatest possible flexiblity, such that all supervision and configuration can be executed on-site or remotely through the existing communication channels.

We define all user-configurable parameters as follows:

Parallelism Mode[1]

Options: *Master*, *Follower*, *Individual* or *Disabled*

Description: Selects if the channel operates as Master, Follower, Individual or Disabled.

Number of Positions

Options: *2* to *50*

Description: The on-load tap changer's number of positions.

Resistance per Position

Opções: *3* to *20* Ω

Descrição: Resistance in Ω per tap changer position.

Synchronism Error Timeout

Options: *10* to *100* s

Description: Interval defined from the instant when failure to follow was detected to this error's indication.

Configuration Error Timeout

Options: *10* to *100* s

Description: Interval defined from the instant when a configuration failure was detected to this error's indication.

Address

Options: *0 to 15*

Description: Configures this MFC-202/P's network address. Each tap changer must have a unique address. A network of MFC-202/Ps can control up to 16 transformers.

Output Current (if any)

Options: *0-1*, *0-5*, *0-10*, *0-20*, *4-20* mA

Description: Refers to the various configurable current loop scales.

[1] This parameter can be only configured using dry contacts.

Relay {7, 8, 9} Configuration

Options: Refer to the table below.

Description: Defines the activation condition for programmable relays 7, 8 e 9.

Activation Condition	Occurrence Site	Default State	MODBUS Value
Synchronism Error	Any MFC-202/P	FC	0
		FO	1
Configuration Error	Any MFC-202/P	FC	2
		FO	3
Communication Error	Any MFC-202/P	FC	4
		FO	5
Position Deviation	Any MFC-202/P	FC	6
		FO	7
Normal Operation	Any MFC-202/P	NC	8
		NA	9

FC: fail closed
FO: fail open
NC: normally closed
NO: normally open

4.1 MODBUS protocol

Parameter: Baud Rate

Options: 9600, 19200, 38400, 57600, 115200 bps.

Description: baud rate for the RS485 link.

Parameter: Format

Options: 8N1, 8E1, 8O1, 8N2.

Description: symbol transmission format, where:

- 8N1: 8 data bits, no parity, 1 stop bit.
- 8E1: 8 data bits, even parity, 1 stop bit.
- 8O1: 8 data bits, odd parity, 1 stop bit.
- 8N2: 8 data bits, no parity, 2 stop bits.

Parameter: Address

Options: 1 to 247.

Description: MODBUS address for the MFC-202/P.

4.2 DNP3 protocol (option)

Parameter: Baud Rate
Options: 9600, 19200, 38400, 57600, 115200 bps.
Description: baud rate for the RS-485 link.

Parameter: Format
Options: 8N1, 8E1, 8O1, 8N2.
Description: symbol transmission format, where:

- 8N1: 8 data bits, no parity, 1 stop bit.
- 8E1: 8 data bits, even parity, 1 stop bit.
- 8O1: 8 data bits, odd parity, 1 stop bit.
- 8N2: 8 data bits, no parity, 2 stop bits.

Parameter: Address
Options: 0x0000 to 0xFFEF.
Description: DNP3 outstation address in hexadecimal notation.

Parameter: Application Layer Confirmation
Options: Only when transmitting events or multi-fragment responses, Always.
Description: Selects when the MFC-202/P outstation should request application layer confirmations.

Parameter: Maximum Inter-Octet Gap
Options: 2 to 100 ms.
Description: The DNP3 specification states that frames should not have inter-octet gaps. In accordance, the MFC-202/P never inserts inter-octet gaps when transmitting data. However, we allow the option to tolerate gaps in incoming transmissions. Frames featuring inter-octet gaps larger than the Maximum Inter-Octet Gap will be quietly dropped.

Parameter: Backoff Delay (Fixed)
Options: 1 to 100 ms.
Description: See description for Backoff Delay (Random).

Parameter: Backoff Delay (Random)
Options: 1 to 100 ms.
Description: The MFC-202/P is designed for multi-drop scenarios where more than one outstation may transmit over the same line. To handle collision avoidance, a backoff

scheme is implemented. Before transmitting, the MFC-202/P always waits for the line to become idle. Once that happens, it waits for $T_{delay} = T_{fixed} + T_{random}$ ms, where T_{fixed} is the fixed backoff delay and T_{random} is a random value, uniformly distributed between 0 and the random backoff delay parameter. If after T_{delay} ms the line is still idle, then the MFC-202/P begins transmission.

Parameter: Insert Inter-frame Gap
Options: Never, Always.
Description: The DNP3 specification states that no inter-frame gaps are required. However, some masters have been observed to drop frames when no inter-frame gaps are provided. This option allows communicating with such non-compliant devices. We discourage its use, given that the forced inter-frame gap implies a forced backoff-delay.

5 Error conditions

5.1 Synchronism error

Synchronism errors occur whenever one or more Follower on-load tap changers stop following their Master, despite commands to do so. These may occur between 3-phase transformers or phases of a 3-phase group of monophase transformers.

Synchronism errors are only set after the user-configurable Syncronism Timeout expires.

Possible causes:

- ▷ Connection failure between the raise/lower voltage regulator and the tap changer.
- ▷ Tap changer failure, preventing it from receiving and/or executing position changes.
- ▷ An Individual transformer is incorrectly configured as Follower.
- ▷ The position was manually altered at the tap changer and not through the parallelism controller.

5.2 Position deviation

Position deviations are characterized by readings which shift considerably from their ideal value. Despite not being large enough to be interpreted as another position altogether, they suggest failure or imminent failure of the position transducer element, either due to calibration, tap changer failure or connection problem.

Possible causes:

- ▷ EMI (electro-magnetic interference) due to faulty or lack of cable shielding.
- ▷ EMI due to failure to ground the cables' shielding.
- ▷ Contact problem.

5.3 Configuration error

Configuration errors may occur in the following scenarios:

- ▷ Follower channels without a Master.
- ▷ Master channel with no Followers.
- ▷ More than one Master.
- ▷ Resistance per Position parameter is mismatched between devices.

5.4 Communication error

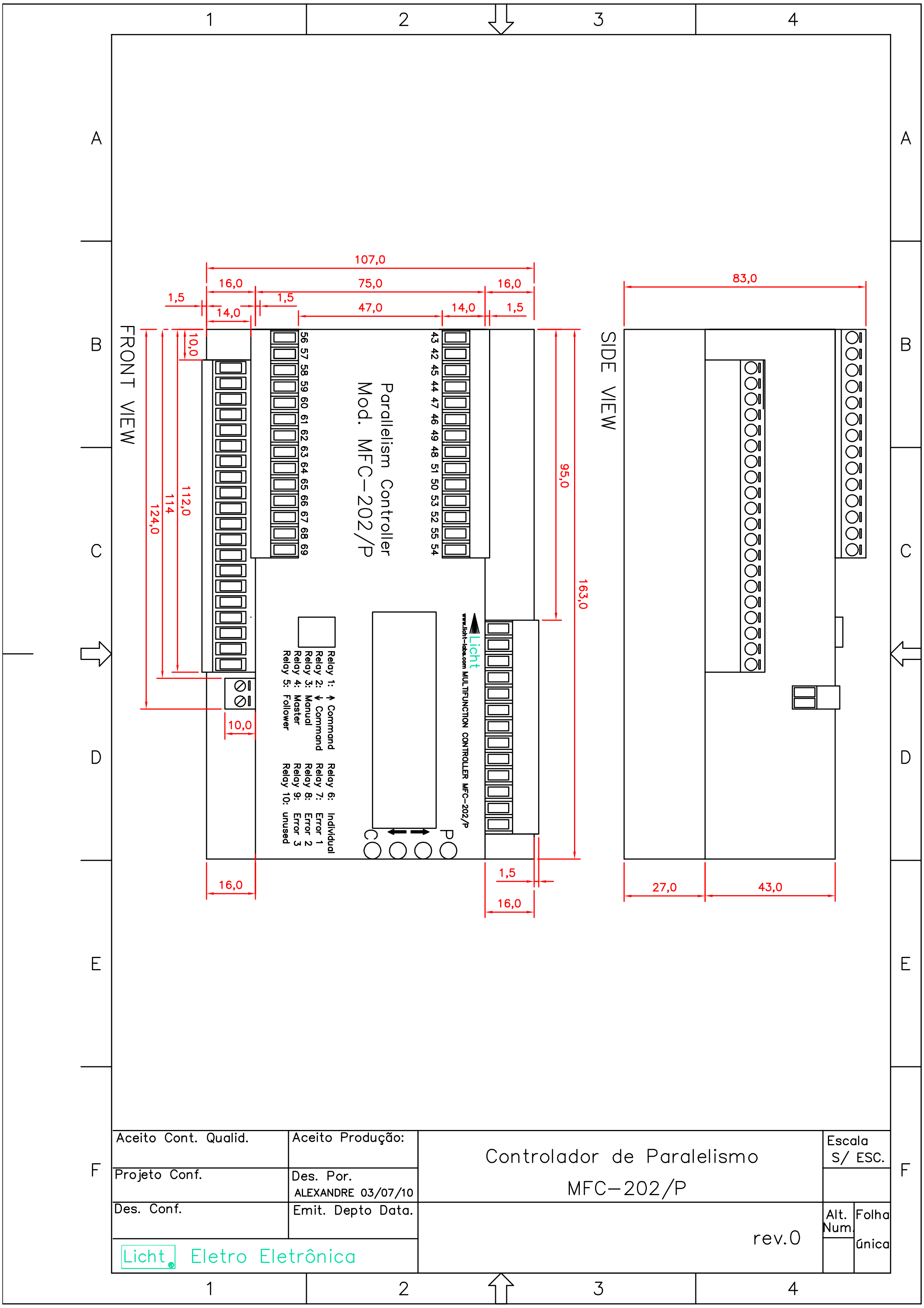
Communication errors are characterized by serial (RS485) communication failures between networked MFC-202/P controllers. Each MFC-202/P is responsible for a given transformer, and they must exchange position information to correctly operate. Possible causes for communication errors are:

- ▷ More than one MFC-202/P set to the same address.
- ▷ Power failure in more than one MFC-202/P.
- ▷ Connection failure between networked MFC-202/Ps.
- ▷ EMI due to lack of shielding.
- ▷ EMI due to failure to ground the cables' shielding.
- ▷ One or more defective MFC-202/P.

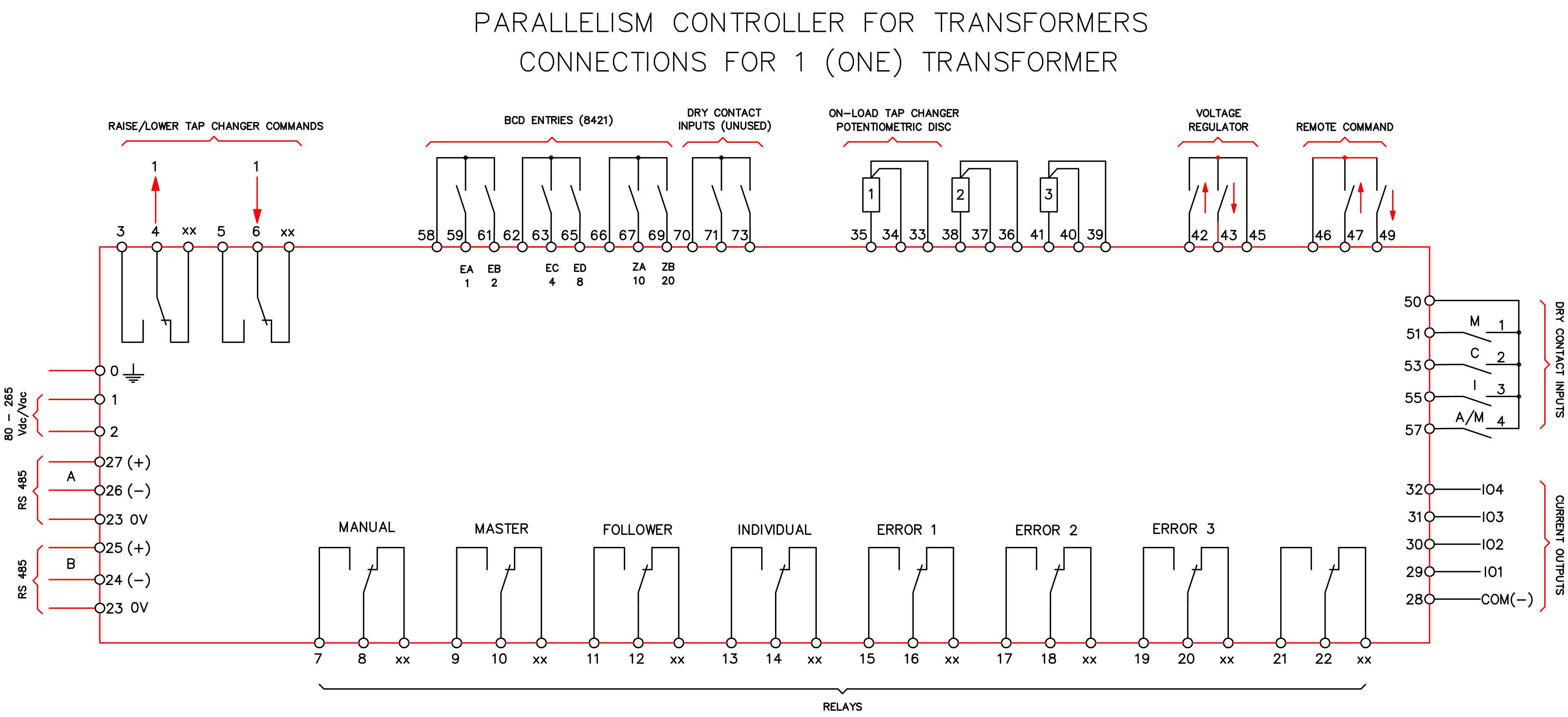
A Specifications

Power Supply	Isolated, 80-260 Vac/Vdc.
Power Consumption	5 W
Operating Temperature	-10 to 70 °C (LCD display) -40 to 70 °C (VFD display)
Enclosure Rating	IP20
Mounting Options	35 mm DIN Rail
Tap Measurement Inputs	2-wire Potentiometric Current (e.g.: 4-20 mA) Voltage (e.g.: 0-10 V)
Number of Positions	2 to 50
Potentiometric Disc Resistance	8 to 1000 Ω
Resistance per Tap	3 to 20 Ω
Dimensions (L x H x D)	160 x 105 x 75 mm
Weight	1.0 kg
DC Scales	0-1, 0-5, 0-10, 0-20, 4-20 mA
Error/Non-linearity (inputs)	0.2% + 0.1% / 10 °C
Error/Non-linearity (outputs)	0.2% + 0.1% / 10 °C
Galvanic Isolation (60 Hz, 1 min.)	Outputs 2.0 kV Communication 2.0 kV
Communication	RS-485 - MODBUS RTU or DNP3 9600, 19200, 38400, 57600, 115200 bps 8N1, 8E1, 8O1, 8N2
Displays	2 lines, 16 characters each (5 mm). LCD with backlight or VFD.
Relays	10 A @ 250 Vac, 0.5 A @ 125 Vdc Galvanic Isolation: 2.0 kV, 60 Hz, 1 min.

B Housing


FRONT VIEW
SIDE VIEW
Parallelism Controller
Mod. MFC–202/P
107,0
75,0
47,0
16,0
14,0
1,5
10,0
112,0
114
124,0
95,0
163,0
83,0
27,0
43,0
56 57 58 59 60 61 62 63 64 65 66 67 68 69
43 42 45 44 47 46 49 48 51 50 53 52 55 54
Relay 1: ↑ Command
Relay 2: ↓ Command
Relay 3: Manual
Relay 4: Master
Relay 5: Follower
Relay 6: Individual
Relay 7: Error 1
Relay 8: Error 2
Relay 9: Error 3
Relay 10: unused
Licht
MULTIFUNCTION CONTROLLER MFC–202/P
Aceito Cont. Qualid.
Aceito Produção:
Projeto Conf.
Des. Por.
ALEXANDRE 03/07/10
Des. Conf.
Emit. Depto Data.
Controlador de Paralelismo
MFC–202/P
Escala
S/ ESC.
Alt. Num.
Folha
única
rev.0
Licht Eletro Eletrônica

C Connection diagrams



Important considerations

The installation of electronic devices in substations should conform with the recommendations given by recent international standards. The most recent and detailed guide for installations is IEC 61000-5-2:1997, which was based on decades of laboratory and field research. We summarize below some of the guidelines contained in IEC 61000-5-2:1997. For further reading, we recommend the articles and application notes available on our web site.

a. Shielded cables must be used for connecting potentiometric sensors, current loop outputs, RS-485 links and the auxiliary supply.
b. Cables must be segregated in trays, ducts or conduits according to their functions. In particular, power cables must never be routed in the proximity of signal cables, even if these are shielded. The minimum distances which must be observed are described in IEC 61000-5-2:1997 and in articles available on-line at this product's web page.
c. The electrical continuity of cables, ducts, trays and conduits must be preserved up to frequencies in the order of MHz, over all their extension, including curves and junctions. In order to guarantee this continuity, joints and bonds should present electrical contact along each cable, duct or tray's transversal section. In particular, trays should be bonded with seam-welded joints (best), U-brackets with multiple fixings (ok) and never with wires.
d. Shielded cables should present no gaps in their screens along their lengths. 360° bonding should be performed instead.
e. Should there be unshielded sections (for example, near terminal block connections), these should be short as possible.
f. Trays, ducts and conduits must be electrically continuous, and must be grounded at both ends. In this configuration, trays, ducts and conduits provide shielding and also perform as parallel earth conductors.
g. Shielded cables should also have their screens bonded at both ends. It is extremely important that the tray, duct or conduit which contains each cable is also grounded at both ends, allowing it to perform as a parallel earth conductor. In the absence of a parallel earth condutor, the cable screens will be exposed to extremely high currents which will severely compromise their operation.
h. RS-485 pairs must be terminated at both ends by 120 Ω resistors.

i. RS-485 devices must be connected in a bus topology. No other network topology (tree, star, ring, etc.) is acceptable.
j. Dry contact inputs (if applicable) must free of potentials.

D Configuration sheet

Parameter	Possible Settings	Selected Setting
Device Address	0 to 15	
Bus Size	1 to 16	
Parallelism Mode	Master, Follower, Individual, Disabled	
Number of Positions	2 to 50	
Resistance per Position	3.0 to 20.0 Ω	
Synchronism Error Timeout	10 to 100 s	
Configuration Error Timeout	10 to 100 s	
Relay 7 Configuration	(See section 4)	
Relay 8 Configuration	(See section 4)	
Relay 9 Configuration	(See section 4)	
Output Current	0-1, 0-5, 0-10, 0-20, 4-20 mA	
MODBUS Address	1 to 247	
MODBUS Format	8N1, 8E1, 8O1, 8N2	
MODBUS Baud Rate	9600, 19200, 38400, 57600, 115200 bps	

E MODBUS registers

Given that each MFC-202/P device only controls a single transformer, network operation is necessary to implement parallel control. Each MFC-202/P has two RS-485 communication ports. One is designed for interlinking controllers in a bus topology, and the other is used for communicating with a SCADA system.

A SCADA system can be connected to any of the networked MFC-202/P controllers. It may be connected to more than one MFC-202/P, or even to all of them if desired. Any MFC-202/P knows the states and parameters from all other MFC-202/P devices connected to it, and is designed to relay this information to a SCADA system.

MODBUS register addresses are 16 bits long. The most significant byte (bits 8-15) must match the Local Bus Address of the destination MFC-202/P. The least significant byte (bits 0-7) addresses the actual register in the chosen device. The following pages list the MODBUS accessible parameters and their associated registers.

As an example, suppose there are 5 interlinked MFC-202/P controllers, with local bus addresses 0, 1, 2, 3, and 4, and that the SCADA system is connected to controller 3. The positioned measured by controller N (where N is one of 0, 1, 2, 3 or 4) may be read by issuing a MODBUS *Read Holding Register* (function 0x03) to register $N \cdot 256 + 200$. (We multiply by 256 to left-shift by 8 bits.) Note that we're referring to MODBUS registers in the 0-65535 range. Several server interfaces refer to MODBUS registers in the 1-65536 range. If 1-65536 indexing is desired, add 1 to the computed register values (in our example, issue a *Read Holding Register* to address $N \cdot 256 + 201$).

The MFC-202/P implements the *Read Holding Register* (0x03), *Write Single Register* (0x06) and *Write Multiple Register* (0x10) MODBUS RTU functions. A frame referring to any other function will be answered with an "unsupported function code" exception. Frames referring to registers in unreachable or unavailable devices will be answered with exception *Gateway Target Device Failed to Respond* (0x0B).

Holding Register	Description	Values	Multiplier
1	Device Address	0 to 15	1
2	Bus Size	1 to 16	1
3	Number of Positions	2 to 50	1
4	Resistance Per Position	3.0 to 20.0 Ω	10
5	Synchronism Error Timeout	10 to 100 s	1
6	Configuration Error Timeout	10 to 100 s	1
7	Relay 7 Configuration	(See section 4)	1
8	Relay 8 Configuration	(See section 4)	1
9	Relay 9 Configuration	(See section 4)	1
21	Current Loop - Output Scale	0: 0-1 mA 1: 0-5 mA 2: 0-10 mA 3: 0-20 mA 4: 4-20 mA	1
201 (read-only)	Transformer Measured Position	2 to 50	1
202 (read-only)	Transformer Expected Position	2 to 50	1
203 (read-only)	Parallelism mode	0: Master 1: Follower 2: Individual 3: Disabled	1
204 (read-only)	Errors	(See table below)	1

Each bit from the error register indicates a specific error. If the bit is set, the erro exists; otherwise, it does not.

Local errors are those who originated in a device. Global errors are those which exist for some device on the bus (not necessarily the device whose error register is being polled).

Instantaneous errors are those which are active when the register is read. Delayed errors are those which have been active at least for the duration of the Configuration Error Timeout (user configurable), Communication Error Timeout (fixed at 10 seconds), Measurement Error Timeout (fixed at 10 seconds) and Synchronism Error Timeout (user configurable).

Register 204 Bit	Error
0	Local instantaneous configuration error
1	Local instantaneous communication error
2	Local instantaneous measurement error
3	Local instantaneous parallelism error
4	Local delayed configuration error
5	Local delayed communication error
6	Local delayed measurement error
7	Local delayed parallelism error
8	Global instantaneous configuration error
9	Global instantaneous communication error
10	Global instantaneous measurement error
11	Global instantaneous parallelism error
12	Global delayed configuration error
13	Global delayed communication error
14	Global delayed measurement error
15	Global delayed parallelism error