

# Temperature Controller model MFC-300/T

14 relay version



Technical Manual



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# 1 Introduction

The MFC-300/T is a precise, highly reliable and versatile microcontrolled system for power transformer temperature control. It is designed to read, infer, display and transmit a transformer's oil and winding temperatures, and to activate alarm, cooling and shutdown systems whenever necessary.

The oil's temperature is measured directly, usually with RTDs (resistance temperature detectors). Winding temperatures are inferred upon evaluating the following parameters:

- ▷ The oil's highest temperature (*top oil*).
- ▷ Currents proportional to each winding's load.
- ▷ Temperature gradients for each winding, referenced to the oil's temperature.
- ▷ The correction exponent for each type of cooling.

Once all temperatures are known, the system activates if necessary cooling systems or alarms, based on predefined setpoints.

Among its features, we highlight: up to 6 compensated and auto-calibrated RTD inputs for temperature measurement, 3 isolated AC true-RMS inputs, 1 isolated RS-485 line, 1 USB port, 12 relays with configurable setpoints and timeouts, 2 pairs of relays with configurable alternate activation and 4 current loop outputs.

The MFC-300/T shares the same form factor with other Licht controllers for transformers, such as the MFC-300/R voltage regulator and the MFC-300/P parallelism controller. All signals that enter and exit the controller are pairwise galvanically isolated, preventing potentially damaging noise and transients from being transferred between subcircuits or retransmitted to other devices.



**Figure 1.1** MFC-300/T Controller (96x48 version)

## 2 System highlights

The MFC-300/T was designed for stable operation under severe conditions, and its project inherits over 20 years of industrial electronics engineering experience. We highlight a few of its design features below:

- ▷ Temperature acquisition is performed with 16-bit resolution. All DC signals are sampled after a 50/60 Hz filter with a rejection band attenuation greater than 100 dB.
- ▷ AC signals representing transformer loads are isolated with highly precise and linear micro CTs. These transfer the signals through magnetic means, such that their characteristics suffer minimal degradation with time.
- ▷ Our CTs offer isolation superior to 2000 V, 60 Hz, 1 min. between primary and secondary windings.
- ▷ Only true-RMS values are considered for AC signals, again minimizing the effect of transients.
- ▷ Noise, surges and transients typically present in communication channels cannot be transferred to the equipment's interior. All communication channels are pairwise galvanically isolated against all other connections.
- ▷ The device automatically activates an alarm relay and all cooling relays in the event of RTD rupture.
- ▷ All components are specified for industrial use or better (85 °C), allowing for continuous operation at up to 70 °C.
- ▷ The standard version features an isolated universal 80 to 260 Vdc/Vac power supply. A special version can be simultaneously supplied with DC and AC currents, any of which automatically serves as a backup.

## 3 Operating principle

### 3.1 General principle

The MFC-300/T's main purpose is to monitor transformer temperatures and activate cooling systems whenever necessary. It features up to 6 RTD inputs, which are automatically compensated for cable length and linearized for each sensor's standardized temperature response. The first RTD represents the oil's highest temperature, while the remaining RTDs (if installed) can be used for other purposes.

The MFC-300/T can monitor the currents of up to 3 windings, which are used to infer the winding temperatures. To correctly model the transformer in question, the following parameters must be configured by the user:

- ▷ Each winding's nominal current.
- ▷ The copper/oil temperature gradient under nominal load.
- ▷ The time constant for the windings.
- ▷ The correction exponent for the type of cooling used.

In this manual, we consider a *channel* to be either an RTD identifier or a winding identifier. The MFC-300/T features 12 user-configurable relays, each of which must be associated with a channel. For example, a relay associated with RTD #2 only responds to temperature variations from RTD #2.

Once all RTD temperatures are measured and winding temperatures are calculated, the device is responsible for activating alarm, shutdown and cooling systems based on predefined temperature setpoints. There are 12 user-programmable temperature setpoints, corresponding to 12 relays. Each relay may be associated with any of the RTD measurements or winding temperatures. There are also 12 user-programmable current setpoints, associated with the same 12 relays. These allow alarm, shutdown or cooling systems to be activated based on winding current values.

The decision to activate a relay may not depend uniquely on a temperature or current, but also on other user-configurable parameters. For example, a relay may be configured to be permanently closed or open. Also, in the event of RTD failure due to a severed connection or short-circuit, the MFC-300/T automatically activates all relays associated with cooling systems.

Whenever a channel's temperature exceeds a temperature setpoint associated with it, a timer is started. There exists one timer per temperature setpoint, responsible for activating its associated relay upon expiration. Likewise, whenever a winding's current exceeds a current setpoint associated with it, a timer is started. There exists one timer per current setpoint, responsible for activating its respective relay upon expiration. Current and temperature timers are independent.

A relay's activation threshold is equal to its setpoint. However, its deactivation threshold includes a bias which we call a hysteresis. If the deactivation threshold were equal to the setpoint, cooling could turn on and off intermittently whenever the transformer oscillated about a threshold. To prevent this from happening, each setpoint has an associated and user-configurable hysteresis value.

We present below a decision diagram for the activation of a generic relay  $k$ , where:

- ▷  $T_k$  is its channel temperature;
- ▷  $I_k$  is its channel current;
- ▷  $SPT_k$  is its temperature set-point;
- ▷  $HT_k$  is its temperature hysteresis value;
- ▷  $SPI_k$  is its current set-point;
- ▷  $HI_k$  is its current hysteresis value.

Note that  $I_k$ ,  $SPI_k$  and  $HI_k$  are only defined if relay  $k$  is associated with a winding channel. Relays associated with RTD channels do not respond to current measurements.

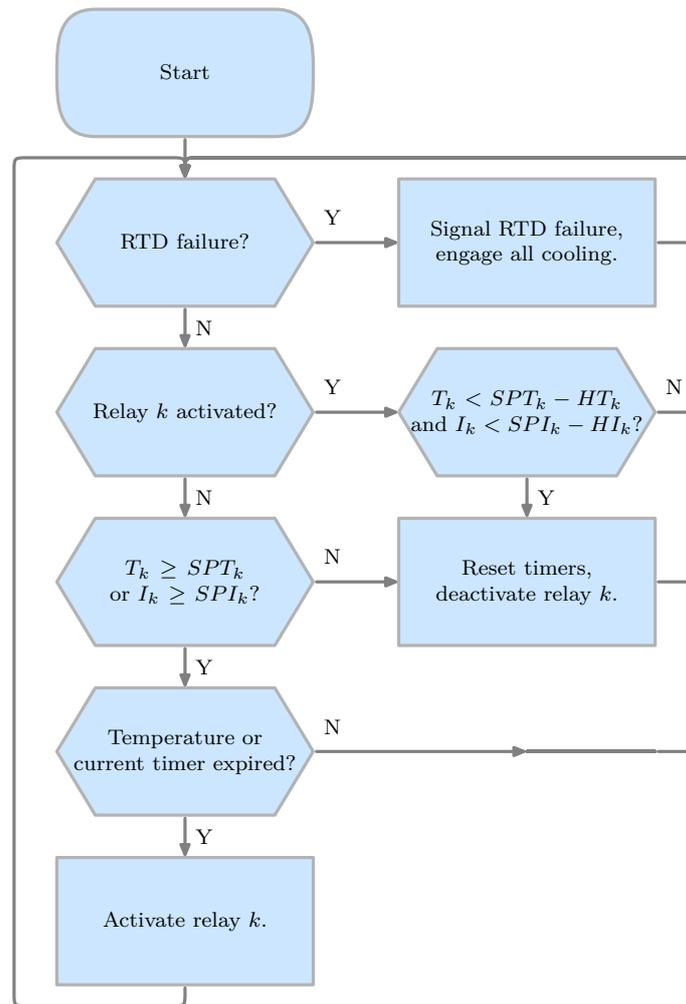
Relays dedicated to cooling functions may also be activated once per day at a configurable time and remain closed for a configurable duration. The daily activation of cooling pumps or fans is desirable in cold climates in order to keep mechanical parts well lubricated and to prevent the accumulation of dirt.

During normal operation, temperature peaks for each channel are registered in non-volatile memory. The maximum temperature per channel per hour for the last 24 hours is kept in memory.

The MFC-300/T has 4 current loop outputs (for the oil and winding temperatures), with scales configurable to 0-1, 0-5, 0-10, 0-20 or 4-20 mA.

## 3.2 RTD operation

The MFC-300/T can be provided in configurations featuring up to 6 independent or redundant RTDs.



**Figure 3.1** Relay Activation Logic

Configurations with independent RTDs feature one temperature channel per RTD, allowing a given relay to be associated freely with any sensor. The first RTD is reserved for oil temperature measurements, and the remaining RTDs can be used for any other purposes.

Configurations with redundant RTDs associate all sensors with the oil temperature channel. The MFC-300/T continuously monitors the state of each RTD and its connection, and automatically ignores sensors which are absent or which present abnormal behavior.

In the redundant RTD setup, the temperature attributed to the oil is the one measured by the first operational RTD. The choice of using only one RTD is intrinsically more robust than alternatives which perform averages between sensors. In fact, given an RTD disturbance probability  $p$  which we consider to be small, an algorithm which computes averages of  $N$  RTDs will increase the system's disturbance probability to approximately

$N \cdot p$ , decreasing overall stability. Given that the accuracy of RTD measurements significantly exceeds the requirements of power transformer temperature control, averaging between sensors turns out to be unnecessary and undesirable.

In both configurations, problems involving one or more RTDs are indicated with an RTD fault relay, which is reserved exclusively for this function. The following events are identified as faults:

- ▷ Measured temperature below 0 °C or above 255 °C.
- ▷ Temperature variation rate exceeding 20 °C/s.
- ▷ Detection of inconsistencies in the measurement circuit.
- ▷ Temperature difference between sensors exceeding the **Maximum Temperature Difference** parameter (only applicable to redundant RTDs).

In the independent RTD configuration, any of the events above triggers the activation of the RTD fault relay, the activation of all relays associated with cooling functions and the inhibition of future relay operations. Whenever the originating fault is resolved (for example, by replacing a damaged RTD), the system returns to normal operation after a 30 second delay.

In the redundant RTD configuration, any of the events above triggers the activation of the RTD fault relay. If all RTDs present faults or if the measured temperature between any pair of sensors exceeds the **Maximum Temperature Difference** parameter, all relays associated with cooling functions are activated and future relay operations are inhibited. In particular, a fault involving a single RTD does not inhibit further operations. As in the previous case, the system only deactivates the RTD fault relay (and re-enables relay operations, if necessary) 30 seconds after detecting the absence of faults.

### 3.3 Event registration (option)

The MFC-300/T can optionally feature a memory module, enabling it to store time-stamped events. An event consists of a relay status change, which in turn can be triggered by user-configurable setpoints or system faults, as described in the sections above. Note that a relay need not be in use (or even physically installed) in order for it to generate events through its setpoints. The MFC-300/T can also be forced to generate events every  $n$  minutes (with  $1 < n \leq 60$ ) by configuring the **Event Timer** parameter.

Whenever an event is triggered, the MFC-300/T stores all system temperatures (RTDs 1-6, Oil and Windings 1-3) and the status of all relays. Every event is associated with a 48-bit value representing the number of milliseconds since January 1, 1970, 00:00:00.

The MFC-300/T writes events in a FIFO (first in, first out) non-volatile queue, which can store up to 3584 events. Note that if **Event Timer** is set to 10 minutes, this queue will recycle in approximately 25 days due to the periodic events alone (not counting relay changes, which are less common). If set to 1 minute, the queue will recycle every 2.5 days.

The event history may be easily reviewed on the MFC-300/T's screen by accessing the **Event History** menu option. The most recent event is shown first, and other events can be accessed by pressing the ↑ or ↓ keys. The event history can also be downloaded into CSV (comma separated value) format by using the USB interface (optional) and the MFC-300/T's software for Windows or Linux, which is available for download at our web site.

## 4 Front panel indication

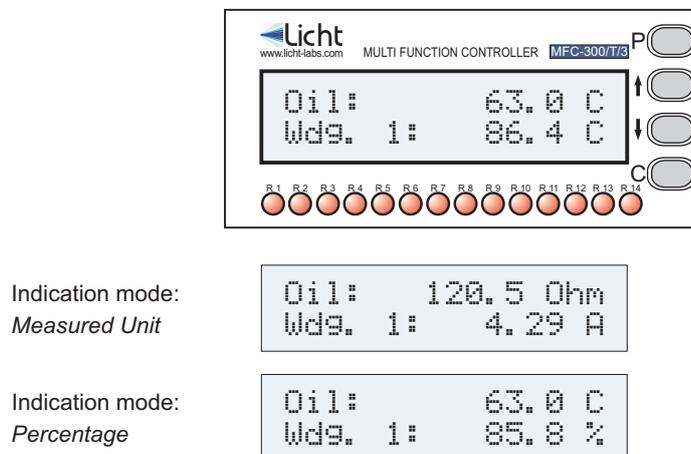
During normal operation, the MFC-300/T alternates between displaying each channel's value and the current date/time. The type of indication can be chosen between Temperature, Current and Percentage.

In the Temperature display, the presented value for the oil is that read by the RTD, compensated for the sensor's intrinsic nonlinearity and the cable resistances. The oil temperatures are inferred and depend on the definition of a model which adequately approximates the transformer (in particular considering the  $\Delta T[1-3]$ ,  $m$  and  $\tau$  parameters).

The Current option presents the physical values read by the MFC-300/T: the resistance measured from the RTD (without the cable resistances) and the current sampled by each CT.

The Percentage option displays each winding's current load, referenced to its nominal value.

The indication type can temporarily be altered by pressing the  $\uparrow$  and  $\downarrow$  keys.



**Figure 4.1** Front Panel

## 5 Configuration

The MFC-300/T 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. Enter the currently configured 4 letter password one letter at a time, using the ↑ and ↓ keys to select each letter and **P** to advance between letters. The default password is AAAA.
3. Using the ↑ and ↓ keys, choose the desired parameter.
4. Press **P** to confirm the parameter's selection.
5. Choose the desired value with the ↑ and ↓ keys.
6. Confirm pressing **P**.

By holding down the ↑ or ↓ keys it is possible to advance through the options faster.

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

### 5.1 Parameter reset

The MFC-300/T can be reset to factory settings. This procedure also resets its password to AAAA. To do so, power up the device while pressing **C**.

## 6 Programmable parameters

The MFC-300/T was developed to provide the user with the greatest possible flexibility, such that all supervision and configuration can be executed on-site (through the keyboard or USB connection) or remotely (via the RS-485 link).

We define all user-configurable parameters as follows.

**Parameter:** Set Point (°C)[1-12]

**Options:** 0 to 255 °C, in increments of 1 °C.

**Description:** Temperature set point for relays 1-12.

**Parameter:** Hysteresis (°C)[1-12]

**Options:** 1 to 255 °C, in increments of 1 °C.

**Description:** Temperature hysteresis for the activation/deactivation of relays 1-12.

**Parameter:** Timeout[1-12]

**Options:** 0.1 to 25.5 minutes, in increments of 0.1 minute.

**Description:** Delay for the activation of relays 1-12.

**Parameter:** Associated Channel[1-12]

**Options:** Oil, Wdg. 1, Wdg. 2, Wdg. 3, RTD 2, RTD 3, RTD 4, RTD 5, RTD 6.

**Description:** Channel associated with each relay. Note that temperature setpoints are active on all channels, and current setpoints are only active on channels associated with windings.

**Parameter:** Forced Activation[1-12]

**Options:** Normal, Activated.

**Description:** Selects if a relay responds to temperature variations (Normal) or if it is permanently activated (Activated).

**Parameter:** Activation Logic[1-12]

**Options:** Normal, Inverted.

**Description:** Defines whether a relay's activation logic is Normal (relay closes when its set point is exceeded) or Inverted (relay opens when its set point is exceeded).

**Parameter:** Set Point (I%)[1-12]

**Options:** 0 to 150% of the associated winding's nominal current, in increments of 1%.

**Description:** Current set point for relays 1-12. Note that this set point is only valid

whenever its relay is associated with a winding. It is ignored if the relay is associated with an RTD.

**Parameter:** Hysteresis (I%)[1-12]

**Options:** 1 to 255%, in increments of 1%.

**Description:** Current hysteresis for the activation/deactivation of relays 1-12.

**Parameter:** Associated Function[1-12]

**Options:** Alarm, Cooling.

**Description:** Defines each relay's associated function. Relays associated with cooling systems are automatically activated on the event of RTD failure, and are activated daily if the Daily Cooling option is enabled.

**Parameter:** Indication Type

**Options:** Temperature, Measured Unit, Percentage.

**Description:** Type of values indicated on the MFC-300/T's front panel.

**Parameter:**  $\Delta T$ [1-3]

**Options:** 0 to 99 °C, in increments of 1 °C.

**Description:** Copper/Oil temperature gradient for windings 1-3. Represents the temperature difference between each winding and the oil under nominal load.

**Parameter:**  $I_N$ [1-3]

**Options:** 0.2 to 5.0 A, in increments of 0.1 A.

**Description:** Nominal current considered by the device for inferring winding 1-3's temperature.

**Parameter:** Alternate Activation

**Options:** Disabled, 9-10 only, 11-12 only, 9-10 and 11-12.

**Description:** Refers to the alternate activation of relays 9/10 and 11/12, typically used to ensure equal wear of the associated cooling hardware.

*A relay pair can be configured for alternate activation only if its Temperature Hysteresis, Current Hysteresis, Delay, Associated Channel and Associated Function parameters are equal. Otherwise, the MFC-300/T won't even display the relevant options in the Alternate Activation menu.*

If the Alternate Activation option is enabled for a given pair of relays, their Temperature Hysteresis, Current Hysteresis, Delay, Associated Channel and Associated Function parameters are automatically kept equal. For example, if Alternate Activation is set to

11-12 only, a modification to the Hysteresis[11] parameter will be automatically repeated on Hysteresis[12].

To allow greater configurability, alternate activation uses the two setpoints from a relay pair. Its operation can be better understood through an example. Let pair 9-10 be set to alternate activation with the following parameters:

- ▷ Set Point[9]: 80 °C
- ▷ Set Point[10]: 90 °C
- ▷ Hysteresis[9], Hysteresis[10]: 1 °C
- ▷ Associated Channel[9], Associated Channel[10]: Winding 1

Ignoring the influence of the hysteresis, if winding 1's temperature is under 80.0 °C, neither relay 9 nor 10 will be activated. If it's between 80.0 and 89.9 °C, only one relay will be activated. If it's greater than or equal to 90.0 °C, both will be activated. The alternation happens when the winding's temperature makes a 89.9 → 90.0 °C transition: in this case, the relay which remained open during the last transition is closed.

**Table 6.1** presents a detailed example.

Transition	Action
75.0 °C → 83.0 °C	Closes relay 9
83.0 °C → 78.0 °C	Opens relay 9
78.0 °C → 86.0 °C	Closes relay 10
86.0 °C → 94.0 °C	Closes relay 9 (relays 9 and 10 are closed)
94.0 °C → 89.5 °C	No effect due to relay 9's hysteresis
89.5 °C → 85.0 °C	Opens relay 9 (relay 10 still closed)
85.0 °C → 79.5 °C	No effect due to relay 10's hysteresis
79.5 °C → 78.0 °C	Opens relay 10 (relays 9 and 10 open)

**Table 6.1** Alternate activation example

**Parameter:** Time Constant ( $\tau$ )

**Options:** 0.0, or from 3.0 to 20.0 minutos, in increments of 0.1 minuto.

**Description:** Time constant for the windings' first-order thermal model. When set to 0.0, considers that the transformer has zero heat capacity.

**Parameter:** m

**Options:** 0.5 to 1.0, in increments of 0.1.

**Description:** Exponent for the cooling method used. Considering its time constant, the temperature response for a current step of amplitude  $I_D$  is:

$$T_{winding}(t) = T_{oil} + \Delta T \left( \frac{I_D}{I_N} \right)^{2m} \left( 1 - e^{-t/\tau} \right)$$

Therefore, the final temperature (under thermal equilibrium) for a winding with under constant current  $I$  is given by:

$$T_{winding}(\infty) = T_{oil} + \Delta T \left( \frac{I}{I_N} \right)^{2m}$$

**Parameter:** Daily Cooling (Start)

**Options:** 00:00 to 23:59, in increments of 1 minute.

**Description:** Time of day at which all cooling relays are forcefully activated. Use this option to ensure the adequate lubrication of fans and pumps in cold climates.

**Parameter:** Daily Cooling (Duration)

**Options:** Disabled, or 1 to 999 minutes, in increments of 1 minute.

**Description:** Duration of the forced cooling cycle.

**Parameter:** Event Timer

**Options:** Disabled, or 1 to 60 minutes, in increments of 1 minute.

**Description:** time interval between the forced registration of events (if this option is installed).

**Parameter:** Maximum Temperature Difference

**Options:** 1 to 200 °C, in increments of 1 °C.

**Description:** in controllers supplied with redundant temperature sensors, sets the maximum temperature difference allowed between different sensors. If any two sensors measure temperatures which differ more than the configured threshold, the MFC-300/T will go into RTD fault mode. This parameter is not available in controllers featuring independent sensors.

## 6.1 Current outputs (option)

**Parameter:** Output Scale

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

**Description:** Refers to the various configurable current loop scales.

**Parameter:**  $T_{FS}$  (Oil)

**Options:** 0 to 255 °C, in increments of 1 °C.

**Description:** Full scale for the oil's temperature. For example, if  $T_{FS}$  (Oil) = 150 °C and Output Scale = 4-20 mA, the displayed temperature will be 0 °C for 4.0 mA and 150 °C for 20.0 mA.

## 6.2 MODBUS protocol

**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:** 1 to 247.

**Description:** MODBUS address for the MFC-300/T.

## 6.3 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-300/T 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-300/T 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-300/T 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-300/T 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-300/T 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.

## 6.4 Clock

**Parameter:** Date/Time

**Options:** HH:MM:SS DD/MM/YYYY

**Description:** sets the local date and time.

## 7 Additional versions



**Figure 7.1** MFC-300/T Controller (96x96 version)

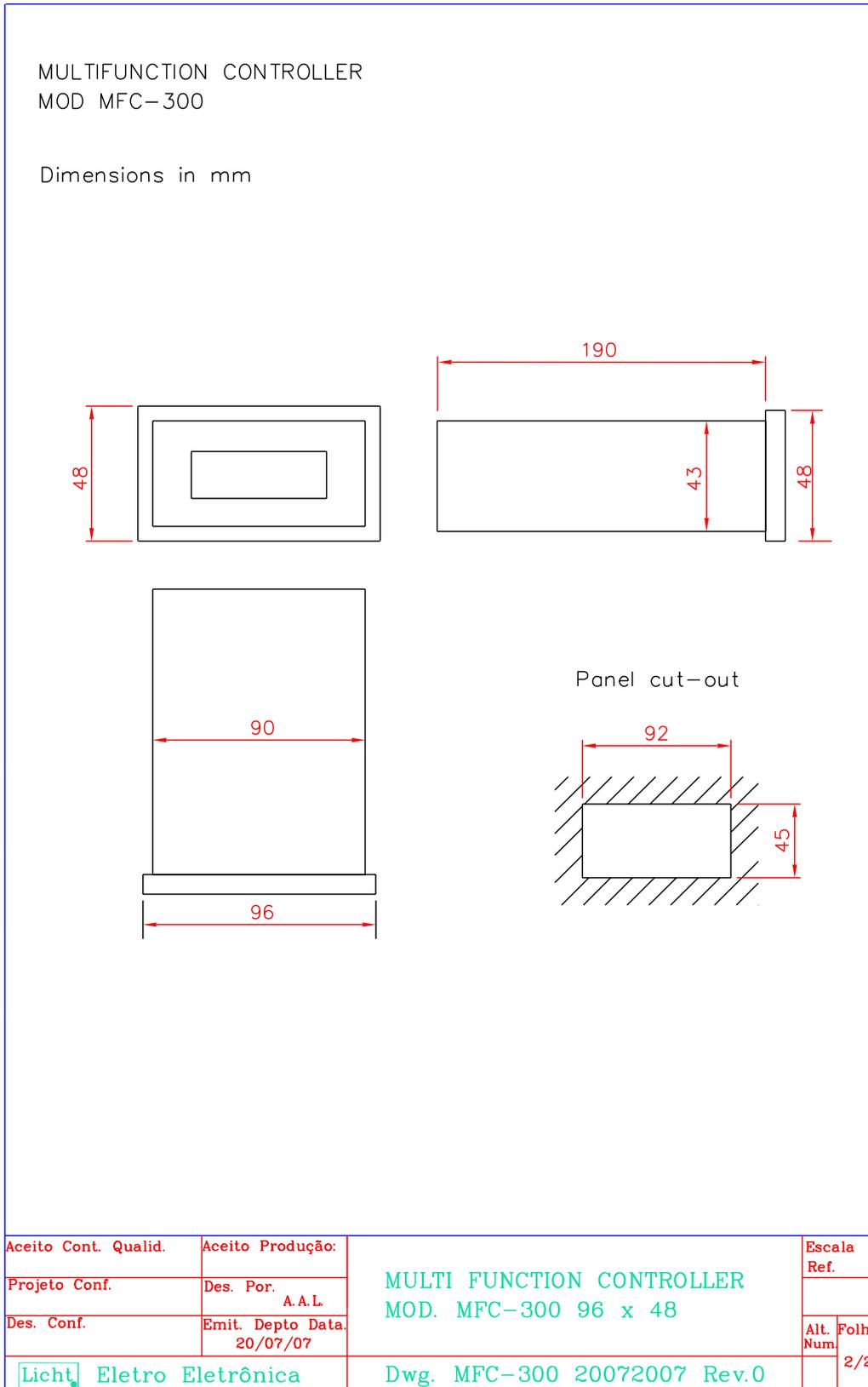


**Figure 7.2** MFC-300/T Controller (with weatherproof enclosure)

## A Specifications

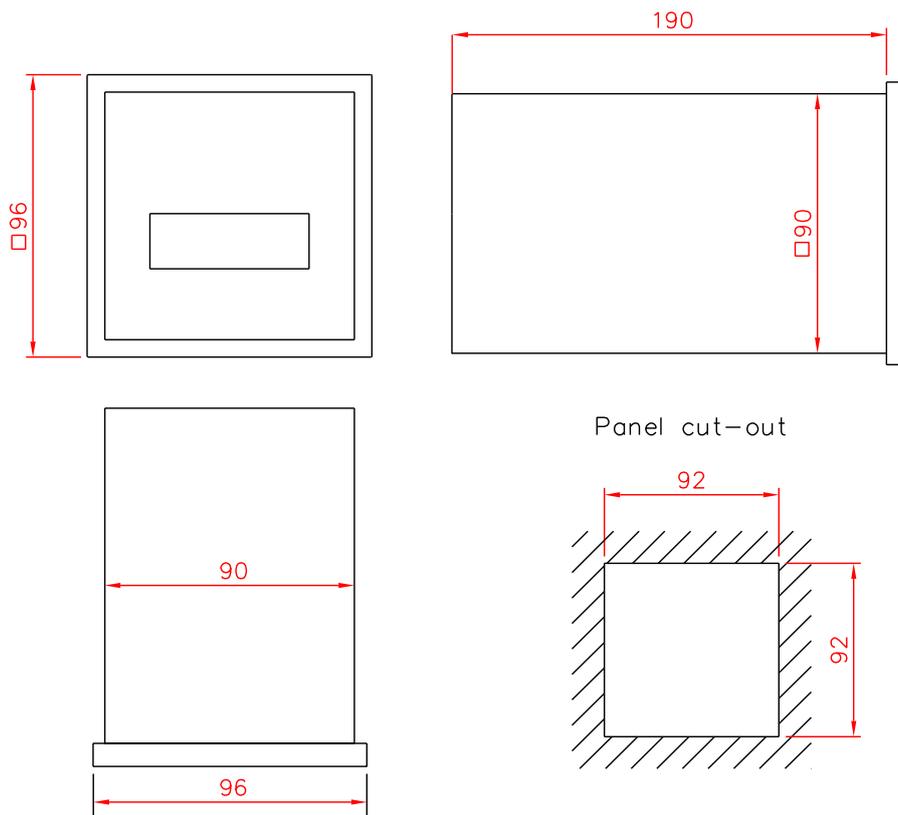
<b>Power Supply</b>	Isolated, 80-260 Vac/Vdc.									
<b>Power Consumption</b>	8 W									
<b>Operating Temperature</b>	-20 to 70 °C (LCD display) -40 to 85 °C (VFD display)									
<b>Enclosure Rating</b>	IP20 (96x48 and 96x96 formats) IP65 (with weatherproof enclosure)									
<b>Mounting Options</b>	Panel-mounted									
<b>Dimensions</b>	96 x 96 x 190 mm or 96 x 48 x 190 mm									
<b>Weight</b>	550 g									
<b>DC Inputs</b>	Types: RTD, current loop, voltage Error/Non-linearity: 0.2% + 0.1% / 10 °C									
<b>AC Inputs</b>	Scale: 0-5 A Error/Non-linearity: 0.5% + 0.1% / 10 °C									
<b>Current Outputs</b>	Scales: 0-1, 0-5, 0-10, 0-20, 4-20 mA Error/Non-linearity: 0.2% + 0.1% / 10 °C									
<b>Galvanic Isolation (60 Hz, 1 min.)</b>	<hr/> <table><tr><td>AC Inputs</td><td>2.0</td><td>kV</td></tr><tr><td>Outputs</td><td>2.0</td><td>kV</td></tr><tr><td>Communication</td><td>2.0</td><td>kV</td></tr></table> <hr/>	AC Inputs	2.0	kV	Outputs	2.0	kV	Communication	2.0	kV
AC Inputs	2.0	kV								
Outputs	2.0	kV								
Communication	2.0	kV								
<b>Communication</b>	RS-485 - MODBUS RTU or DNP3 9600, 19200, 38400, 57600, 115200 bps 8N1, 8E1, 8O1, 8N2									
<b>Displays</b>	2 lines, 16 characters each (5 mm). LCD with backlight or VFD.									
<b>Relays</b>	10 A @ 250 Vac, 0.5 A @ 125 Vdc Galvanic Isolation: 2.0 kV, 60 Hz, 1 min.									

## B Housing diagrams

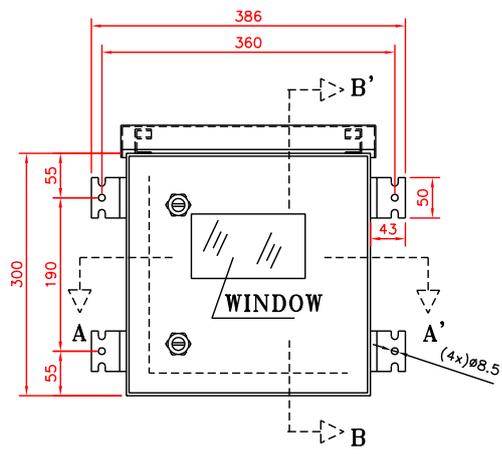


MULTIFUNCTION CONTROLLER  
MOD MFC-300

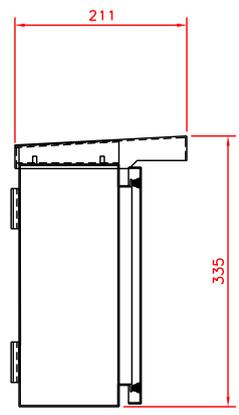
Dimensions in mm



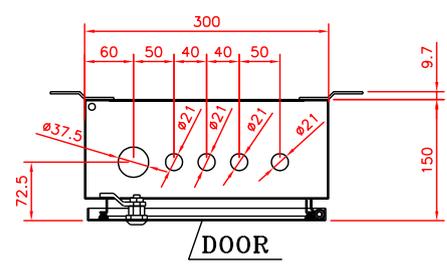
Aceito Cont. Qualid.	Aceito Produção:	MULTI FUNCTION CONTROLLER MOD. MFC-300 96 x 96	Escala Ref.	
Projeto Conf.	Des. Por. A.A.L.			
Des. Conf.	Emit. Depto Data. 20/07/07		Alt. Num	Folha
Licht Eletro Eletrônica		Dwg. MFC-300 20072007 Rev.0		1/2



Frontal View



B-B' Cross-section

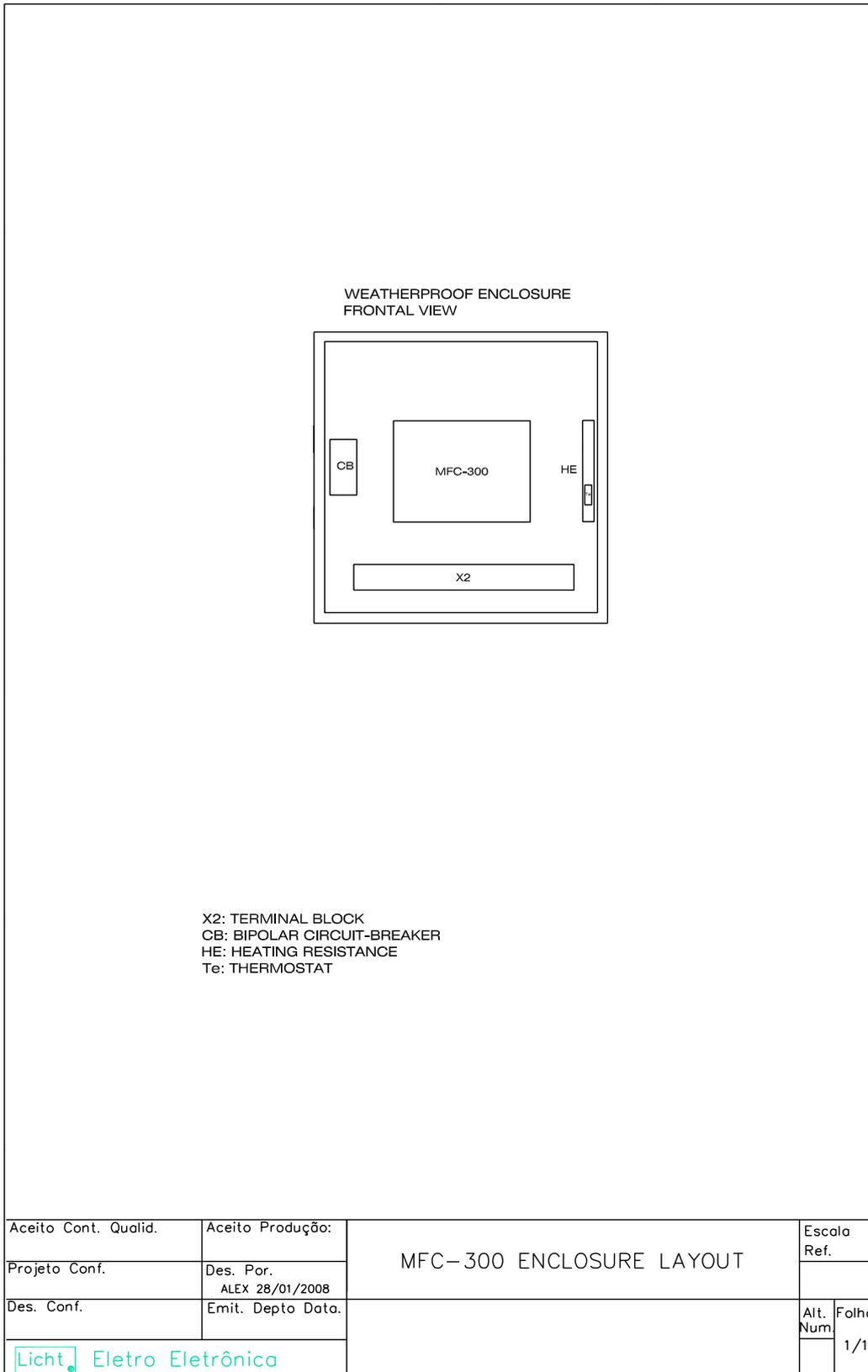


A-A' Cross-section

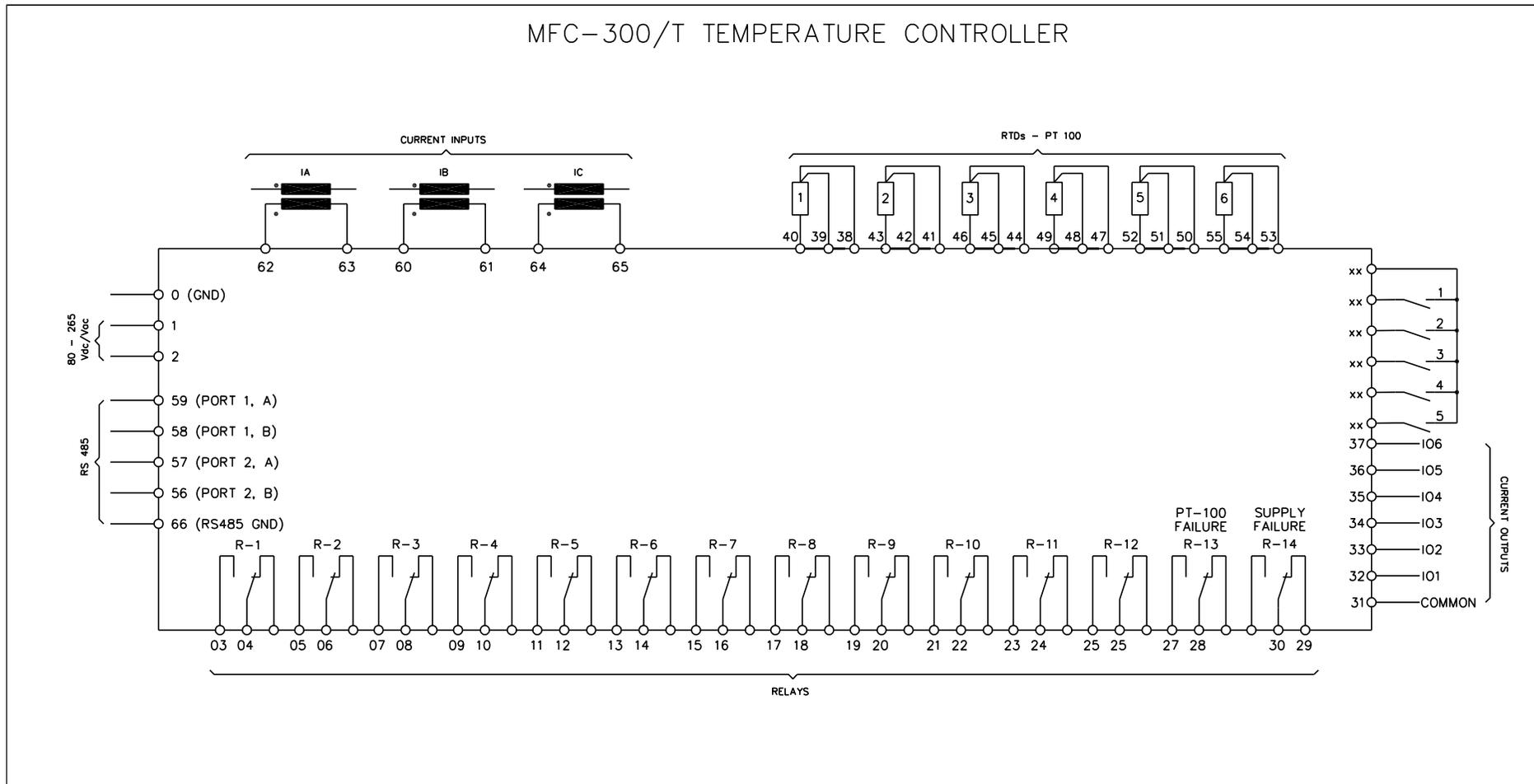
Material: Steel Plate  
Thickness: 1,25 mm  
Paint: 40 micron epoxy power coating, RAL 7032 color  
Rating: IP 65

Aceito Cont. Qualid.	Aceito Produção:	MFC-300 HOUSING WEATHERPROOF ENCLOSURE	Escala S/ ESC.	
Projeto Conf.	Des. Por. ALEX 28/01/08		Alt. Num	Folha 1/1
Des. Conf.	Emit. Depto Data.			
Licht Eletro Eletrônica				

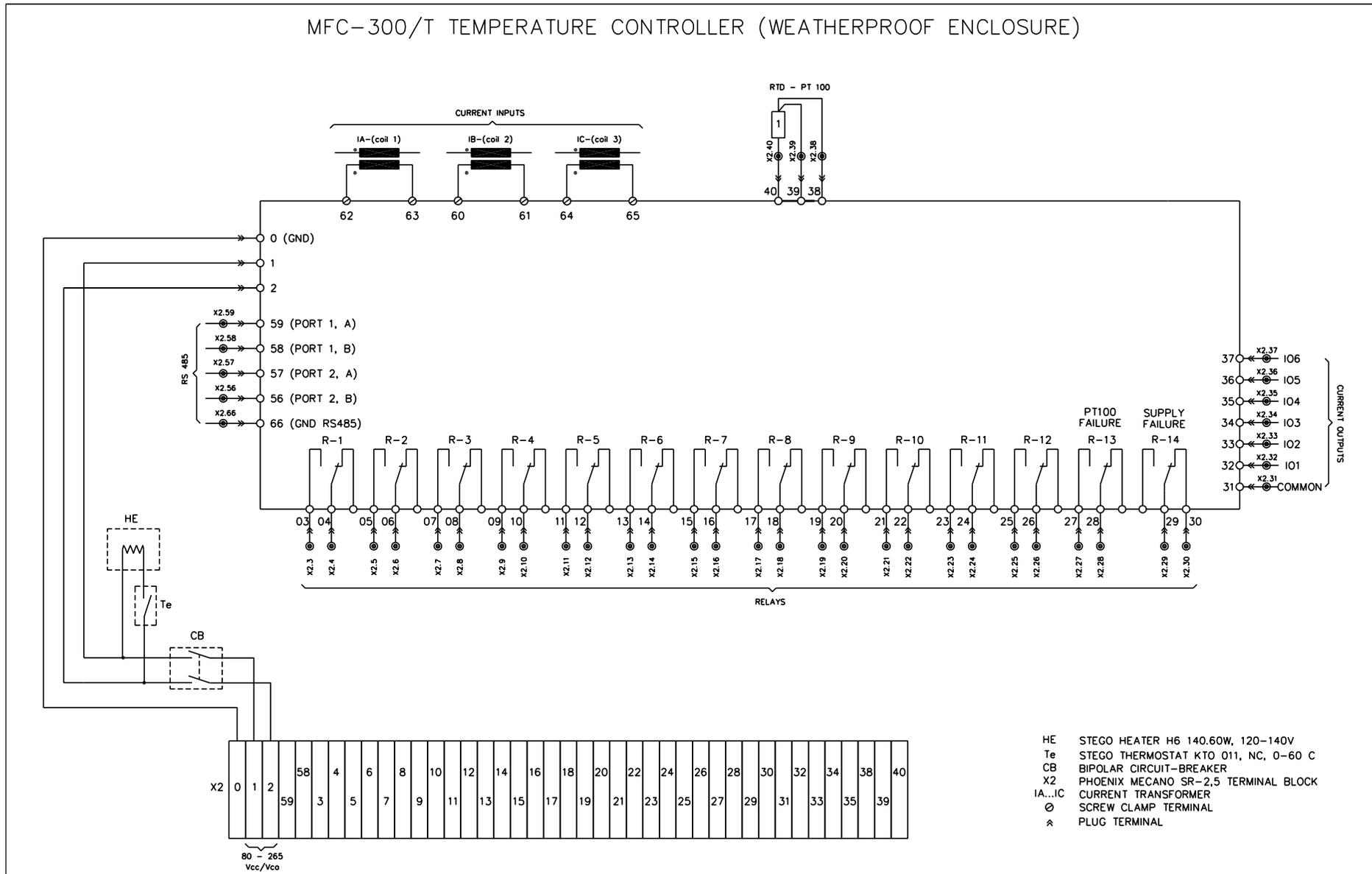
## C Weatherproof enclosure layout



## D Connection diagrams



### MFC-300/T TEMPERATURE CONTROLLER (WEATHERPROOF ENCLOSURE)



## 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 RTDs, 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 conductor, 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  $\Omega$  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.

## E Configuration sheet

Parameter	Possible Settings	Selected Setting
Relay	1 to 12	
Function	Alarm, Cooling	
Set Point (°C)	0 to 255 °C	
Hysteresis (°C)	1 to 255 °C	
Set Point (I%)	0 to 150 %	
Hysteresis (I%)	1 to 255 %	
Timeout	0.1 to 25.5 min.	
Associated Channel	Oil, Winding 1-3, RTD 2-6	
Forced Activation	Normal, Activated	
Activation Logic	Normal, Inverted	

Parameter	Possible Settings	Selected Setting
Indication Type	Temperature, Measured Unit, Percentage	
$\Delta T1$	0-99 °C	
$\Delta T2$	0-99 °C	
$\Delta T3$	0-99 °C	
$I_{N1}$	0.0-5.0 A	
$I_{N2}$	0.0-5.0 A	
$I_{N3}$	0.0-5.0 A	
Alternate Activation	Disabled, 9-10 only, 11-12 only, 9-10 and 11-12	
Time Constant	0.0, 3.0-20.0 min.	
m	0.0, 0.5-1.0	
Operating Frequency	60 Hz, 50 Hz	
Daily Cooling (Start)	00:00 to 23:59	
Daily Cooling (Duration)	Disabled, 1 to 999 minutes	
Event Timer	Disabled, 0 to 60 minutes	
Maximum Temperature Difference	1-200 °C	
Output Scale	0-1, 0-5, 0-10, 0-20, 4-20 mA	
$T_{FS}$	0-255 °C	
Baud Rate	9600, 19200, 38400, 57600, 115200	
Format	8N1, 8E1, 8O1, 8N2	
Address	1-247	
Date	01-Jan-2000 to 31-Dec-2099	
Hour	00:00:00-23:59:59	

## F MODBUS registers

The MFC-300 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.

We present below the table of remotely accessible registers.

Register	Description	Values	Multiplier
1-12	Set Point (°C)[1-12]	0 to 255 °C	1
21-32	Hysteresis (°C)[1-12]	0 to 255 °C	1
41-52	Timeout[1-12]	0.1 to 25.5 min.	10
61-72	Associated Channel[1-12]	0: Oil 1-3: Windings 1 to 3 4-8: RTDs 2 to 6	1
81-92	Forced Activation[1-12]	0: disabled 1: enabled	1
101-112	Activation Logic[1-12]	0: disabled 1: inverted	1
121-132	Set Point (I%)[1-12]	0 to 150 %	1
141-152	Hysteresis (I%)[1-12]	1 to 255 %	1
161-172	Associated Function[1-12]	0: alarm 1: cooling	1
201	Indication Type	0: temperature 1: measured unit 2: percentage	1
202-204	$\Delta T$ [1-3]	0 to 99 °C	1
205-207	$I_N$ [1-3]	0.2 to 5.0 A	10
208	Alternate Activation	0: disabled 1: 9-10 only 2: 11-12 only 3: 9-10 and 11-12	1
209	Time Constant ( $\tau$ )	0.0 or 3.0-20.0 min.	10
210	m	0.0 or 0.5-1.0	10
211	Operating Frequency	0: 60 Hz 1: 50 Hz	1
212	Daily Cooling (Start)	0 to 1439 (in minutes from 00:00)	1
213	Daily Cooling (Duration)	0 to 999	1
214	Event Timer	0: disabled 1 to 60 minutes	1

Register	Description	Values	Multiplier
215	Maximum Temperature Difference	1 to 200 °C	1
301	Current Loop - Output Scale	0: 0-1 mA 1: 0-5 mA 2: 0-10 mA 3: 0-20 mA 4: 0-20 mA	1
302	T <sub>FS</sub> (Oil)	0 to 255 °C	1
401	Local Hour	0 to 23	1
402	Local Minute	0 to 59	1
403	Local Second	0 to 59	1
404	Local Day	1 to 31	1
405	Local Month	1 to 12	1
406	Local Year (2000-2099)	0 to 99	1
501-503	Winding[1-3] Temperature	0.0 to 255.0 °C	10
504-506	Winding[1-3] Sampled Current (A)	0.00 to 5.00 A	100
507-509	Winding[1-3] Sampled Current (%)	0.0 to 200.0 %	10
510	RTD1/Oil Temperature	0.0 to 255.0 °C	10
511	RTD1 Resistance	0.0 to 255.0 Ω	10
512	RTD2 Temperature	0.0 to 255.0 °C	10
513	RTD2 Resistance	0.0 to 255.0 Ω	10
514	RTD3 Temperature	0.0 to 255.0 °C	10
515	RTD3 Resistance	0.0 to 255.0 Ω	10
516	RTD4 Temperature	0.0 to 255.0 °C	10
517	RTD4 Resistance	0.0 to 255.0 Ω	10
518	RTD5 Temperature	0.0 to 255.0 °C	10
519	RTD5 Resistance	0.0 to 255.0 Ω	10
520	RTD6 Temperature	0.0 to 255.0 °C	10
521	RTD6 Resistance	0.0 to 255.0 Ω	10
601-612	Relay State[1-12]	0: disabled 1: enabled	1



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