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451-455-461

Range

EUROTHERM

Thyristor units

User Manual

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Manufactured by EUROTHERM AUTOMATION S.A.
ISO 9001 - EN 29001 Certified

Printed in France 12/94 Part No HA 174485 Issue 1

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Logic and Analogue Input Thyristor Units

User Manual

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451-455-461
USER MANUAL

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Chapter 1 INTRODUCTION

The Eurotherm 451-455-461 thyristor unit range offer a vast number of possibilities which, for the most part, meet the requirements of the low and medium power market. The current range is from 15 A to 150 A for voltages of up to 660 V rms.

The range is divided into **two** main groups:

- **Solid state contactors (451 series)**

The thyristor units, driven by a logic signal, operating in ON/OFF mode with firing of the thyristors when the supply voltage changes to zero.

- **Power units (455 and 461 series)**

The thyristor units driven by an analogue signal emit an output signal proportional to the thyristor firing angle and burst firing input signal, or a combination of both signals.

Thyristor unit voltage selection

- Single-phase power supply from 100 to 240 V:
  Nominal voltage of unit 240 V.
- Single-phase power supply from 380 to 415 V:
  Nominal voltage of unit 440 V.
- Three-phase power supply, mounting 3 wires plus neutral:
  Nominal voltage of unit: take into account the voltage between phase and neutral.
- Three-phase power supply, mounting 3 wires (star or delta) or
  6 wires (open delta):
  Nominal voltage of unit: take into account the voltage between phases.

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451 series (models 451 to 454)

Three sorts of isolated logic input are available:

- The **standard** input is suitable for all control signals for solid state contactors, generated by the Eurotherm controllers.
- The **TTL** input, available as an option, allows greater sensitivity, without increasing the current consumption. This input can be driven by a standard TTL logic.
- The "**multi-input**", available as an option, is used when several units must be driven by the same logic signal, and with a minimum current consumption.

The 451 series can be equipped with a partial load failure **detection**.

455 series (models 455 to 458)

The input signal and thyristor firing mode configurations are **set** at order and cannot be changed (soldered bridge configuration).
The 455 series has a "**Slave**" output and an **inhibition** function.

461 series (models 461 to 464)

The input signal and thyristor firing mode configurations are easy to **modify** by the user with configuration mini-switches.

The 461 series has current **limit**, partial load failure **detection, gating** (except on the 461 model), **inhibition** functions and the "**Slave**" output.

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Chapter 2

TECHNICAL SPECIFICATIONS

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Chapter 2 TECHNICAL SPECIFICATIONS

2.1 GENERAL INFORMATION COMMON TO THE 3 SERIES

. Supply voltage : +10 % -15 % of the nominal voltage
. Residual load current in locked status : < 30 mA

Heat dissipation

Each unit dissipates a maximum of 1.3 W per amp issued.
This dissipation induces a rise in the ambient temperature if the units are mounted in cabinets.

It is essential to check that the external ambient temperature of the cabinet does not exceed 50°. Otherwise, provide a fan cooling system.

If this system includes dust removal filters, systematically perform a preventive cleaning operation every 3 or 6 months depending on the degree of pollution.

Operating temperature: 0°C to 50°C with radiator in vertical position
Storage temperature: -10°C to + 70°C.

Unit cooling

The heat dissipation of the thyristors induces an overheating of the heatsink on which they are mounted.
Two types of cooling are provided:

- by convection cooling
- by fan cooling.

7VA CONSUMPTION
30VA CONSUMPTION
} SEE 4-4

- **15 to 75 A** nominal units:
  cooling by **convection** cooling.

- **100 to 150 A** nominal units:
  cooling by **fan** cooling.
  In this case, the unit is equipped with a temperature safety switch which inhibits thyristor firing in the event of overheating.

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2.2 PARTIAL LOAD FAILURE DETECTION

Partial load failure detection exists as an option for the **451** series and comes as standard for the **461** series.

- Partial load failure (PLF) detection **principle**:

comparison of the load current and voltage (451 series) or
of the power supply (461 series)
to detect an increase in impedance.

- Improved 20% discrimination of the current in the load, does not depend on supply voltage variations.

- Setting: with a potentiometer on the front fascia from 10 to 100 % of the unit's nominal current.

- Indication on front fascia with an LED.

- PLF output made via relay switch.

2.3 (OVERALL) DIMENSIONS AND WEIGHT

Table 2.1

Model	Height	Width	Depth	Weight
	mm	mm	mm	kg
451/455/461	247	76	236	3
452/456/462	247	114	236	4
453/457/463	247	152	236	5
454/458/464	280	152	236	5

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2.4 INSTALLATION

Each module is inserted in a pressed steel baseplate.
The baseplate can be mounted:

- on an asymmetrical pair of DIN rails
- or attached on a vertical wall.

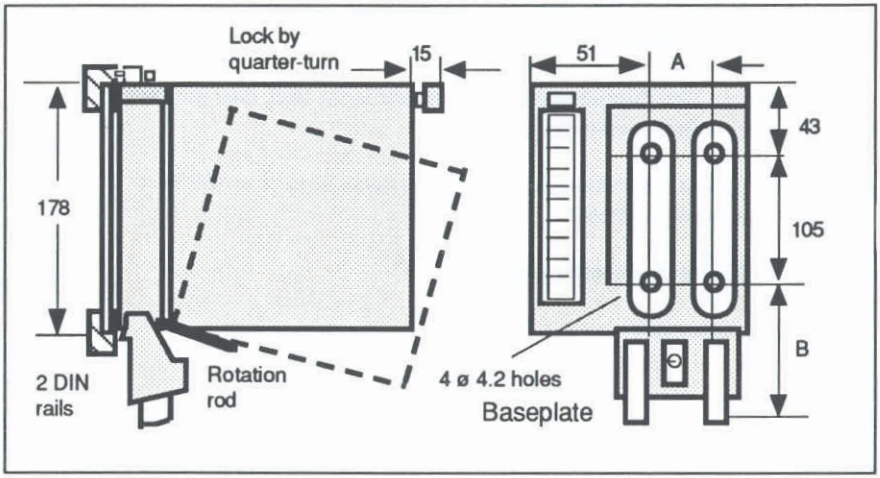


Figure 2.1 Attachment

Table 2.2

Model	Attachment dimensions on a vertical wall (mm)	
	A	B
451, 455, 461	0	149
462, 456, 462	42	149
453, 454, 457	75	149
458, 463, 464	75	178

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For **assembly:**

- tilt the module approximately 20 degrees forwards in relation to the horizontal
- insert the rotation rod in the baseplate recipient (see fig. 2.1)
- raise the module to the horizontal
- turn the lock by a quarter-turn.

The minimum space between 2 modules side by side must be at least 20 mm.

If the modules are mounted on top of each other, it is essential to leave a vertical space of at least 80 mm between 2 modules, in order to guarantee good ventilation.

For installations in fan-cooled cabinets, it is recommended to fit a fan failure detection device.

For **disassembly:**

- unlock the top attachment by a quarter-turn
- tilt the module approximately 20 degrees forwards in relation to the horizontal
- release the module from its baseplate.

Warning

Before disassembling the module, make sure that the heatsink is not hot.

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The external **wiring** is made via the front of the baseplate terminal block, with the module pulled out.

For low currents, the connections are made with screws.

The power cables are attached to the power terminal blocks marked "L" (Phase) and "≷" (Load).

From 125 A, the power cables must be connected using round lugs.

Terminal block parameters

Table 2.3

Terminal blocks		Wire cross-sect. mm²	Tightening torque N.m
Driver		0.5 to 2.5	0.6
Power	15 A to 40 A	6 to 16	1.0
	50 A to 100 A	16 to 35	2.15
	125 and 150 A	35 to 50	4.0

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2.5 INTERNAL HIGH SPEED FUSE REPLACEMENT

The 451 series static contactors and the 455 and 461 series power units (nominal currents from 15 to 125 A) are equipped with **internal** high speed fuses.
They are fitted at the rear of the pull-out module.

For the 150 A nominal current, the high speed fuse and its support are **external** and driven separately from the thyristor unit.

Important

The high speed fuses are only used to protect the thyristors against over-loads of wide amplitudes.

The user's installation must be protected (non-high speed fuses, thermal, magnetic or electromagnetic circuit breaker, suitable isolating switch) and comply with applicable standards.

In the event of **blow-out** of the internal fuse, a **red indicator light** on the front panel of the unit lights up (except for the 150 A nominal unit).

The fuse can be accessed via the rear of the module.

To replace the fuse:

- pull out the module from its baseplate
- unfasten the 2 fuse attachment screws
- fit the suitable fuse (the references of which are given in the table overleaf).

Tightening torque 3.5 N.m.

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Warning

- Do not use fuses other than those given in the table below. Otherwise, we cannot guarantee the protection of the unit against over-currents.
  The guarantee is subject to the use of the high speed fuses in this table.
- For the use of different high speed fuses, consult Eurotherm Automation beforehand.

Table 2.4

Model	Current	Max voltage	References				
				Suppliers			
			Eurotherm	Ferraz	I.R.	Brush	G.E.C
451 455 461	15 A	240 V 500 V	CH 380 163 CH 110 153	Q 76650 D 97063	E 1000.15	15 ET	
	25 A	240 V 500 V	CH 380 253 CH 110 253	R 76651 V 82450	E 1000.25	25 ET	GSG 1000.25
	40 A	500 V	CH 110 044	R 82447	E 1000.40	40 ET	GSG 1000.40
	55 A	500 V	CH 110 753	S 75893	E 1000.75	75 ET	
452 456	55 A	660 V	CH 120 094	A 99958	EE 1000.90	90 EET	
462	75 A	660 V	CH 120 114	B 99959	EE 1000.110	110 EET	GSG1000.110
453 457 463	100 A	660 V	CH 120 154	C 99960	EE 1000.150	150 EET	GSG1000.150
454	125 A	660 V	CH 120 154	C 99960	EE 1000.150	150 EET	GSG1000.150
458 464	150 A	660 V	External fuse: CH 340 025 / H300019 Fuse-holder: CP 171 482 / V98711				

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Chapter 3

451 SERIES
SOLID STATE CONTACTORS

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Chapter 3. 451 SERIES SOLID STATE CONTACTORS

3.1 MAIN FUNCTION PERFORMED

"ON/OFF" thyristor firing as a function of a logic input signal.
Setting of thyristor firing **to zero** voltage.

As a option, partial load **failure** detection.

Application:

Resistive load with low temperature coefficient (low resistance variation).

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3.2 CODING

Model / Current code / Voltage code / Fan power supply / Option / 00

Model	Nominal current	Current code
451	15 A (500 V max)	081
451	25 A (500 V max)	082
451	40 A (500 V max)	083
451	55 A (500 V max)	062
452	55 A (660 V max)	062
452	75 A (660 V max)	113
453	100 A (660 V max)	114
454	125 A (660 V max)	117
454	150 A (660 V max) *	100

Nominal voltage	Voltage code
120 V	10
240 V	13
277 V	32
440 V	28
500 V	29
660 V	30

* The external fuse mounted on a fuse-holder is the subject of a separate order under the reference LA 171760

Fan power supply (for 453 and 454) *	Code
115 V	11
230 V	36
85-115 V and 200-260 V	41
100-130 V and 200-260 V	19
350-450 V and 200-260 V	43
380-500 V and 200-260 V	47
170-230 V and 200-260 V	42
425-575 V and 200-260 V	44
240-320 V and 200-260 V	46

* See page 3-7

Options	Code
TTL logic input	10
"Mult-input" for single control of several units connected in series	24
Partial load failure (PLF) detection. Contact **open** in alarm	37
Partial load failure (PLF) detection. Contact **closed** in alarm	37/83
Unit without baseplate	76
Over-load detection *	68

* Only with PLF option

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3. 3 TERMINAL IDENTIFICATION

Table 3.1

Term. No.	Description
1 2	Relay contact open in alarm status (code 37) or closed in alarm status (code 37/83)
3 4	Not used Not used
5 6	Logic input (+) Logic input (-)
7	Not used
8	PLF detection circuit and fan power supply Neutral or second phase
9 10	Fan power supply 220 V phase Phase other than 220 V
11-16	Not used

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3.4 WIRING DIAGRAM

3.4.1 Power

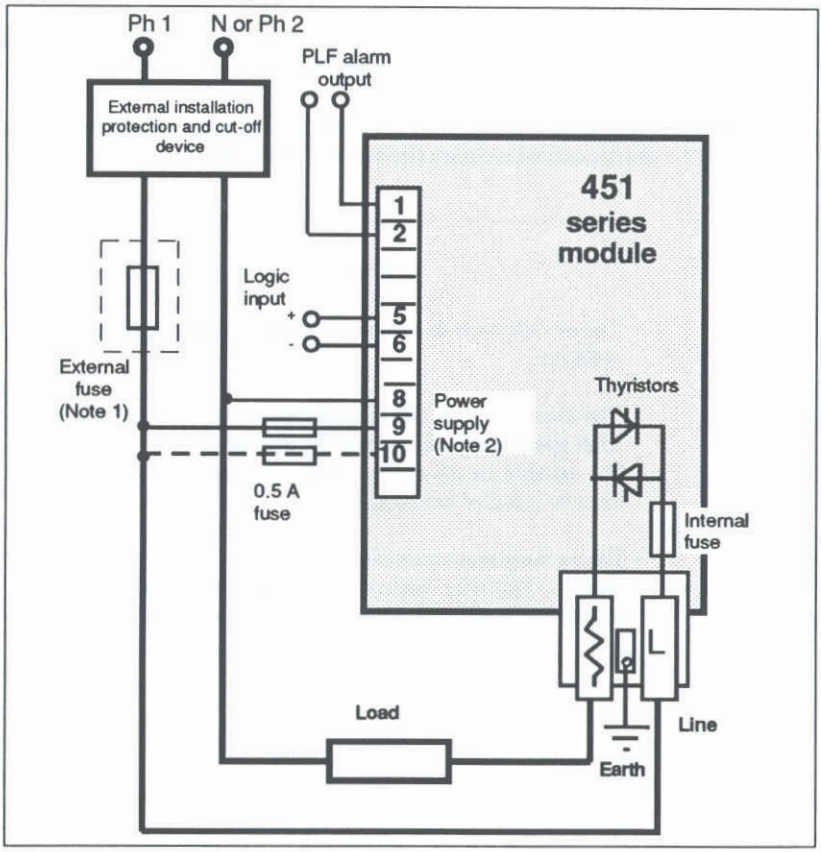


Figure 3.1 Wiring diagram of a 451 series solid state contactor in single-phase configuration.
Control signal from a controller

Note 1. External fuse only for the 150 A nominal current.
Note 2. Power supply between terminals 8 and 9 for the 220 V phase voltage. For other voltages use terminals 8 and 10.

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The load current passes through the power terminals "**L**" (Line) and "$\}$" (Load).

It is essential to observe the identification of these 2 terminals in order to prevent any incorrect operation.

The "**L**" terminal must be linked to the supply **phase**.

The other end of the load is connected either to the neutral or to the second phase, according to the selected configuration (beween phase and neutral or between phases).

This end of the load must also be connected to terminal **8** in the case of the "Partial load failure" or for the fan-cooled modules (models 453 and 454).

Warning

- The module must be connected to earth via the appropriate terminal.
- The internal ($I_{NOM} \leq 125$ A) and external ($I_{NOM} = 150$ A) high speed fuses only protect the thyristors. The suitable cut-off and installation protection device must be installed before power-up.
- Fasten the power connections correctly. Incorrect fastening may cause incorrect operation of the thyristor unit and serious consequences for the installation.

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3.4.2 Power supply

The supply voltage is used to power the fan (**453** and **454** module) and the partial load failure detection circuit (optional).

In the case of the "Partial load failure" **option**, terminal **8** must be connected to the neutral or to the second phase, directly connected to the load (see figure 3.1 and chapter 5).

Ventilated units ($I_{NOM} \geq 100$ A) :

Connect the fan according to the following table.

Table 3.2

Solid state contactor Nominal voltage (V)	Supply Voltage (V) (Note 1)	Fan		
		Power supply	Code	Term.
120	110-115-120	115	11	8 - 10
		100-130	19	8 - 10
	100	85-115	41	8 - 10
240	220-230-240	200-260	36	8 - 9
		200-260	43	8 - 9
	200	170-230	42	8 -1 0
277	277	240-320	46	8 - 10
440	380-400-415	350-450	43	8 - 10
	440	380-500	47	8 - 10
500	480-500	425-575	44	8 - 10
660	550-600-660	(Note 2)		

Note 1. Phase-Neutral voltage (single-phase configuration between phase and neutral or three-phase configuration with neutral) or Phase-Phase voltage (single-phase configuration between phases three-phase in 2 phase control or in open delta).

Note 2. Use an external lowering transformer (secondary voltage 230 V) to power the fans with 230 V (terminals 8 and 9) and a fan code 36, 42 to 44, 46, 47.
In the case of a three-phase configuration without neutral with PLF, use 3 transformers, with terminal 8 of the PLF circuit connected to a phase.

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3.4.3 Partial load failure detection output

For the modules equipped with the partial load failure detection (optional, code 37 or 37 / 83), the alarm is indicated:

- by the luminous **indicator light** mounted on the front fascia
  (lit when a partial load failure is detected)
- by the **contact** of an alarm relay
  (the contact output is available on terminals 1 and 2)

The alarm relay is **exited outside the alarm status** when the unit is on.
The alarm contact (250 mA with 250 Vac or 30 Vdc) may be:

- **open** in alarm status (option **37**)
- **closed** in alarm status (option **37 / 83**).

3.4.4 Logic Input

The logic signal from a temperature controller may be connected to terminals 5 and 6 of the module, while observing the polarities (with terminal 5 the positive terminal and terminal 6 negative).

The logic input is isolated from the power part by an opto-coupler.

Logic input signal

To guarantee thyristor firing:

Minimum level

- Standard input : 10 V with 6 mA
- TTL input : 4 V with 6 mA
- "Multi-input" (low impedance input)
  for single drive of several units connected in series
  2.5 V with 6 mA.
  The current must be limited externally to 25 mA.

Maximum level

25 mA and 28 V.

To guarantee thyristor chop off:

current $< 150\ \mu A$; voltage < 0.6 V.

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3.4.5 "Multi-input"

In the "Multi-input" **option**, the module inputs must be connected in series.

To protect the 451 series module inputs (which are in the **low impedance** "Multi-input" option), two types of connection can be made.

The inputs must be connected either in series with a unit at the standard input, or in series with an equivalent resistor.

- Connection with a **protection resistance R**, which must be placed in series on the control signal

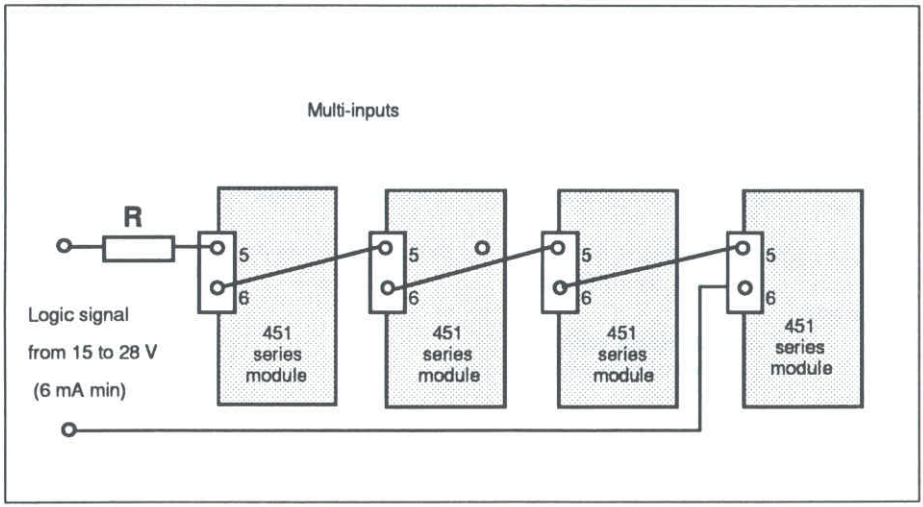


Figure 3.2 Wiring diagram of "Multi-input" option with resistor

The value R of this resistance in kΩ is:

$$R = (V - 2.5\ N) / 6$$

V : control signal voltage

N : number of units placed in series.

R must correspond to $R/N \geq 50\ \Omega$.

The resistor must be able to dissipate 1 W.

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- **In series with a** standard input

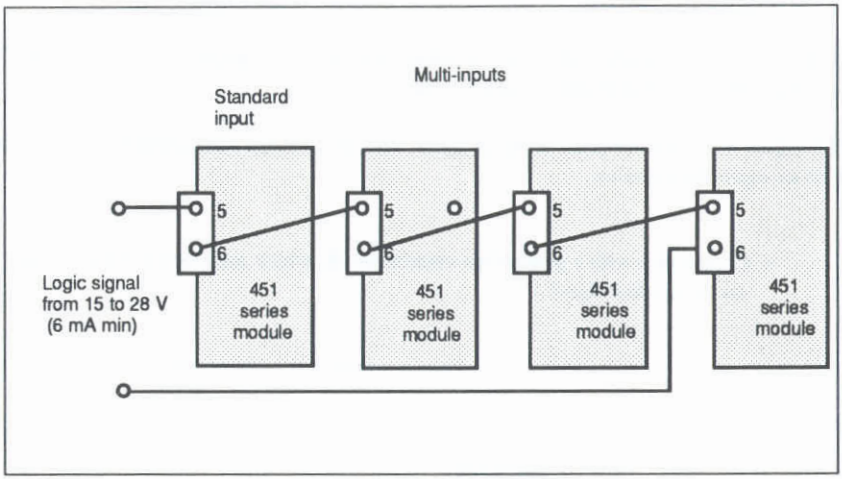


Figure 3.3 Wiring diagram of the "Multi-input" option with a standard input

The maximum number of units which can be driven in series is:

$$N = (V - 7.5) / 2.5$$

where

V : control signal voltage

N : number of units placed in series.

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3.5 PARTIAL LOAD FAILURE DETECTION SETTING (OPTIONAL)

To guarantee correct operation, the load current cannot be less than 10 % of the nominal current of the thyristor unit (if a 100 W bulb is used as a load to monitor to module in a workshop, the fault indicator light on the front fascia will always be lit up).

During commissioning, the following setting must be made:

- First of all, make sure that the module is connected correctly (do not forget to connect terminal 8 to the neutral or to the second phase) and that the thyristors are in permanent firing (the load current should not be less than 10 % in order to be able to make this setting).
- Turn the partial load failure detection setting potentiometer completely (see figure 3.4) clockwise and check that the indicator light does not light up.
- Turn the potentiometer slowly clockwise until the indicator light on the front fascia lights up.
- Turn the potentiometer slowly anti-clockwise until the indicator light has just switched off.

The potentiometer set in this way gives the maximum level of sensitivity in the partial load failure detection.

The button on the front fascia, (marked "**Test**", see figure 3.4) which simulates a current drop of 10 % in the load, is used to check the operation of the partial load failure circuit without having to disconnect the load.
This button must set the module to alarm status if the setting is correct.

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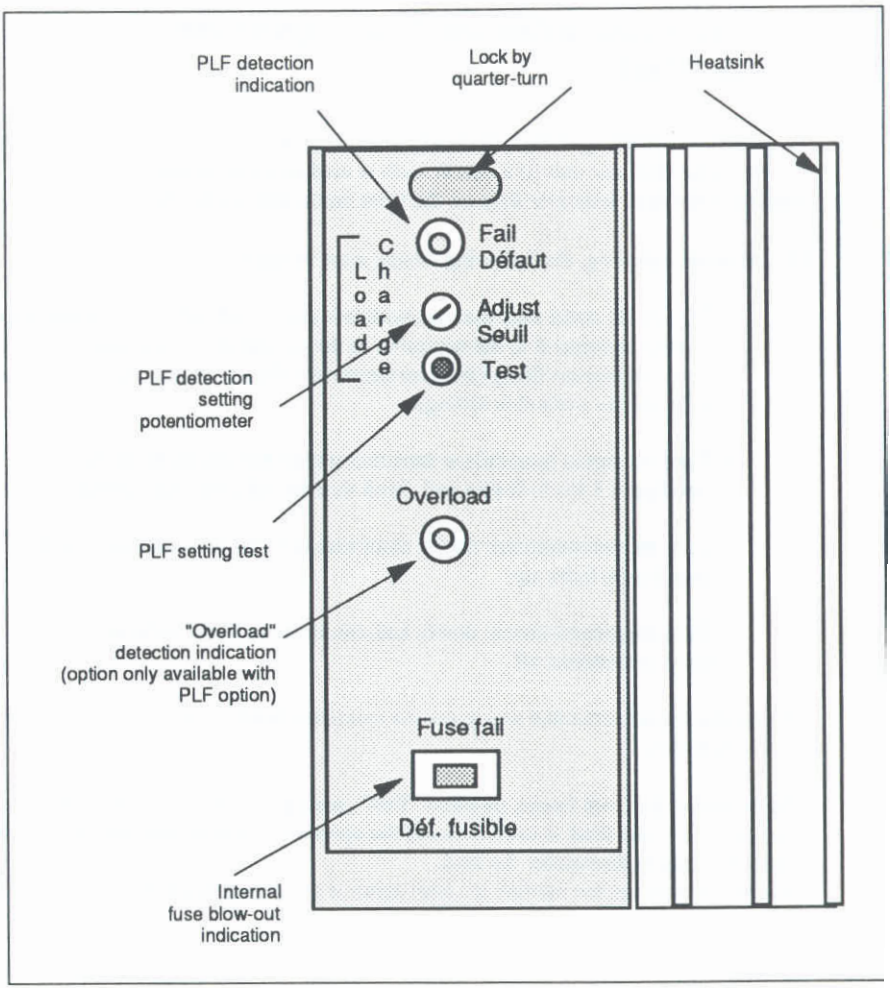


Figure 3.4 Front fascia of a 451 series module

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Chapter 4

455-461 SERIES POWER UNITS

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Chapter 4. 455 AND 461 SERIES POWER UNITS

4.1 MAIN FUNCTION PERFORMED

- Electrical power monitoring as a function of an analogue input signal.
- Thyristor firing mode:
  - thyristor phase angle
  - slow cycle (cycle time 10 s at 50% power) and fast cycle (cycle time 800 ms at 50% power)
  - (fast and slow) cycle with soft start in thyristor phase angle
  - (fast and slow) cycle with soft start and end in thyristor phase angle.
- Application:
  - loads with high temperature coefficient
  - transformer primary circuits
  - inductors.

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4.2 TECHNICAL CHARACTERISTICS

The 455 and 461 series units contain an internal feedback loop.

The **square of the rms load voltage** represents the dissipated power for a purely resistive load, the value of which is constant with the working temperature variation.

The 455 and 461 series are equipped with compensation of the supply variations of -15% to +10% of the nominal voltage.

The unit output (load power) is proportional to the setpoint according to the figure below.

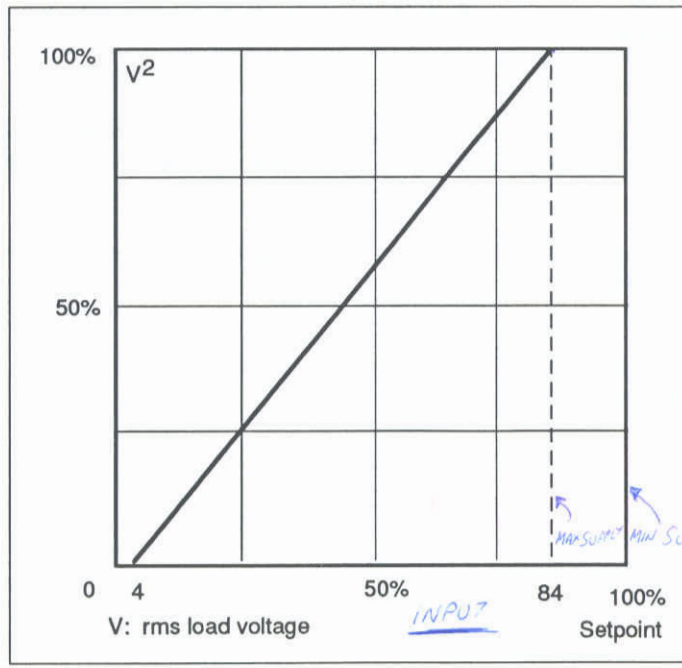


Figure 4.1 Unit output as a function of the setpoint

For a constant resistive load, this feedback is used to maintain the output power constant despite the supply voltage variations, measured using the power supply.

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The following table shows the stabilization of the output power on a constant resistance as a function of the supply variations;

Table 4.1

Power supplied (%)	Supply voltage variation range (%)	Power feedback with reference to the maximum power (%)
100	0 to 10	± 1
95	- 2 to 10	± 1.5
90	- 4.5 to 10	± 1.5
85	- 7 to 10	± 1.5
80	- 10 to 10	± 2
75	-13 to 10	± 2
Less than 71	-15 to 10	± 2

If the power supply falls **below 70%** of its nominal value, the unit automatically switches to **inhibition** (removal of the power drive for a drop in power greater than 30%) of the nominal value.

It is revalidated **automatically** if the voltage returns to a value greater than or equal to 85% of the nominal value.

Operating temperature: 0°C to 50°C with heatsink in vertical position
Storage temperature: -10°C to + 70°C.

Unit consumption:
- non-fan-cooled: 7 VA
- fan-cooled : 30 VA

Residual load current in blocked status : < 30 mA

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In the 455 and 461 series, the thyristors are fired by a trigger **pulse train** of a maximum of **5 ms**.

To reduce the cost price of the electronics, it is possible, in most single-phase applications, to send trigger pulses every 10 ms so that the thyristors are polarized directly (anode positive in relation to cathode) or inversely (anode negative). Each thyristor will only fire when its voltage is positive; when it is negative, the anti-parallel thyristor fires.

In certain applications, trigger pulses on the inversely polarized thyristor may lead to operating problems: firing instability, fuse blow-out.

It is therefore essential to eliminate the trigger pulses when the thyristor is inversely polarized: this function is performed by the **gating** circuit available in the standard version of models 456 to 458 and 462 to 464.

This selective locking of the trigger pulses is essential for configurations in which several units are distributed between the phases of a three-phase supply with an electrical coupling by the load which causes a voltage **phase shift**.

For example:

- monitoring of heating electrodes (in the transformer secondary circuit) immersed in the same glass bath
- load in star with neutral, with the central point of the star connected to the neutral of the supply by a wire of a non-negligible resistance in relation to that of the load.

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4.3 CODING

4.3.1 General

The unit coding can be performed with a **full code** (all the coding fields given below) or with a **simplified code (461 series only)** without the specification of the drive signal or of the thyristor firing mode.

With a **simplified code,** the 461 series units are delivered with:

- the Input signal configured at 4-20 mA
- the "Phase angle" thyristor firing mode
- the frequency 50 Hz
- the position of the ramp potentiometer or of the delay at triggering, at a maximum.

The **455** series has the following functions:

- the output for "Slave" module drive (10 Vdc; 10 mA)
- the gating circuit (from the 456 model)
- inhibition.

The **461** series has the following functions:

- current limit.
- partial load failure detection, alarm relay contact open in alarm status (as an option, the partial load failure is indicated by the contact closed in alarm status)
- the output for "Slave" module drive (10 Vdc; 10 mA)
- the gating circuit (from the 462 model)
- inhibition.

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4.3.2 455 series. Coding

Model / Current / Voltage / Power / Control / Firing / Option / 00
code code supply signal mode

Model	Nominal current	Current code
455	15 A (500 V max)	081
455	25 A (500 V max)	082
455	40 A (500 V max)	083
455	55 A (500 V max)	062
456	55 A (660 V max)	062
456	75 A (660 V max)	113
457	100 A (660 V max)	114
458	125 A (660 V max)	117
458	150 A (660 V max)	100

Nominal voltage	Code
120 V	10
240 V	13
277 V	32
440 V	28
500 V	29
660 V	30

Control signal	Code
0-5 V	008
1-5 V	068
0-10 V	060
0-5 mA	069
0-10 mA	071
0-20 mA	072
4-20 mA	073

Bi-voltage power supply: 200-260 V and voltage below	Code
100-130 V	19
85-115 V	41
170-230 V	42
350-450 V	43
425-575 V	44
240-320 V	46
380-500 V	47

Option	Code
Unit without baseplate	76

Firing mode	Code
Fast cycle	001
Slow cycle	050
Single cycle	160
Phase angle	002
Fast cycle with soft start	055
Slow cycle with soft start	056
Fast cycle with soft start and end	SDF
Slow cycle with soft start and end	SDS

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4.3.2 461 series. Coding

Model / Current code	/ Voltage code	/ Power supply	/ Control signal	/ Firing mode	/ Option	/ 00

Model	Nominal current	Current code
461	15 A (500 V max)	081
461	25 A (500 V max)	082
461	40 A (500 V max)	083
461	55 A (500 V max)	062
462	55 A (660 V max)	062
462	75 A (660 V max)	113
463	100 A (660 V max)	114
464	125 A (660 V max)	117
464	150 A (660 V max)	100

Nominal voltage	Code
120 V	10
240 V	13
277 V	32
440 V	28
500 V	29
660 V	30

Control signal	Code
0-5 V	008
1-5 V	068
0-10 V	060
0-5 mA	069
0-10 mA	071
0-20 mA	072
4-20 mA	073

Bi-voltage power supply: 200-260 V and voltage below	Code
100-130 V	19
85-115 V	41
170-230 V	42
350-450 V	43
425-576 V	44
240-320 V	46
380-500 V	47

Options	Code
Contact closed in alarm status (Partial load failure: PLF)	83
Unit without baseplate	76

Firing mode	Code
Fast cycle	001
Slow cycle	050
Single cycle	180
Phase angle	002
Fast cycle with soft start	055
Slow cycle with soft start	056
Fast cycle with soft start and end	SDF
Slow cycle with soft start and end	SDS

baseplate	76

soft start and end	SDS

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4.4 TERMINAL IDENTIFICATION

Table 4.2

Terminal no.	Description	
	455 series	461 series
1	Not connected	"Partial load failure" alarm ouput
2	Not connected	"Partial load failure" alarm output
3	Not connected	Current image *
4	Manual input	Manual input
5	External signal input	External signal input
6	0 V	0 V
7	Not connected	Not connected
8	Neutral or second phase	Neutral or second phase
9	Phase (220 V)	Phase (220 V)
10	Phase (other than 220 V)	Phase (other than 220 V)
11	Not connected	Not connected
12	+ 10 V	+ 10 V
13	"Slave" output	"Slave" output
14	Not connected	Current limit input
15	Voltage image *	Voltage image *
16	Inhibition	Inhibition

* 0-5 V signals rectified in double wave

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4.5 WIRING DIAGRAM

4.5.1 Power

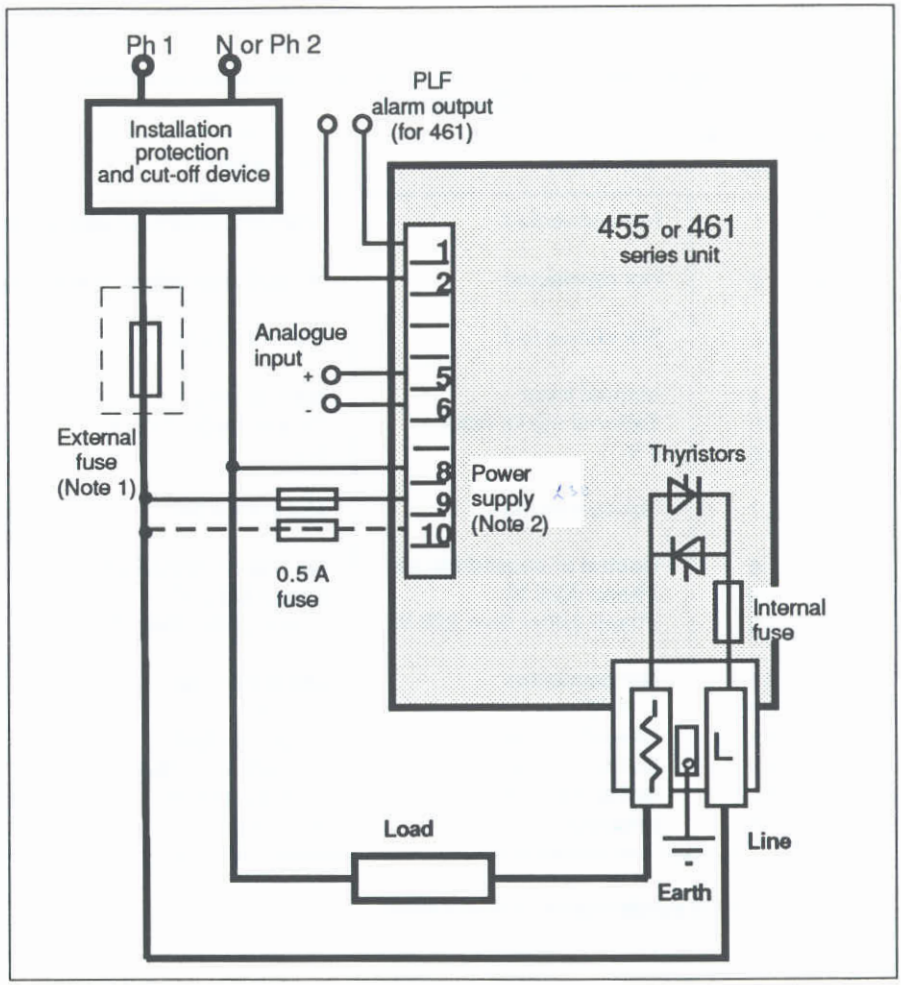


Figure 4.2 Wiring diagram of a thyristor unit in single-phase configuration. Control signal from a controller

Note 1. External high speed fuse only for the 150 A nominal current.
Note 2. Power supply between terminals 8 and 9 for the 220 V phase voltage. For other voltages, use terminals 8 and 10.

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The load current passes through the power terminals "**L**" (Line) and "≷" (Load).

It is essential to observe the identification of these 2 terminals in order to prevent any incorrect operation.

The "**L**" terminal must be connected to the supply **phase**.

The other end of the load is connected either to the neutral or to the second phase, depending on the selected configuration (between phase and neutral or between phases).

Warning

- The unit must be connected to earth by a suitable terminal.
- The internal ($I_{NOM} \leq 125$ A) and external ($I_{NOM} = 150$ A) high speed fuses only protect the thyristors.
  The suitable cut-off and external installation protection device must be installed before power-up.
- Fasten the power connectors correctly.
  Incorrect fastening can induce incorrect operation of the thyristor unit and serious consequences for the installation.

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4.5.2 Control (General)

Figure 4.3 shows the wiring diagram of the control and electronic power supply. Terminal **14** (current limit) is only used for the **461** series.

The analogue control input can be in voltage or in current.
The "**Auto**" position corresponds to the remote control or a controller, for example. The "**Manual**" position corresponds to the control by a potentiometer connected between terminal 12 (+10 V) and terminal 6 (0 V) or to a 0-10 V external voltage.

If the external current limit (by external setting potentiometer or by voltage) is not used, it is essential to connect terminal 12 to terminal 14 directly (as indicated as a dotted line in figure 4-3).

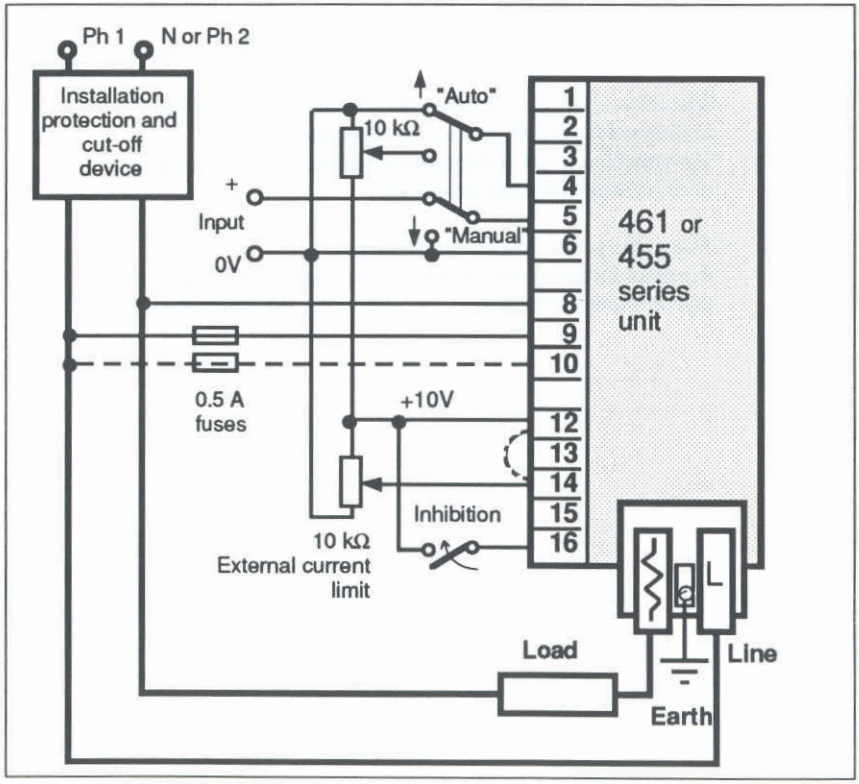


Figure 4.3 Drive wiring diagram
For the 455 series, the "External limit" function is not available

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4.5.3 Power supply

The wiring diagram of the voltage between terminals 8 and 9 (220 V) or 8 and 10 (voltage other than 220 V) provides the power supply:

- of the electronic drive (see fig. 4.3)
- of the fan (for fan-cooled units)
- of the partial load failure detection circuit (for the 461 series).

Terminal 8 is the neutral or the reference phase, while terminal 9 is only used when the electronic control is powered with 200 - 260 V.

Terminals 8 and 10 are used for the voltages other than the 200-260 V range (110 or 400 V, for example).

This voltage is specified in the unit code.

Warning

- The phases arriving on terminals 8, 9 or 8, 10 must be the same as those which are present on the unit power terminals, especially when several units are distributed between several phases of a three-phase supply.
- The drive power must be switched on after or at the same time as the power.
- The drive power must be switched off before or at the same time as the power.

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4.5.4 Control signal

The unit control can be performed by an external analogue signal or manually (by a potentiometer, see fig.4.3, page 4-12).

External analogue signal (from a controller or another signal source)

The connection is made between terminals 5 and 6 (where terminal 5 is the positive polarity and terminal 6 is the reference 0 V).

Warning
For the **461** series units, check that the configuration of the mini-switches accessible on the front fascia corresponds to the required input signal and firing mode.
Configuration marked on the label on the side of the device.

The inputs of several units can be connected in **parallel** or in **series.**

All the thyristor units must be of the same type. Similarly, the inputs must be configured for the same signal.

Parallel wiring diagram.

The input impedance per unit is 50 kΩ.
The current required for each unit is 0.2 mA.

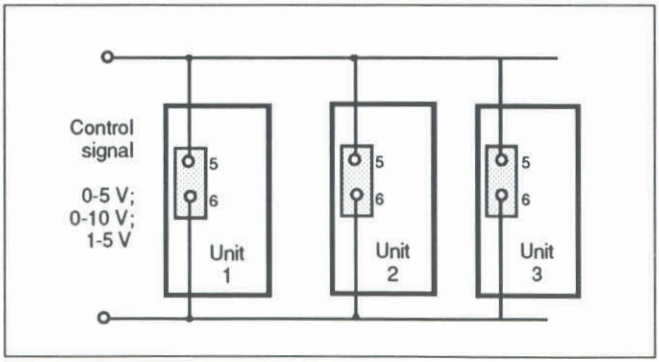


Figure 4.4,a Parallel inputs

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Serial wiring diagram

For a 0-10 mA input, the input impedance of each unit is 1 kΩ.
The 10 V voltage is required by the unit at 10 mA.

For the 0-20 mA and 4-20 mA inputs, the impedance of an input is 250 Ω.
The voltage of each input is 5 V to 20 mA.

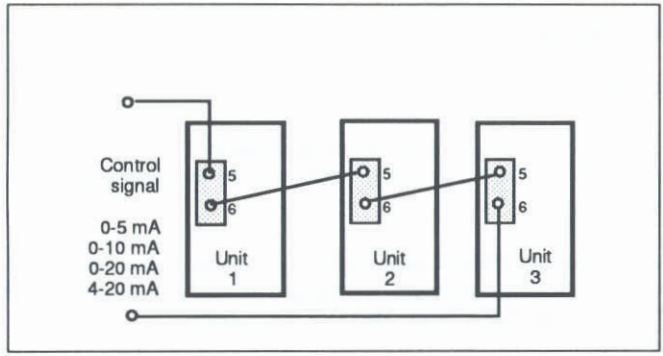


Figure 4.4,b Serial inputs

Manual drive.

An external potentiometer can be connected between terminals 6 (0 V) and 12 (10 V) and the mid-point at terminal 4 (see fig. 4.2, page 4-8).
Use a potentiometer of 5 to 10 kΩ.

The user can choose the input type (Analogue signal from a controller or other signal source or Manual drive using an external potentiometer) by the switching shown in figure 4.3.
The "Auto" position (inverter or relay contacts) corresponds to an external drive and the "Manual" position corresponds to a manual drive.

The "Manual" input range depends on the "Auto" input configuration (see "Configuration" section).

Warning

If the input signal was not disconnected from terminal 5, the 2 signals would be added.

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4.5.5 Current limits (461 series)

As indicated in the "Technical characteristics" section, the 455 and 461 series contain an internal feedback of **V^2**.

The 461 offers two additional functions for each load current measurement:

- a **linear** current limit and
- a **threshold** current limit.

These two limits are **independent**.

Linear current limit

This is, in fact, a feedback of the square of the rms load current **I^2**.
The units **automatically choose** the feedback which provides the best control from the two feedbacks **V^2** and **I^2**.

Load with **low** temperature coefficient: little variation in resistance as a function of temperature (iron alloys, nickel, chromium, aluminium, Inconel etc) feedback in **V^2**.
For this type of load, use the "Burst firing" thyristor firing mode.

Load with **high** temperature coefficient: significant variation in resistance as a function of temperature (molybdenum, molybdenum bisilicide, tungsten, platinum, etc.)

- **I^2** feedback at cold start
- followed by automatic change of feedback type to hot **V^2**, enabling optimal temperature control and feedback at all temperatures.

In this case, use the phase angle thyristor firing mode.

With the linear current limit, the "**Load current / Input signal**" equivalence can be adjusted using the potentiometer marked "**I limit / Limit I**" on the front fascia.

Warning

This setting must always be made at **maximum** setpoint.

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Threshold current limit

This function is used to **limit the load current to a desired value**, independent of the input signal and the linear current limit.

The "Threshold current limit" input (terminal 14) can be controlled:

- by an external setting potentiometer (connected between terminal 12 and terminal 6, with the slide contact powering terminal 14)
- by an external 0-10 V DC voltage (0 V at terminal 6, "+" at terminal 14).

When the threshold limit (by potentiometer or by voltage) is not used, terminal 14 must be connected to the 10 V voltage (terminal 12) **directly**. Otherwise, the threshold current limit is set to zero and the unit cannot discharge.

In this case, the current is limited to 110% of the unit's nominal current.

To adjust the current limit, see page 4.21.

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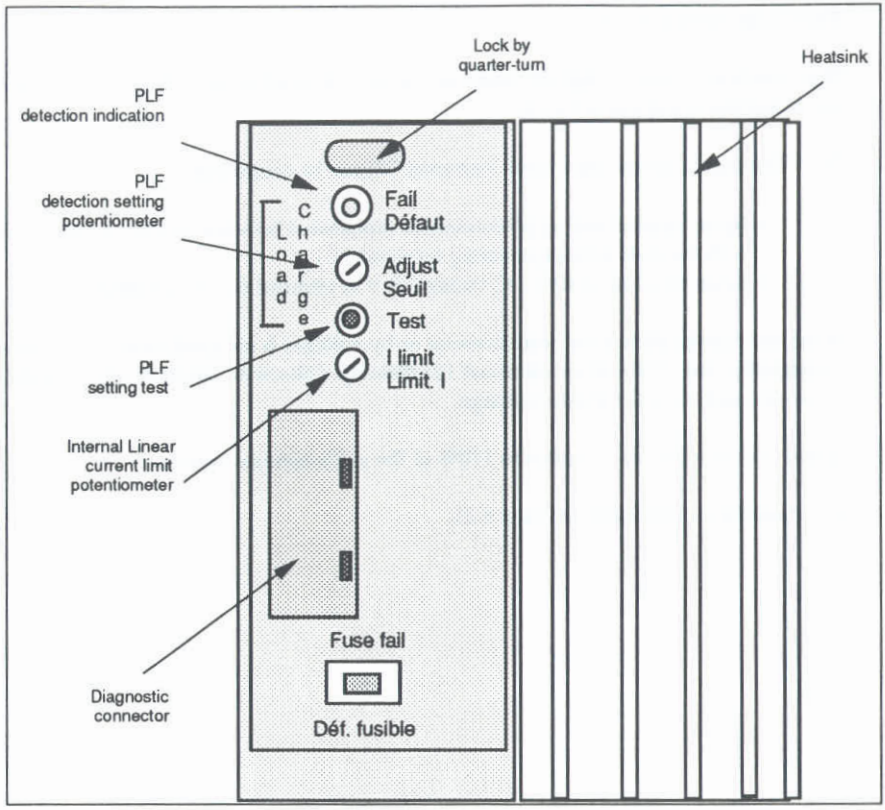


Figure 4.5 Front fascia of a 461 series unit

4.5.6 Inhibition

Inhibition signifies that thyristor firing is not authorized irrespective of the input signal. The inhibition input is available between terminal 16 and terminal 6 (0 V).

Inhibition is effective when a DC voltage between 4 V and 32 V is set on terminal 16 in relation to terminal 6 (see fig. 4.3, page 4-12).

To ensure that the inhibition is not active, terminal 16 must not be connected or a DC voltage between - 2 V and 1 V must be set.

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4.5.7 Partial load failure detection circuit output (461 series)

On 461 series units, equipped with a partial load failure detection in their standard version, the alarm is indicated:

- by an **indicator light** mounted on the front fascia (lit when a partial load failure is detected)
- by the **contact** of an alarm relay (contact output is available on terminals 1 and 2)

The alarm relay is exited outside the alarm status when the unit power is on.

The alarm contact (cut-off power 0.25 A ; 250 Vac or 30 Vdc) is **open** in alarm status or in the event of a supply failure.
As an option (code 83), this contact is closed in alarm status.

This output is suitable to drive a EUROTHERM, type 603 alarm unit.

4.5.8 Load current image output (461 series)

The "Load current image" output is available between terminals 3 and 6 (0 V) on 461 series units. It can be used for tests or for an external measurement (rms value using 443 converter).

The double wave rectified output signal is directly proportional to the load current (mean 5 V for the nominal unit current of the thyristors in full firing).

4.5.9 Load voltage image output

The "Load voltage image" output is available between terminals 15 and 6 (0 V).
It is a double wave rectified signal (mean 4.3 V) representing the load voltage in full firing, produced from the **power supply**.

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4.5.10 "Slave" output

The logic signal (10 Vdc ; 10 mA) available between terminals 13 and 6 (0 V) is used to **drive** static contactors.

The capacity of this output is characterized by the number of "Slaves" as follows:

- one 451 series contactor, standard input, or
- four 451 series contactors, parallel TTL inputs, or
- four 451 series contactors, serial "Multi-inputs".

Note

The following low level inputs / outputs:

- control signal
- load current image output
- load voltage image output
- "Slave" control output
- inhibition

are **isolated** (by transformers) from the supply voltage and the power part.

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4.6 INPUT AND DRIVE MODE CONFIGURATION (461 SERIES)

The 461 series units are equipped with a strip of DIL-switches used to select the required input type, thyristor firing mode and the frequency used (50 or 60 Hz).

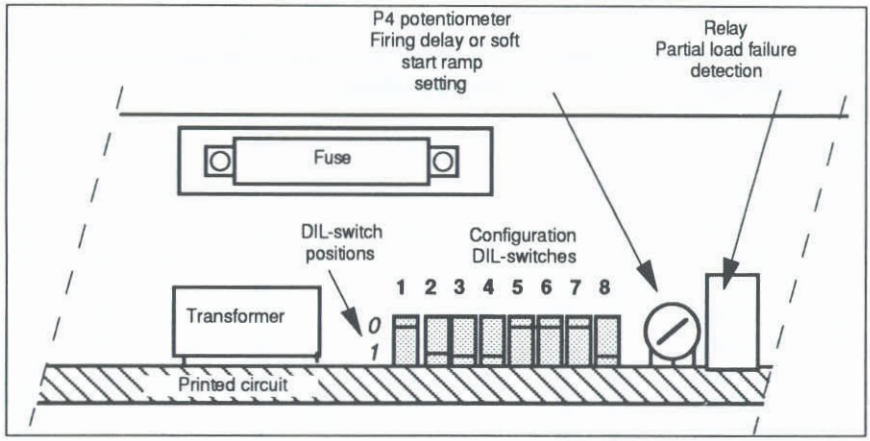


Figure 4.6 Location of DIL-switches and delay time setting potentiometer (461 series, rear view)

The positions of the DIL-switches correspond to:

1 - switch **down**
0 - switch **up**

Without any specification at order, the units are delivered with the following configuration:

- input: 4-20 mA
- firing mode: phase angle
- 50 Hz
- firing delay potentiometer set to maximum.

Note

For the **455** series, the configuration is made with **soldered bridges.**

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4.5.1 Input type

The input signal type is configured with Switches **1** to **4**.

In tables 4.3 to 4.6, **1** indicates the lowered switch position.

- **External input (external signal)**

Table 4.3

Automatic input signal	DIL-switch position			
	1	2	3	4
0-5 V	0	0	0	0
0-10 V	1	0	0	0
1-5 V	0	1	0	0
0-5 mA	0	0	1	0
0-10 mA	1	0	1	0
1-5 mA	0	1	1	0
0-20 mA	0	0	1	1
4-20 mA	0	1	1	1

- **Manual input** (external potentiometer)

The manual input range depends on the automatic input configuration.

Table 4.4

Manual input signal	DIL-switch position	
	1	2
0-5 V	0	0
0-10 V	1	0
1.25 V - 6.25 V	0	1
1.25 V - 11.25 V	1	1

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4.6.2 Thyristor firing mode

The thyristor firing modes available for the power units can be configured with **DIL-switches 5 to 7 (461 series)** or **soldered bridges 5 to 7 (455 series) and** with two **jumpers J1** and **J2** fitted on the board.

Table 4.5

Thyristor firing mode	Position				
	DIL-switches			Jumpers	
	5	6	7	J1	J2
Phase angle	0	0	0	-	-
Single cycle	1	0	0	-	-
Fast cycle	1	1	0	0	-
Slow cycle	1	1	0	1	-
Fast cycle with soft start	1	1	1	0	1
Slow cycle with soft start	1	1	1	1	1
Fast cycle with soft start and end	1	1	1	0	0
Slow cycle with soft start and end	1	1	1	1	0

4.6.3 Frequency

The frequency used is configured with DIL-switch 8 (461 series) or with soldered bridge 8 (455 series).

Table 4.6

Frequency	Position of DIL-switch 8
50 Hz	1
60 Hz	0

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4.7 461 SERIES SETTINGS

4.7.1 Partial load failure detection

To guarantee correct operation, the load current cannot be less than 10 % of the nominal current of the thyristor unit (if a 100 W bulb is used as a load to monitor to module in a workshop, the fault indicator light on the front fascia will always be lit up).

During commissioning, the following setting must be made:

- First of all, make sure that the module is connected correctly and that the thyristors are in permanent firing (the load current should not be less than 10 % in order to be able to make this setting).
- Turn the partial load failure detection setting potentiometer completely (see figure 4.5) anti-clockwise and check that the indicator light does not light up.
- Turn the potentiometer slowly clockwise until the indicator light on the front fascia lights up.
- Turn the potentiometer slowly anti-clockwise until the indicator light has just switched off.

The potentiometer set in this way gives the maximum level of sensitivity in the partial load failure detection.

The button on the front fascia, (marked "**Test**") which simulates a current drop of 10 % in the load, is used to check the operation of the partial load failure circuit without having to disconnect the load. This button must set the module to alarm status if the setting is correct.

Reminder: for the partial load failure detection, the PLF detection circuit does not use the load voltage but the **supply voltage**.

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4.7.2 Current limit

Linear limit (by potentiometer on the front fascia)

First of all, make sure that the load is connected.

In the event of use of an external potentiometer or an external 0-10 V signal, make sure that the "Threshold current limit" setpoint is set to the maximum.

- Turn the linear current limit potentiometer (indicated on the front fascia "**I limit / Limit I**") completely anti-clockwise (minimum position which corresponds to a minimum current).
- Apply a 0 V signal to the input and connect the supply voltage.
  The rms voltage at the load terminals must be zero.
- Increase the input signal to 100 % (if possible).
  The load voltage must represent approximately 15 % of the supply voltage.
- Gradually turn the current limit potentiometer clockwise and check that the current is increased slowly. Set the potentiometer in order to obtain the maximum admissible current for the load.

Warning

For the current limit setting, only use an ammeter giving the true rms value to prevent risks of errors which may reach 50 %.

For a **three-phase installation**, care must be taken to turn each of the potentiometers gradually in succession in order to retain the balanced currents in each of the phases.

Warning

For a "3 phase plus neutral" configuration, the neutral current for a load with a high temperature coefficient can be 1.7 times greater than the phase currents, limited by the current limit.
Take this into account when designing the installation.

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Threshold current limit. External potentiometer

This limit independent of the drive signal is:
- 110% of the nominal unit current (terminal 14 directly connected to terminal 12),
- or adjustable controlled by an external potentiometer, of approximately 10 kΩ, connected between terminal 12 (+ 10 V) and terminal 6 (0 V); the cursor is connected to terminal 14,
- or adjustable controlled by an external DC voltage (0-10 V); R ≥ 150 kΩ.

The limit of I^2 is linear from 0 to 10 V. At 10 V read on position 5 of the diagnostic unit), the limit acts at approximately 110 % of the nominal current.

For the threshold current limit setting:

- After installing the unit and setting the linear limit (with potentiometer on front fascia), switch on the unit.
- Set the drive to the maximum value and gradually decrease the "Threshold current limit" setpoint until the current starts to decrease.
- Identify the setpoint of the corresponding current limit in diagnostic position 5, and increase it by approximately 10% so that it only acts as a safety device in relation to the linear current limit.

The threshold current limit can be **preset** when a unit of the series is powered but not energized.

The value of the square of the rms load current is proportional to the "Threshold current limit" setpoint observed at diagnostic point 5. Two examples are given in the table below.

Table 4.7

Reading in diagnostic position 5	I_{RMS}^2	I_{RMS}
10 V	100%	100%
5 V	50%	71%

The **simultaneous** use of two limits is possible. For example, it makes it possible to set an absolute current limit with the threshold limit (external potentiometer or external voltage) and adjust the linear setpoint limit with the front fascia.

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4.7.3 Soft start and trigger delay settings

To access the setting potentiometer, the module must be **plugged out** of its baseplate.

The same potentiometer (**P4,** see figure 4.4) is used to make two different settings depending on the selected thyristor firing mode.

• **Start time**

Start (or start and end) time setting for the following thyristor firing modes:

- slow cycle with soft start
- fast cycle with soft start
- slow cycle with soft start and end
- fast cycle with soft start and end.

.
With switches **5, 6** and **7** in position **1** for the 461 series power units (or with soldered bridges 5, 6 and 7 for series 455), P4 sets the duration of the start (or start and end) ramp in phase angle.

The soft start (or start and end) ramp can be adjusted between 0 and 250 ms.
The maximum ramp is obtained with P4 turned completely anti-clockwise.

For transformer primary circuit control with a secondary load with a **low temperature coefficient** (constant resistance with the temperature variation), set this potentiometer to obtain the maximum ramp.

For the control of a load with a **high temperature coefficient** (wide resistance variation as a function of the temperature) **use the** Special 677.

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• **Trigger delay time**

Trigger delay time setting for the thyristor firing modes

- Single cycle
- Burst firing without soft start.

In the single cycle or fast or slow cycle modes, P4 sets the **delay of the first firing** of each burst mode.

This delay can be adjusted between 0 and 90° and only acts on the first wave.

The maximum delay is obtained with P4 set completely to the right in the clockwise direction.

When it leaves the factory, P4 is set as shown in table 4.8.

Table 4.8

Thyristor firing mode	**Position of potentiometer P4**
Fast cycle Slow cycle Single cycle	To minimum (Minimum delay)
Firing angle variation Soft start Non-specified (short code)	To maximum (Maximum ramp)

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Chapter 5

THREE-PHASE WIRING DIAGRAMS

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5.3 "Master-Slave" configuration 5-7

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Chapter 5. THREE-PHASE WIRING DIAGRAMS

Warning

- All the modules must be connected to the earth by a suitable terminal
- The internal high speed fuses only protect the thyristors
- According to the unit operating conditions, the supply parameters and applicable standards, the User must install an external cut-off and installation protection device.

5.1 451 SERIES SOLID STATE CONTACTORS

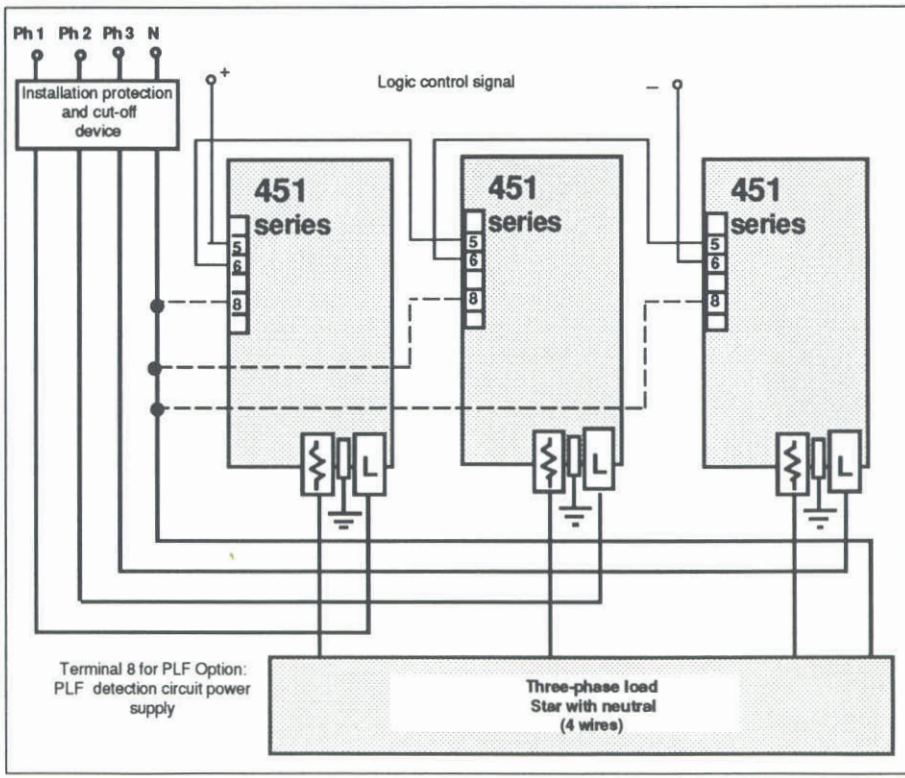


Figure 5.1 Example of 451 series unit three-phase wiring diagram (non-fan-cooled). Load in star with neutral.

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For simple and cost-effective wiring, only two solid state contactors can often be used in a three-phase configuration (if the three-phase load is connected in 3 wires: star without neutral or closed delta).

An example of a wiring diagram of the two fan-cooled units on a 380 V supply between phases is given in figure 5.2 (supply of fan code **43**, bi-voltage 350-450 V and 200-260 V).

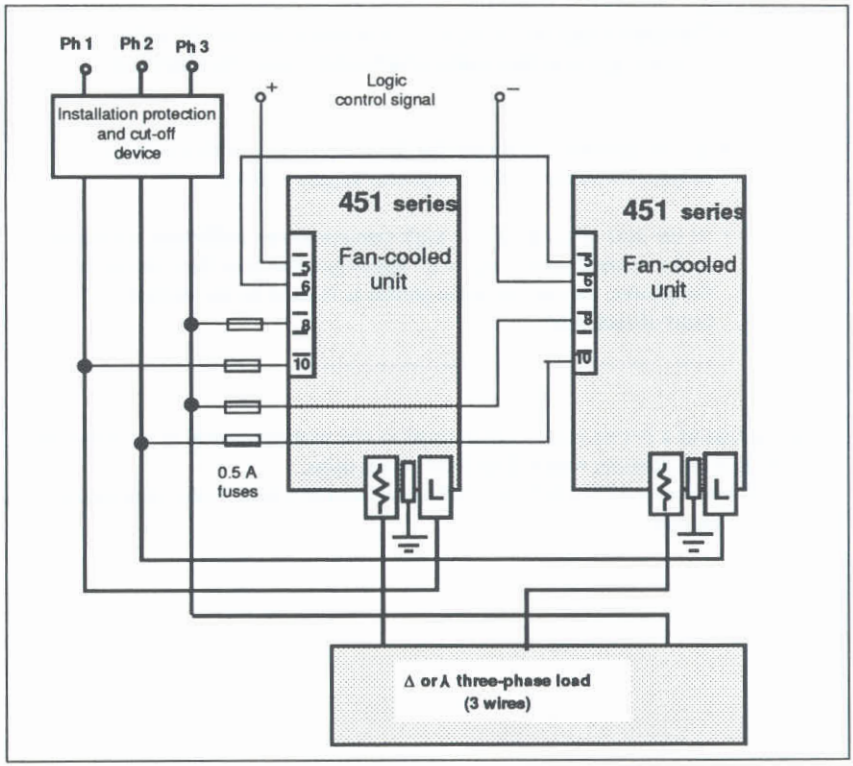


Figure 5.2 Example of 451 three-phase wiring diagram in two phase control
Fan-cooled units.
380 V supply between phases.
Load in star without neutral or in closed delta.

Reminder: for the PLF option, the 451 PLF detection circuit is powered by terminal 8, common to the fan power supply.

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5.2 455 AND 461 SERIES POWER UNITS

The use of 3 power units (455 and 461 series) in three-phase is only possible for a load in a star with neutral or in an open delta.

Warning

- For correct unit operation, the power and power supply wiring diagram, given in the figures which follow, must be **observed**.

- It is fundamental to supply the drive electronics with a voltage **in phase** with the load and thyristor supply voltage.

- In the case of a load with a **high temperature coefficient**, the current in the **neutral** may be up to **1.7 times greater** than the currents in the phases; the current in the phases is limited by the current limit of each unit.

In the case of a 3 wire configuration (load in star without neutral or in closed delta, 3 phase control is not possible with 455 and 461 series units.
In this case, use a 455 or 461 unit ("**Master**") and 451 series solid state contactors ("**Slaves**"), see next section.

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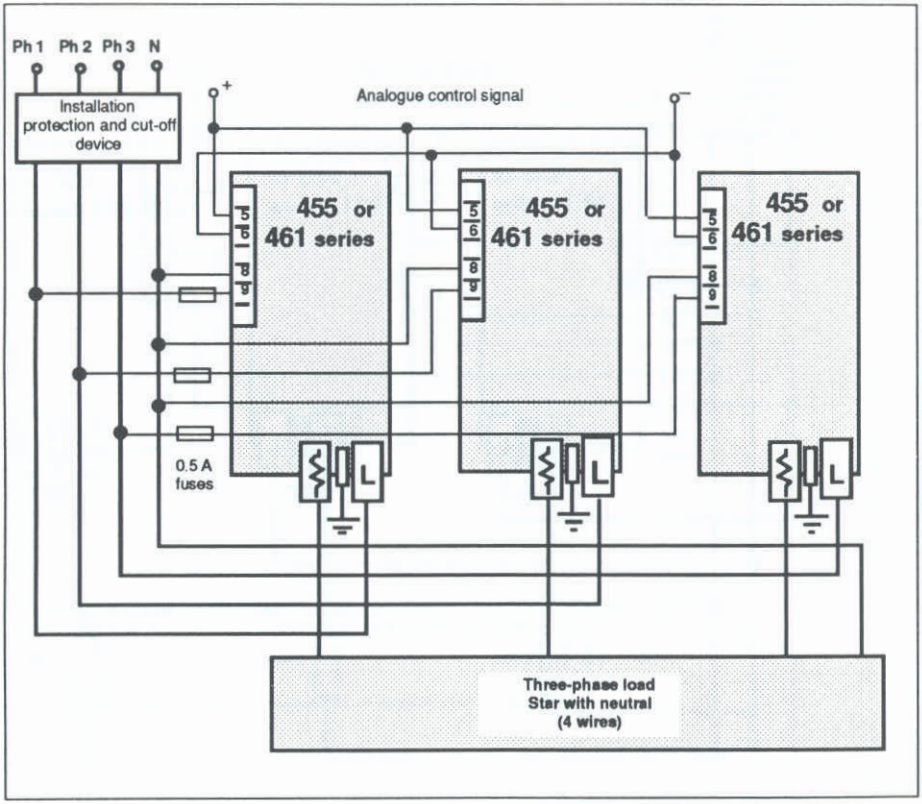


Figure 5.3 Example of three-phase wiring diagram.
380 V supply between phases.
Load in star with Neutral.

Warning

The electronics wiring diagram must be observed (terminal 8 and 9).

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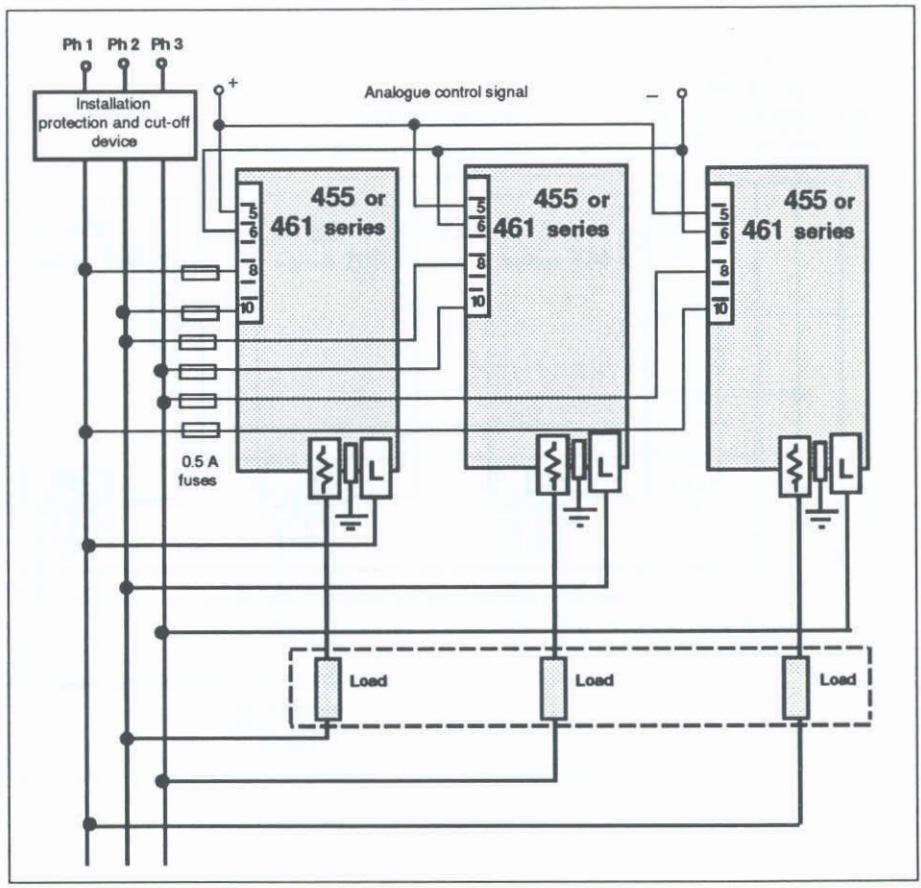


Figure 5.4 Example of three-phase wiring diagram.
Voltage between phases 380 V.
Load in open delta (6 wires).

Warning

The electronics wiring diagram must be observed (terminal 8 and 10).

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5.3 "MASTER-SLAVE" CONFIGURATION

If it is necessary for the firing modes independent of the units to be synchronized, a power unit is used with the analogue control signal ("Master") to control the power on 1 phase and drive one or two solid state contactors ("Slave") which controls the power on one phase ("Two phase control") or on two phases ("Three phase control").

The 455 and 461 series are used as a Master (analogue control signal); the 451 series (logic input) is used as a Slave.

Three phase control

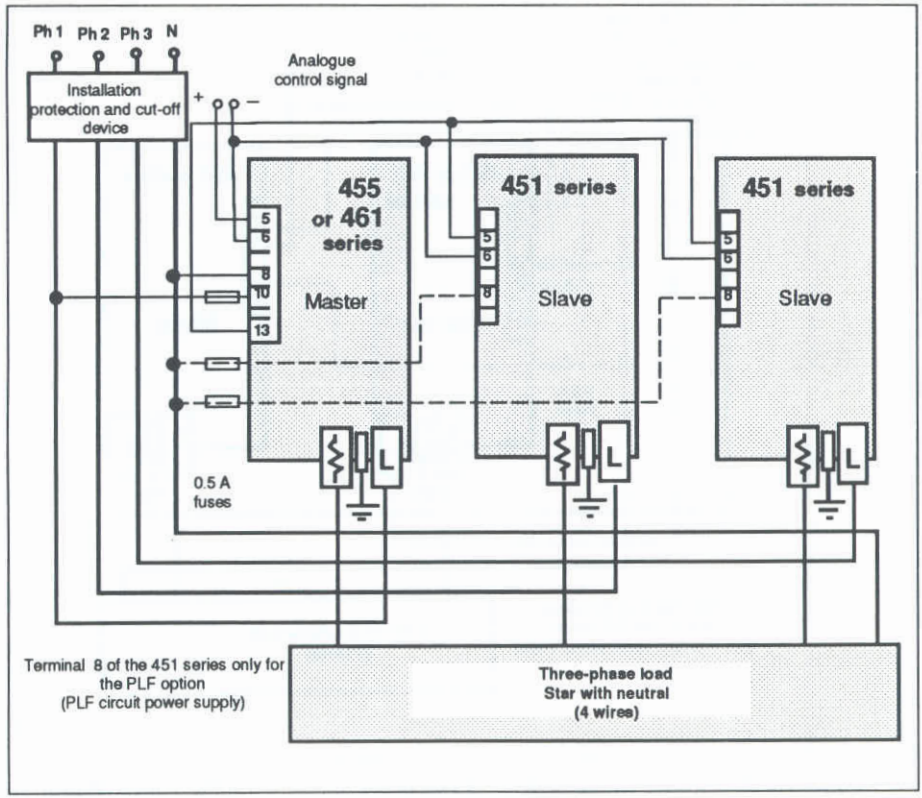


Figure 5.5 Example of wiring diagram in three phase control (Master - Slaves)
380 V voltage between phases.
Configuration in star with neutral on resistive loads with low temperature coefficient.

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Two phase control

In this configuration, a prior recognition of the order of the phases must be performed in order to connect **in the following obligatory order**:

- 451 series (Slave) on phase 1
- 455 or 461 series (Master) on phase 2
- direct line on phase 3.

If the order of the phases is incorrect, the thyristor firing will be incorrect and the load voltage between 2 and 3 phases will have a value slightly greater than the supply voltage (for example, 405 V for a 380 V supply).

Non-fan-cooled units (I_{NOM} = 15 to 75 A) 380 V between phases.

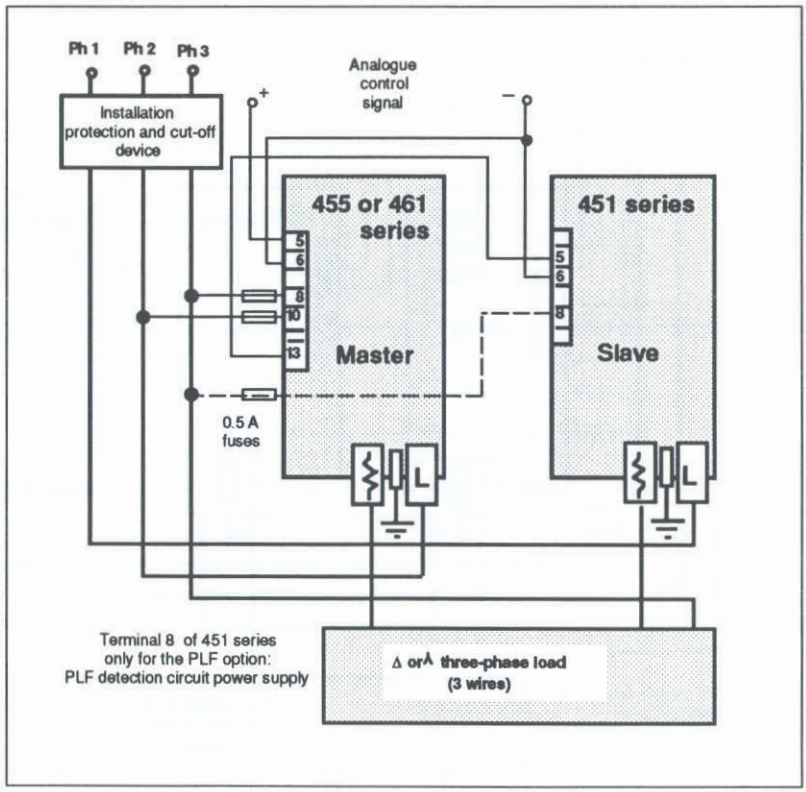


Figure 5.6 Example of wiring diagram in two phase control (Non-fan-cooled Master-Slave).
Voltage between phases 380 V.
Load in star without neutral or in closed delta.

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Fan-cooled units ($I_{NOM} \geq 100$ A). 220 V between phases

For the fan and electronics power supply, use terminal **8** and **9** in the order shown in the figure below.

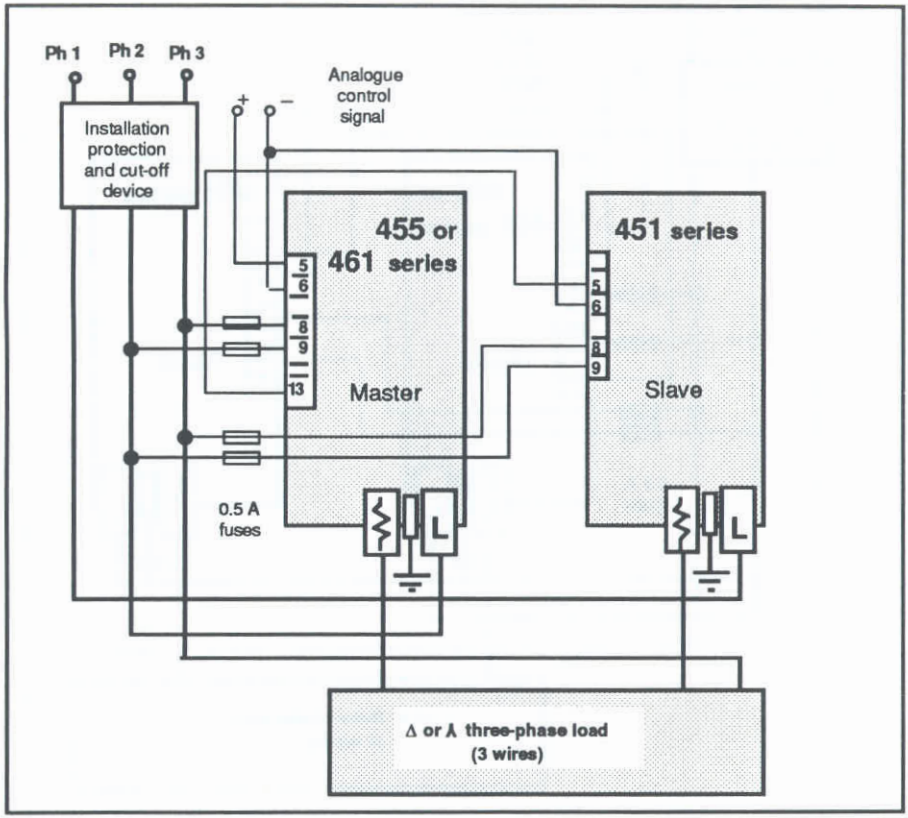


Figure 5.7 Example of wiring diagram in two phase control (Fan-cooled Master-Slave). Voltage between phases 220 V.

Fan supply code:
36 (220 V), 19 (220 V between 8 and 9), or 43 (110 or 380 V between 8 and 10).
Load in star without neutral or in closed delta.

For the use of a 451 series module (Slave) with the PLF option, terminal 8 is also used for the partial load detection circuit power supply.

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Fan-cooled units ($I_{NOM} \geq 100$ A). 380 V voltage between phases

For the fan and electronics power supply, use terminals **8** and **10** in the order shown in the following figure.

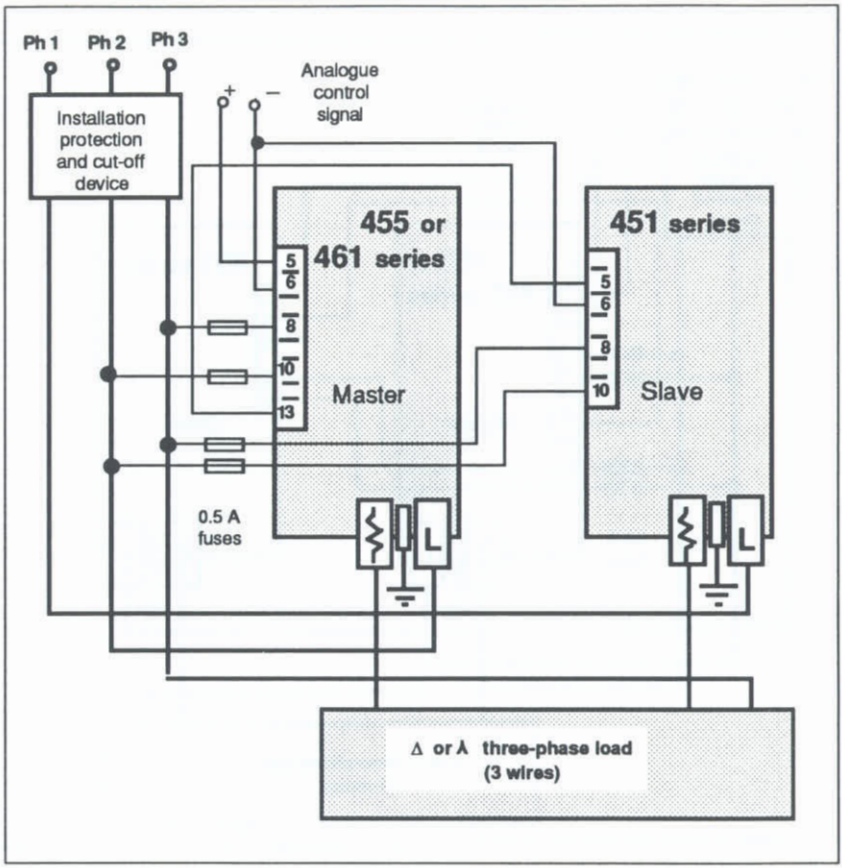


Figure 5.8 Example of wiring diagram in two phase control (Fan-cooled Master-Slave). Voltage between phases 380 V.

Fan supply code:
43 (380V between 8 and 10 or 220V between 8 and 9) or 19 (110V between 8 and 10 or 220V between 8 and 9).

Load in star without neutral or in closed delta.

For the use of a 451 series module (Slave) with the PLF option, terminal 8 is also used for the partial load detection circuit power supply.

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APPENDIX

DIAGNOSTICS
455 AND 461 SERIES UNITS

For easier commissioning and maintenance setting and to diagnose the condition of the unit, it is recommended to use the EUROTHERM type 260 Diagnostic unit which can be connected on the front fascia.

The 20-way connector of the EUROTHERM type 260 unit is used to display the unit parameter values on a digital display.

These signals can also be observed using an oscilloscope.

The tables which follow indicate the description of each position of the EUROTHERM type 260 diagnostic unit and the typical values of the signals measured.

Warning

The values measured
are **mean DC voltages.**

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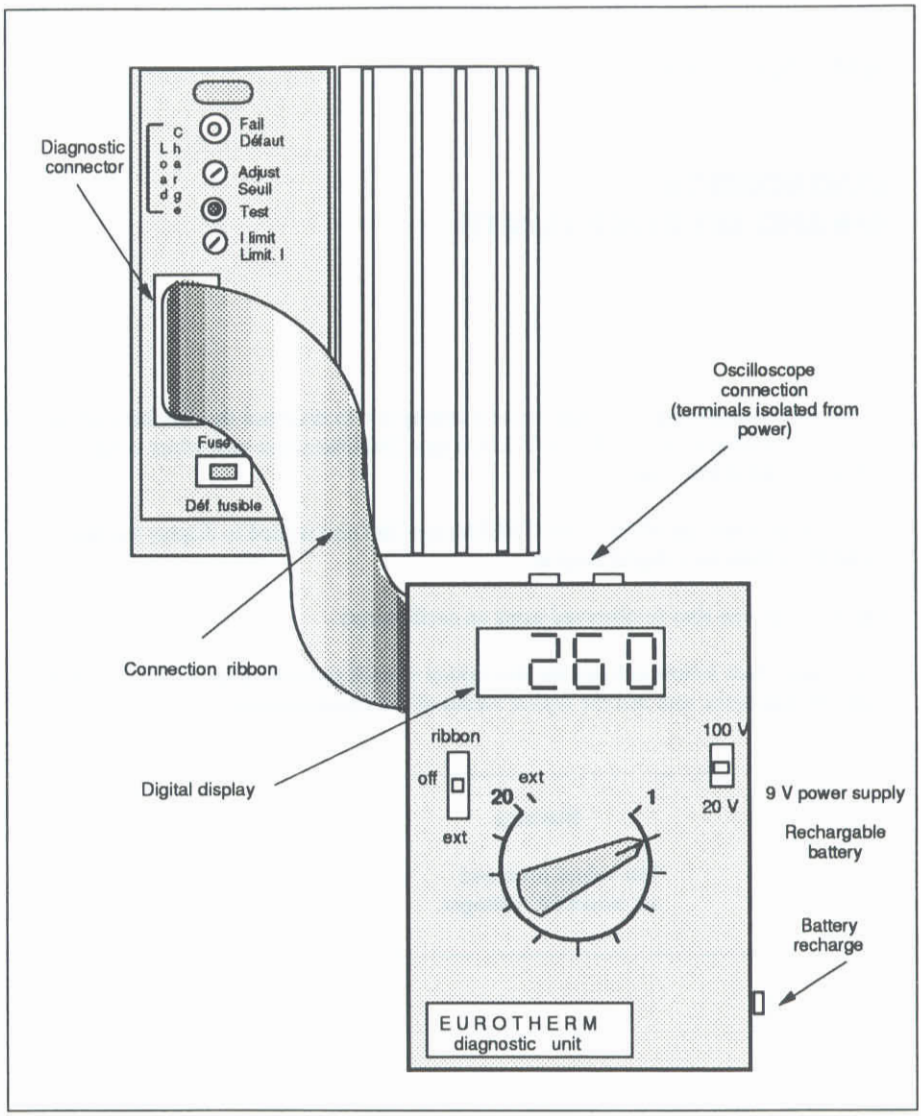


Figure App.1 Wiring diagram of the EUROTHERM type 260 diagnostic unit with a 455 or 461 series unit

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Thyristor firing mode: Phase angle (Θ)

Table App.2

Position	Description	For 0 % Power Θ = 0°	For 50 % Power Θ = 90°	For 100 % Power Θ = 180°
1	Current image (nominal load)*	0 V	2,5 V	5 V
2	Manual input Not used	-	-	-
3	PLF alarm (outside alarm) *	+14 V	- 12.6 V	- 12.6 V
4	External setpoint (Input)	0 V	2.5 V	5 V
5	External current limit (100%)*	app. 0 V	app. 10 V	app. 10 V
6	Current image for PLF *	0 V	- 2.5 V	- 4.6 V
7	Load voltage image	0 V 0 V	2.25 V - 2.5 V	4.1 V - 5 V
8	Amplified setpoint			
9	"Slave" output	0 V	5.4 V	10.2 V
10	Firing request	0 V mean 1V peak	8.4 V	12.7 V 10 V ± 20 mV
11	Reference "+ 10 V"	10 V ± 20 mV	10 V ± 20 mV	
12	-24 V rectified double wave	- 20 V	- 20 V	- 20 V
13	Pulse output	No pulses	Pulses 20 V	Pulses 20 V
14	Power supply " - 15 V"	- 15 V ± 150mV	- 15 V± 150mV	- 15 V± 150mV
15	Oscillator input	0 V	1.2 V 6.4 Vpeak 90° pulses	1.2 V 6.4 Vpeak 90° pulses
16	Power supply "+ 15 V"	+ 15 V ± 150mV	+ 15 V± 150mV	+ 15 V± 150mV
17	Switching pulse to "0" voltage	-10.5 V ±12Vpeak 0.6ms	-10.5 V ±12Vpeak 0.6ms	-10.5 V ±12Vpeak 0.6ms
18	0 V	0 V	0 V	0 V
19	Saw-tooth generator	3.6V 8.4Vpeak 10ms	3.6V 8.4Vpeak 10ms	3.6V 8.4Vpeak 10ms
20	Validation	<- 10 V	<- 10 V	<- 10 V

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Thyristor firing mode:
Fast cycle and Single cycle

Table App.2

Position	Description	For 0 % power	For 50% power	For 100 % power
1	Current image (nominal load)*	0 V	Modulation 0-5 V	5 V
2	Manual input Not used	-	-	-
3	PLF alarm * (outside alarm)	+ 14 V	- 12.6 V	- 12.6 V
4	0-5 V input	0 V	2.5 V	5 V
5	External current limit (100%)*	app. 10 V	app. 10 V	app. 10 V
6	Current image for PLF *	0 V	Modulation 0 - (-4.6 V)	-4,6 V
7	Load voltage image	0 V	Modulation 0 -4.1 V	4,1 V
8	Amplified setpoint	0 V	-2.5 V	- 5 V
9	"Slave" output	0 V	Modulation 0-13.5 V	10.2 Vmean (0-13.5V)
10	Output power	0 V mean 1V peak	6.25 Vmean 12.5V peak	12.5 V
11	Reference "+ 10 V"	10 V ± 20 mV	10 V ± 20 mV	10 V ± 20 mV
12	- 24 V rectified double wave	- 20 V	- 20 V	- 20 V mean
13	Pulse output	No pulses	Pulses 0-26 V	Pulses 0-26 V
14	Power supply " - 15 V"	- 15 V ± 150 mV	- 15 V ± 150 mV	- 15 V ± 150 mV
15	Oscillator input	0 V	6.4 V peak	1.2 V 6.4 Vpeak
16	Power supply " + 15 V"	15 V ± 150 mV	+ 15 V ± 150 mV	15 V ± 150 mV
17	Pulses at "0" voltage	-10.5 V ±12.5 Vpeak 0.6ms	- 10.5 V ±12.5 Vpeak 0.6ms	-10.5 V ±12.5Vpeak 0.6ms
18	0 V	0 V	0 V	0 V
19	Saw-tooth generator	3.6 V (8 V peak)	3.6 V (8 Vpeak 10 ms)	3.6 V (8.4 Vpeak 10 ms)
20	Validation	<- 10 V	<- 10 V	<- 10 V

*** - for the 461 series only**

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