EUROTHERM
DRIVES

5401 Field Controller

Product Manual

Printed in England HA464436 Issue 1

WARRANTY

Eurotherm Drives warrants the goods against defects in design, materials and workmanship for the period of 12 months from the date of delivery on the terms detailed in Eurotherm Drives Standard Conditions of Sale IA058393C.

Eurotherm Drives reserves the right to change the content and product specification without notice.

INTENDED USERS

This manual is to be made available to all persons who are required to configure, install or service the equipment described herein or any other associated operation.

PACKAGING: The packaging is combustible and if disposed of in this manner incorrectly may lead to the generation of toxic fumes which are lethal.

WEIGHT: Consideration should be given to the weight of the product when handling.

REPAIRS: Repair reports can only be given if sufficient and accurate defect reporting is made by the user.

Remember, the product without the required precautions can represent an electrical hazard and risk of injury, and that rotating machinery is a mechanical hazard and risk of injury.

PROTECTIVE INSULATION:

1. All exposed metal insulation is protected by basic insulation and bonding to earth i.e. Class 1.

   NOTE: Earth bonding is the responsibility of the installer. **THE UNIT MUST BE PERMANENTLY EARTHED.**

2. All signal and control terminals are SELV i.e., protected by double insulation (Class 2). The purpose of this protection is to allow safe connection to other low voltage equipment and is not designed to allow these terminals to be connected to any unisolated potential.

   

   Care must be taken not to mix the live (blocks D1 - 8) and SELV (blocks A1 - 8, B1 - 8) terminal blocks on the control and power boards as they are of the same type and may easily be interchanged.

   Ensure all wiring rated for highest system voltage.

ENCLOSURE: To maintain compliance with the European Low Voltage Directive Standards VDE 0160 (1994)/prEN50178(1995) the unit should be mounted inside a suitable control cubicle requiring a tool for opening.

RCDS: Compatible with Type B RCDs only.

EUROTHERM DRIVES RESERVE THE RIGHT TO CHANGE OR ALTER THE SPECIFICATION OF THIS PRODUCT WITHOUT NOTICE

Contents

Chapter 1 Product Overview

DESCRIPTION

The 5401 is essentially a DC current controller for the excitation windings of a DC machine, usually called the "field". The load presented by a field winding is usually highly inductive with an associated electrical time constant of from a few hundred milliseconds to seconds, but also quite resistive with an associated resistance of tens to hundreds of Ohms. As such, the load presented by the field is quite different to that presented by the armature of the same machine, which appears practically as a short circuit. The 5401 is a purpose designed field controller and should never be used for armature control or for any other purpose for which it was not intended.

The control of DC field current is achieved using a half-controlled (thristor/diode) bridge supplied from the AC mains. Using phase angle control, the applied DC voltage to the field is varied to give the required field current. The advantages of using a half-controlled bridge are that the field current is smoother (i.e., has less ripple) than that supplied from a fully controlled bridge, also a guaranteed "flywheel" path exists across the load at all times ensuring that if the supply is interrupted, there is always a "safe" path for the DC current established in the highly inductive load.

The 5401 consists of two closed loops, one inside the other. The inner, "current loop" controls field current linearly over a maximum 10:1 range and may be used on its own or in conjunction with the outer, "voltage loop" which controls the voltage across the motor armature terminals by adjusting field current demand. Both loops are "zero error" so that under steady state conditions there is no error between the demand value and the actual value.

"Field weakening" DC motors where the armature voltage is maintained constant above a certain speed, referred to as base speed, are high speed machines and are potentially dangerous. To ensure maximum user protection and convenience, several special features have been incorporated into the 5401. These include, in particular, a latching fault trip feature called simple "OVER 'E' TRIP" which has three distinct fault detection mechanisms:-

1)	OVERVOLTAGE:	Average armature voltage exceeds 150% of that required.
2)	TACHO REVERSAL:	Tacho feedback voltage and armature voltage are of opposite sign: Commissioning aid.
3)	LOSS OF TACHO:	Tacho feedback has been lost whilst field weakening: Prevents overspeeding.

For mechanical details and fixings, refer to the Installation and Dimensional Detail Drawing (drawing number HG049020D).

PRINCIPLE OF OPERATION

When the 5401 is operating as a field weakener, the controlled machine variable is normally the back e.m.f. (E), which is maintained at a preset value (Emax) above base speed (Nb) all the way up to top speed (Nmax). It does this by progressively reducing or "Weakening" the applied voltage to the field windings, which reduces the current, which in turn reduces excitation flux as speed increases. Non-linearity between field voltage and current is removed and response improved by closing the inner current loop; non-linearity between field current and flux is removed by closing the outer voltage loop.

Since when operating as a field weakener the 5401 tries always to maintain Emax in the motor, it will make more current at low speed and less current at high speed. The current is however constrained between a preset upper and lower limit which has a maximum span ration of 10:1. Below the base speed (Nb) field-weakening threshold the upper limit will persist and the voltage loop will "saturate".

The feedback for the voltage loop is obtained by directly measuring armature voltage. This measurement is impedance isolated and can be used directly to maintain a constant armature terminal voltage (Va) above base speed (Nb), or the appropriate armature resistive drop compensation can be made to the terminal voltage to calculate the motor back e.m.f., E.

If the 5401 is to be used as a simple field current regulator, then because no feedback is required, the voltage loop stays in saturation and the maximum current limit is always demanded. The maximum current limit level can then be externally adjusted, functioning as a current setpoint.

Manufacturer's Declaration

Although being largely electrical the 5401 does not fall under the machinery directive, we supply a manufacturer's declaration for when the 5401 is used (as a component) in machinery.

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MANUFACTURER'S DECLARATION

The following Electronic Products

5401 Field Controller

are components to be incorporated into machinery and may not be operated alone.

The complete machinery or installation using this equipment may only be put into service when the safety considerations of the Directive 89/392/EEC are fully adhered to.

Particular reference should be made to EN60204-1 (Safety of Machinery - Electrical Equipment of Machines).

All instructions, warnings and safety information of the Product Manual must be adhered to.

.....
Dr Martin Payn,
Conformance Officer
Eurotherm Drives Ltd

.....
Dr Dan Slattery,
Technical Director
Eurotherm Drives Ltd

1st September 1997
.....
Date

EUROTHERM DRIVES LIMITED
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File Name: P:\PRODUCTS\CE\SAFETY\PRODUCTS\5401\PRODFILE\HK463340.918				
ISS:	DATE	DRN: FEP	DRAWING NUMBER: HK463340C918	
A	01.09.97	CHKD: MP EUROTHERM DRIVES	TITLE: 5401 Manufacturers Declaration	SHT 1 OF 1 SHTS

Issue D 20.02.1995 GA387648C017

EC Declaration of Conformity (Low Voltage Directive)

The 5401 is CE marked in accordance with the low voltage directive for electrical equipment and appliances in the voltage range 50-1000V ac and 75-1500V dc when installed correctly.

CE

EUROTHERM DRIVES

EC DECLARATION OF CONFORMITY

In accordance with the EEC Directive 73/23/EEC and amended by 93/68/EEC,

Article 13 and Annex III, (LOW VOLTAGE DIRECTIVE)

We Eurotherm Drives Limited, address as below, declare under our sole responsibility that the following Electronic Products

5401 Field Controller

When installed and used in accordance with the instructions in the Product Manual (provided with each piece of equipment) is in Conformity with the following standard:-

VDE0160(1994)/prEN50178(1995)

Following provisions of EEC-Directive

73/23/EEC with amendment 93/68/EEC

.....
Dr Martin Payn,
Conformance Officer
Eurotherm Drives Ltd

.....
Dr Dan Slattery,
Technical Director
Eurotherm Drives Ltd

1st September 1997
.....
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File Name: P:\PRODUCTS\CE\SAFETY\PRODUCTS\5401\PRODFILE\HK463340C955				
ISS:	DATE	DRN: FEP	DRAWING NUMBER: HK463340C955	
A	01.09.97	CHKD: MP EUROTHERM DRIVES	TITLE: 5401 EC Declaration of Conformity for Electrical Safety	SHT 1 OF 1 SHTS

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Chapter 2 Technical Specifications

UNDERSTANDING THE PRODUCT CODE

On the inner surface of the right-hand side panel is a white label, normally referred to as the "rating label". The rating label gives information about the input supply ratings and the intended field current and voltage ratings. This, plus some additional information is also contained in the 17 digit product code, appearing on the label as "Model No." This product code is explained by the table shown overleaf.

5401 Motor Field Controller Product Code

TYPE	RATING	SUPPLY VOLTAGE (IT/TN)			SUPPLY CONTROL	FIELD VOLTAGE Vf (base)	ARMATURE VOLTAGE @ BASE SPEED Va(base)	SPECIAL
5401	000	0			0	000	000	00 - standard
1 phase, 1 Quad Field weakener single-ended Half-controlled	Field current (If) at Full Load. 000 = XX.X Amps (i.e. last digit in units of 1/10 an amp - decimal point not used in product code. Permitted range 000 - 200 (i.e., 20 amps max)	0 - 110 volts 1 - 115 volts 2 - 208 volts 3 - 220 volts 4 - 240 volts	5 - 380 volts 6 - 415 volts 6 - 415 volts	7 - 440 volts 8 - 460 volts 9 - 480 volts	0 - 11 volts 1 - 115 volts 2 - 3 - 220 volts 4 - 240 volts	Field voltage (Vf) nom e.g. 200 = 200v	Armature voltage at base speed at which field weakening starts e.g., 180 = 180v	01 - 99 Documented Special Options
General Information								
	Calibration $RB = \frac{2200}{I_f}$ Ohms				tap 1 for 0,1 tap 2 for 3,4	Calibration R19 + R20 (KΩ) + 10KΩ = V (nom)	Set on preset pot P4	

RATINGS AND DIMENSIONS

Electrical Ratings

Power Configuration	:	Single phase, single quadrant half-controlled (diode/thyristor) DC bridge.
Power Supply	:	Single phase 45/65Hz, no adjustment necessary for frequency change. Voltage ranges 110-240V; 380 - 415V; 440-480V ± 10%.
Control Voltage Supply (Auxiliary)	:	Single phase 45/65Hz, 110-120V, 220-240V ± 10% by tap selection.
Output Current Rating (Field)	:	200mA - 20A. This is the controllable range of current.
Minimum Field Time Constant	:	100mS.
Field Voltage Range	:	80 - 400V average.
Armature Voltage Input Range	:	0 - 750V peak.
Internal Regulated Power Supplies	:	± 15V ± 0.7V
		± 10V ± 0.03V.
External Reference Supply	:	+ 10V ± 0.03V (25mA Max).
Unregulated Supply	:	+24V + 6V/-2V (Normal run conditions).
Pollution Degree	:	2.
Installation/Overvoltage Category	:	3.
Electrical Safety Standards	:	VDE0160(1994), prEN50178(1995).

Control Specification

Control Circuits	:	Fully isolated from power circuits. (Class 2)

WARNING!

Care must be taken not to mix the live (blocks D1 - 8) and SELV (blocks A1 - 8, B1 - 8) terminal blocks on the control and power boards as they are of the same type and may be easily interchanged.

Control Modes	:	Armature voltage control. Field current control.
Voltage control	:	By armature terminal voltage feedback via built-in isolator circuit.
Armature voltage setpoint	:	0 - 4.6V (Va maximum).
Isolator linearity	:	5%.
Isolator accuracy	:	± 2%.
Field current control	:	Linearity and accuracy over control range better than 2%.
Maximum field weakening ratio	:	10:1.
Nominal field current trim	:	± 20%.
Turn-off delay timer range	:	1 sec - 25 secs (approximately).
Protection	:	High energy MOV's.
		High speed fusing.
		Armature over voltage.
		Tacho reverse.
		Tacho failure.
		Line failure.

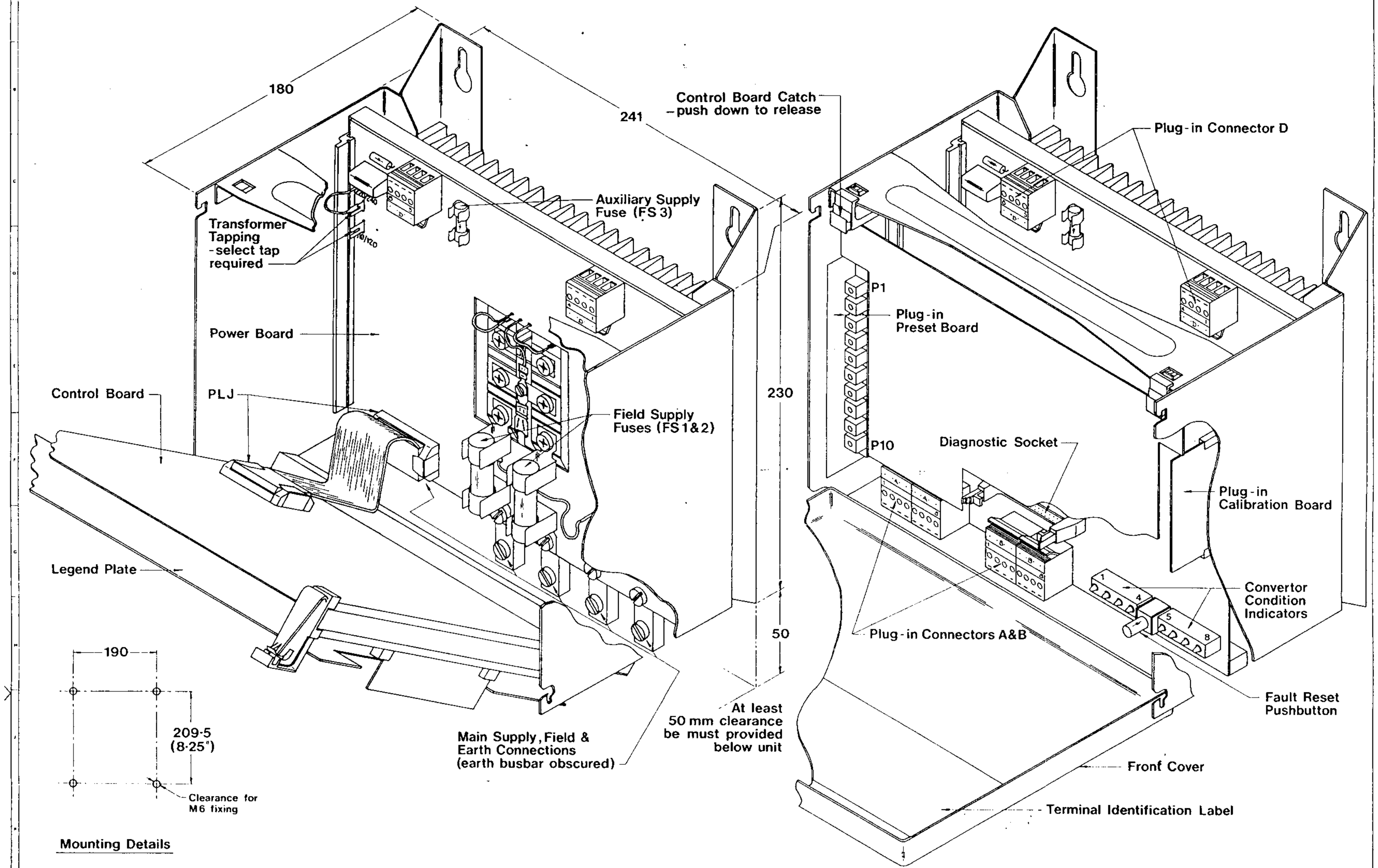
Mechanical Specification

Mounting centres	:	Vertical 209.5mm (8.25 inches).
	:	Horizontal 190mm (7.48 inches).
Overall width	:	241mm (9.49 inches).
Overall height	:	230mm (9.06 inches).
Overall depth	:	180mm (7.09 inches).
Weight	:	4.4kg (9.7 lb.).
Control terminations	:	Plug-on circuit screw terminal connections.
Power terminations	:	Busbar with bolt and captive nut (5mm).

Environmental Specification

Enclosure Rating	:	IP00, to be built into a suitable cubicle.
Operating Temperature Range	:	0°C — +55°C.
		Derate linearly above 35°C for force cooled units.
		Derate linearly above 45°C for naturally cooled units.
Storage	:	-25°C — +55°C.
		Protect from direct sunlight.
		Ensure dry, corrosive free environment.
Transport Temperature	:	-25°C — +70°C .
Humidity	:	85% Relative humidity maximum.
		Relative humidity is temperature dependent.
		If the ambient temperature falls the relative humidity will rise and may ultimately cause condensation. This should be avoided.
Climatic Conditions	:	Class 3k3, as defined by prEN50178(1995).
Atmosphere	:	Non-flammable, non-condensing.

DO NOT SCALE | THIRD ANGLE PROJECTION | GENERAL DRAWING PRACTICE TO BS 308 / BS 3939



Mounting Details

DATE 1 28·6·82	DRAWN D.J.H.	MATERIAL	DIMS IN MM APPLY OVER FINISH (EXCEPT FOR PAINT AND LACQUER)	ASSEMBLED UNIT	SCALE	5401 Field Controller Installation And Dimensional Details
	CHECKED		GENERAL TOLERANCES .X = ±.05, .XX = ±.02, .XXX = ±.01; HOLES +0.7mm -0.03 +0.07	SSD Shackleton system drives	EI	DRAWING NUMBER HG 049020D SHT. 1 OF 1 SHTS.
	DESIGN APPROVAL	FINISH				
	MAINT APPROVAL					

KA049020F

Chapter 3 Basic Installation and Wiring Instructions

WIRING INSTRUCTIONS AND RULES

Power cables must have a minimum rating of 1.5 x full load current.

Control wiring must have minimum cross-section of 1.5 sq.mm. (14 AWG). This includes the armature sense leads.

All incoming main power supply connections should be separately protected by suitable fuses. Armature sense leads should also be protected by suitable fuses and mounted as close to DC power terminals as practical, (i.e., nearest either the drive or the motor terminals, which ever is most practical or suitable).

The unit must be permanently earthed using one cable of minimum cross sectional area of $10mm^2$ connected to the earth busbar on the 5401 marked ⏚.

The main contactor should be operated by connecting the coil to terminals D8 (line) and D7 (neutral).

If the coil inrush current of the main contactor is likely to exceed 3 amps a suitable slave relay must be used.

The auxiliary or control power supply (single phase 50/60Hz) should be connected to terminals D6 (neutral) and D5 (line) with the appropriate external fuse protection.

Verify that the transformer tapping on the internal power supply printed circuit board is connected to a compatible voltage.

Check that the contactor coil voltage and frequency is compatible to the auxiliary supply voltage.

Connect the motor field (+) to busbar terminal F+ and motor field (-) to busbar terminal F-.

When the 5401 is used with a Eurotherm DC drive it will be necessary to override the internal field fail protection circuits. How to achieve this is described in the appropriate manual.

The main single phase power supply is connected to busbar terminals L1 and L2.

These connections should be made via suitably rated fuses and the normally open contacts of the main contactor.

Connect sense leads from the armature controller (drive) DC busbars to terminals D1 (Va+) and D4 (Va-). Use wire with insulation sufficient to withstand the main supply voltage and fuse these sense leads appropriately, mounting the fuses as close to the drive terminals as possible.

The maximum current limit is adjustable by means of input terminal B3. For normal operation this input should be connected to the +10V reference terminal B4, corresponding to 100% maximum current.

NOTES ON WIRING

Terminals D2 and D3 should never be used for any purpose at all.

All connections made to terminal blocks A and B MUST BE ISOLATED VOLTAGES (SELV).

BASIC WIRING DIAGRAM

See overleaf drawing number HJ048848D.

DO NOT SCALE | THIRD ANGLE PROJECTION | GENERAL DRAWING PRACTICE TO BS 308/ BS 3939

NOTES- 1. P1-10 ASSEMBLED ON PRESET BD (AH046821U001) FIELD VOLTAGE CALIBRATION RESISTORS R19 & 20, FIELD CURRENT CALIBRATION RESISTORS R123A-E ASSEMBLED ON CALIBRATION BD.(AH046789U001)
2. FOR NORMAL OPERATION LED'S 1-8 SHOULD BE ILLUMINATED

BUFFERED +10V REF (25mA)
MAIN CURRENT LIMIT (0-10V)
BUFFERED |EMF| (NORMALISED $\hat{E}$=10V OR CALIBRATED : $\frac{E}{100}$ V)
FROM MAIN DRIVE
ARM. CURRENT COMP (0-2·2V)
BUFFERED TACHO VOLTS (0-10V)
SHAFT STATIONARY
0V
EXT. TRIP RESET
BUFFERED FIELD CURRENT ($\hat{I}$ = 10V)
FIELD READY (ENERGISED WHEN CONTROLLER IS O.K.) 50mA
START / DELAY STOP
AUX. ENABLE
DIAGNOSTIC POSITION
P9 V_a METER CAL
P8 I_aR_a COMP
IaRa
DELAY 1-25S
P6 TURN OFF DELAY
RESET
2 I/P NAND
OVER 'E' TRIP $E > 1{\cdot}5E_a$
5 I/P NAND
R19 R20 R123 CAL BOARD (AH046789U001)
P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 PRESET BOARD (AH046821U001)
'POSITIVE ROTATION' LED 9
$-|E_{fb}|$
P7 V_a STABILITY
P4 V_a MAX.
'MIN CURRENT' LED 10
P3 I_f MIN
Imin
'MAX. CURRENT' LED 11
Imax -10V
I_f STABILITY P5
SET I_f NOM R123
P10 I_f ±20% CAL
'I_f PRESENT' LED 7
$I_f > 0{\cdot}05I_{f\,nom}$
'I_f READY' LED 8
'MAIN SUPPLY' LED 2
ENDSTOP PULSE GEN.
FILTER -70°
FILTER -90°
E/S PULSES
SOT (kΩ / V_f) R19 R20
OSC.
RAMP COMP.
2 I/P NOR
2 I/P AND
'INHIBIT'
LED 3 'AUX ENABLE'
LED 4 'START'
LED 1 'AUX. SUPPLY'
'V_a NORMAL' LED 5
LED 6 'CONTACTOR ON'
RLA
FIRING CIRCUITS
PULSE TRANS.
T1,T2 Q1 $\overline{Q}$1
TH1 TH2 D1 D2 MOUNTED ON HEATSINK
CONTROL BOARD AH048626U001
POWER BOARD AH048627U001

ISOLATION BOUNDARY
R 100R 100R R
$\frac{-Va}{100}$
Va + Va - MOTOR ARMATURE
P.S.U. 20 0 20
220/240 110/120 SELECT TAP REQUIRED
FS3 AUX SUPPLY FUSE
AUXILIARY SUPPLY L N
FS1 FS2 MAIN FUSES
D/ACCT
MAIN SUPPLY L1 L2
ISOLATION FOR SYNCHRONISATION
CONTACTOR COIL D8 D7
MOTOR FIELD F+ F-

ISS	DATE	
1A	25-3-82	
1B	30-3-82	
1C	14-5-82	
1D	26-8-82	
1	5-7-83	

DRAWN
CHECKED
DESIGN APPROVAL
MANF. APPROVAL

MATERIAL
FINISH

DIMS IN M.M. APPLY OVER FINISH (EXCEPT FOR PAINT AND LACQUER)
GENERAL TOLERANCE: X ± 0.4, X.X ± 0.2, X.XX ± 0.1, HOLES (Ø7mm +0·02 +0·07)

ASSEMBLED ON

SCALE

Shackleton system drives

TITLE SINGLE PHASE, SINGLE QUADRANT, FIELD CONTROLLER BLOCK DIAGRAM 5401

DRAWING NUMBER HH048699E

SHT. 1 OF 1 SHTS

TERMINAL IDENTIFICATION TABLE

TERMINAL	FUNCTION	COMMENTS
A1	0v (SIGNAL)	Signal reference for other signal inputs and outputs.
A2	ARMATURE CURRENT COMPENSATION	Input from drive, to compensate for armature resistive drop. On Eurotherm series drives the maximum signal is ± 2.2V.
A3	EXTERNAL CURRENT DEMAND	Actually, maximum current limit input. Normally connected to +10V but may also be used as an external current demand when the 5401 is used as a simple field regulator 10V = 100% 1 V = 1%
A4	BUFFERED + 10V REFERENCE	+10V (25mA) reference output
A5	RESET TRIP	In addition to the reset push button on the control board, the trip may be reset externally via this AC coupled input by momentarily applying +24V.
A6	AUXILIARY ENABLE	Must be connected to voltage ≥ 15V (normally + 24V) for 5401 to operate.
A7	START	Must be connected to voltage ≥ 15V (normally + 24V) to bring in the field AC supply contactor (if fitted) and for the 5401 to run. NOTE: After START is removed (≤ 0V) the 5401 will continue to pass current for the duration of the delay time.
A8	+24V	+24V (+6/-2V) for contact or link connections to START, AUXILIARY ENABLE or RESET TRIP inputs.
B1	0V (SIGNAL)	Signal reference for other signals.
B2	BUFFERED TACHO	Input from drive, giving motor speed and direction. Normally in the range +10V to -10V.
B3	SHAFT STATIONARY	Input from drive (zero speed output) which is high ≥ 15V (normally +24V) when the motor is at standstill. If this input goes high when the 5401 is field weakening it will immediately trip and field current will be stopped.
B4	BUFFERED E	Output (e.g., for power calculations) whose average value represents the modulus of motor back e.m.f. 'E' This output is either calibrated to V/100 or normalised (e.g., 100% = 10V) by use of pot P9.
B5	BUFFERED FIELD CURRENT	Intended primarily as a meter drive output to indicate field current. 10V = 100%, 1V = 10%.
B6	SPARE	This terminal is not connected to the circuit.
B7	FIELD READY	Relay drive (50mA) output from +24V to indicate to a drive or any other unit that the 5401 is passing properly controlled field current and is operating correctly.
B8	0V (POWER)	Return connection for FIELD READY relay drive output

TERMINAL	FUNCTION	COMMENTS
D1	Va+	Armature voltage sense input connected to the positive armature drive or motor terminal. NOTE: We recommend that an in-line fuse, correctly sized to the sense lead rating be used.
D2 D3		Although these terminals have no circuit function connection must not be made to them.
D4	Va-	Armature voltage sense input connected to the negative armature drive or motor terminal. NOTE: We recommend that an in-line fuse, correctly sized to the sense lead rating be used.
D5	L	Auxiliary AC supply live input. Check mains selection tap on Power Board before applying auxiliary supply.
D6	N	Auxiliary AC supply neutral input.
D7	CN	Main supply contactor coil neutral output.
D8	CL	Main supply contactor coil live output. Check contactor coil inrush current does not exceed rating of FS3 (3A).
L1 L2	MAIN SUPPLY	Main AC supply inputs. NOTE: Check input supply rating before connecting main supply.
F+ F-	POSITIVE FIELD OUTPUT NEGATIVE FIELD OUTPUT	Check field current and voltage rating before connection.

Chapter 4 Basic Setting Up and Operating Instructions

BEFORE ATTEMPTING TO TURN ON POWER:

CAREFULLY CHECK:

1. Auxiliary power supply voltage is correct.
2. Main power supply voltage is correct.
3. Field voltage and current rating.

} In general check the product code is correct for the application (see Chapter 2)

4. External wiring circuits. --- Power connections
   Control connections
   Motor connections

NOTE: Completely disconnect the controller before point to point checking with a buzzer or when checking insulation resistance with a megger.

LOOK OUT FOR:

1. Damage to equipment or wiring.
2. Loose wire ends, clippings, drilling chips, etc., lodged in the drive or electrical equipment.

ENSURE:

1. That rotation of the machinery in either direction will not cause a hazard.
2. That nobody else is working on another part of the equipment that can be affected by powering up.
3. That other equipment will not be adversely affected by powering up.

SETTING UP

As supplied, the 5401 the field controller unit has the nominal field voltage and current calibration and the armature voltage setting already made. These are the minimum necessary adjustments for the 5401 to operate as a field weakened on the specified motor and no further setting up is necessarily required.

For more critical applications, or if an application problem is encountered, further adjustments and checks will be necessary as described further on in this Chapter. These adjustments relate to motor base speed, minimum current level, armature resistance compensation, stability and/or turn off delay.

PREPARATION

1. Prevent the main single phase power supply from becoming connected to the controller by removing the main external fuses.
2. Plug in Diagnostic Test Unit type 5570. This is not essential to the successful commissioning of a field-controller but it very much simplifies the procedure and can save a considerable amount of time.
3. Check the field voltage calibration and field current calibration resistors on the small plug-in card which is accessible under the front cover on the right hand side of the control board.

   FIELD VOLTAGE CALIBRATION: The two resistors R19 and R20 are scaled as follows:-

   R19 + R20 = (Rated field voltage (Vf) - 10) K Ω

   FIELD CURRENT CALIBRATION: The total resistance R123 (A, B, C, D and E) is scaled as follows:-

   $$R123 = \frac{2200}{\text{Full Rated Field Current}} \text{Ohms}$$

   NOTE: The field current calibration should NEVER be changed to increase the current above the factory set value without prior consultation with Eurotherm Drives Limited.
4. Check the preset potentiometer settings on the preset plug-in card on the left hand side of the control board as follows:-

POT NO.	DESCRIPTION	NORMAL INITIAL SETTING
1	No function	-
2	No function	-
3	**If MINIMUM:**	
	Clockwise rotation increases minimum current level.	c.c.w.
4	**Va MAXIMUM:**	FACTORY PRESET & SEALED
	Clockwise rotation decreases field weakening armature voltage.	
5	**If STABILITY:**	
	Clockwise increases current loop gain.	MID-WAY
6	**TURN-OFF DELAY:**	
	Clockwise decreases field maintain time after STOP instruction.	c.w.
7	**Va STABILITY:**	
	Clockwise increases lead compensation in voltage loop.	MID-WAY
8	**Ia Ra COMPENSATION:**	
	Clockwise increases armature resistive drop compensation component.	c.c.w.
9	**Va METER CAL:**	
	Clockwise decreases meter output towards absolute reading (i.e. V/100)	c.w.
10	**If ± 20% CAL:**	
	Clockwise increases current by 20% counter-clockwise decreases current by 20%.	MID-WAY

CHECKING THE FIELD CONTROLLER AND SETTING UP

When all the preceding steps are completed, the auxiliary supply can be connected to terminals D5 and D6 (but do not connect the main single phase supply at this stage).

1. NOW CHECK:-

   i) The field controller indicators - these are 8 LED's at the lower right-hand corner of the Main Control printed circuit board. LED 1 and 5 should be on. Also LED 3 should be on if no external interlock is being used. (For LED field controller condition description, see Diagnostic Test Facility - Chapter 5).

   ii) Check the unregulated +24V supply between terminals A8 and B1.

   iii) Check the external +10V reference supply between terminals A4 and A1.

   Alternatively, if a diagnostic unit is available:

   iv) Check the +24V unregulated supply on position 10.

   v) Check the ± 15V regulated supplies on diagnostic positions 1 and 4.

   vi) Check the ± 10V reference supplies on diagnostic positions 2 and 3.

2. If a diagnostic test unit is available, check the factory preset setting of Va MAX (potentiometer P4) by measuring off position 17 in V/100, corresponding to the armature field weakening voltage.

   When the 5401 is used as a simple field controller, the setting of P4 is arbitrary and provided it is not fully clockwise, the voltage loop P+I controller will saturate as required.

3. Connect START on terminal A7 to +24V on terminal A8 or otherwise initiate START. The main supply contactor should now pull in and LED's 4 and 6 should be on.

   Removing START should result in LED's 4 and 6 going out and the main contactor opening <u>after</u> approximately one second (the minimum turn-off delay time).

   NOTE: The main contactor should NEVER be operated by any means other than the field controller internal contactor control circuit as shown in the wiring diagram HJ048848.

4. Turn off all power supplies to the equipment and when the whole system is totally isolated and safe, replace the main external fuses.
5. Turn on the auxiliary control supply.
6. Turn on the main supply.
7. Initiate the START input. LED's 4 and 6 should come on, then LED 2 should be on indicating that the main supply is present.
8. With the Auxiliary Enable input on terminal A6 high (LED 3 on), LED's 1 to 6 should now be on. Providing the field circuit is complete, field current should now start flowing, indicated by LED's 7 and 8 coming on. If not, disconnect all supplies and check the continuity of the field circuit with a low voltage Ohm-meter.

   Also check that LED 11 is on indicating that the current demand is the maximum level set by input terminal A3 (normally connected to A4). Check the current is at the rated level, indicated by +10V on diagnostic position 7 or by measuring the current with a meter.
9. The complete control range of the current can be checked by disconnecting terminal A3 from A4. LED 10 should come on indicating that the current demand is at the minimum current limit. Diagnostic position 7 should read 1V, or the actual current should measure 10% of rated current. Ensure that potentiometer P3 is fully counter-clockwise.

   Reconnecting A3 and A4 should re-establish rated (100%) current.

   NOTE: THE FOLLOWING STEPS IN THE SETTING UP PROCEDURE SHOULD ONLY BE MADE AFTER THE EUROTHERM DC DRIVE (ARMATURE CONTROLLER) HAS BEEN FULLY AND PROPERLY COMMISSIONED.
10. Prevent the 5401 from passing field current. This is most easily achieved by disconnecting the link between terminals A8 and A6, then connecting a link between terminals A8 and B7. This enables the drive without field current passing, providing the interconnections between drive and field weakener have been made according to wiring diagram HJ048848.
11. IaRa COMPENSATION: Start the drive and pass as much armature current as possible (say 100%) without overheating the motor. Increase the IaRa Compensation setting (potentiometer P8) from fully ccw until 0.0V is read on either a DVM connected between terminals B4 and B1 or on diagnostic position 16. The most accurate setting is obtained by watching for the sign to change on the DVM. Ensure for this adjustment that the motor does not rotate.
12. Stop the drive, remove the link between A8 and B7 on the 5401 and reconnect the connection to A6 (i.e. the reverse of step 10).

RUNNING AND PERFORMANCE ADJUSTMENTS

Before proceeding, check that the main drive setpoint is ramped with a ramp rate of a few seconds, otherwise the armature voltage may overshoot excessively when accelerating too quickly through base speed. Check also that the main current limit is at 100% i.e., +10V on terminal A3 and/or +10V on diagnostic position 20 and 25 with LED 11 on.

1. Prevent the 5401 from field weakening by rotating P3 fully clockwise so that the I_f minimum is set at 100% (+10V on 19).
2. SETTING THE FIELD WEAKENING THRESHOLD

   Ensure the main ramped setpoint to the drive is zero. Start the drive/field weakener combination. Check that condition indicator LED numbers 1 to 8 on the field weakener are on. Slowly increase the main setpoint in a positive direction until the motor reaches "base" speed, as specified on the motor nameplate. Check that LED number 9 is "on".

   Measure the voltage on either terminal B4, or, if a diagnostic unit is available, on diagnostic position 16. This voltage corresponds to the scaled armature voltage in V/100.

   (or to the motor back e.m.f. if IaRa Compensation has been set).

   The voltage should be approximately that specified in the product code and on the nameplate of the machine, (scaled in V/100) and also approximately the same as that on 17, the voltage setpoint set by P4.

   Adjust potentiometer P10 (I_f ± 20% CAL) until the motor voltage is the required field weakening voltage level (as set on P4). This exactly scales the field current to give full motor voltage at base speed, which will be maintained in the field weakening speed range.

3. Rotate potentiometer P3 fully counter-clockwise, allowing full field weakening range of 10:1. Diagnostic position 19 should read 1V. LED 11 should be on indicating that full field current (as scaled in step 2) is flowing at base speed.

4. CURRENT LOOP STABILITY

   Increase the speed setpoint from base speed all the way up to top speed. Monitor the field current on diagnostic position 7, or on the current meter drive output on terminal B5: If excessive low frequency ripple is observed on the field current as it reduces it can be damped by turning potentiometer P5 more clockwise.

5. MINIMUM FIELD SETTING

   Once top speed is reached, the Minimum Field current setting on potentiometer P3 may be increased until the motor voltage just starts to rise from that set in step 2. Note that LED 10 should now be continuously on.

6. SETPOINT RAMP RATE

   The normal operating parameters of the 5401 have now been set, so it is safe to completely reverse the speed setpoint to the drive, providing it is a 4-quadrant controller. NOTE that as the motor goes through zero speed LED 9 goes out. Full field weakening should occur in either direction.

   The Setpoint Ramp rates on the drive should now be re-adjusted to the required rates.

7. VOLTAGE LOOP STABILITY

   If the faster ramp rate set in step 6 results in excessive voltage overshoot whilst accelerating through base speed (monitoring diagnostic position 15) then more voltage lead compensation may be necessary. To achieve this, rotate potentiometer P7 more clockwise, a little at a time and repeat the acceleration test through base speed. Too much may result in Voltage Loop instability.

   (Note that the primary effect of voltage overshoot is to affect the actual ramp rate of the motor, caused by the motor accelerating faster than field current can be removed).

8. TURN - OFF DELAY TIME (for dynamic braking applications)

   Potentiometer P6 should be adjusted to maintain the field current for at least as long as the maximum time for the motor to stop from maximum speed under full dynamic (rheostat) braking conditions. The time is increased from approximately one second with P6 fully clockwise to approximately 25 seconds with P6 fully counter-clockwise.

This completes the setting up procedure of the 5401 field weakener and drive combination and they should now be ready to operate under the specific application conditions. It will now be essential however, to check that all associated Emergency Stop pushbuttons and external interlocks operate properly.

Chapter 5 Diagnostic Test Facility

DESCRIPTION OF DIAGNOSTIC TEST UNIT

The controller is fitted with a multi-pin socket on the lower edge of the main control printed circuit board to provide the interconnection for the type 5570 Diagnostic Test Unit.

The type 5570 Diagnostic Test Unit is a small, portable, plug-in module which when connected to the controller provides access to a selector switch to 27 internal test points. The unit incorporates the following features:

1. A digital voltmeter to permit accurate measurement of steady state signals.
2. An analog voltage "trend indicator" in the form of a row of LED displays which span signal levels in the range ± 10V. This is a fast responding indicator which shows the magnitude of rapidly changing signals.
3. A pair of output sockets (standard 4mm) to enable signals to be monitored externally on an oscilloscope.

Under normal operating conditions, all signals which appear on the Diagnostic Test Unit are isolated from the main power supplies and field and armature circuits.

DIAGNOSTIC TEST PROCEDURE

The Diagnostic Test Unit should always be used in conjunction with the field controller condition indicators located on the main control printed circuit board.

In attempting to determine causes of fault conditions it is essential to follow the normal setting up procedure for the controller as set out in sections 3 and 4.

If you reach a stage in the set-up procedure where the required conditions are not satisfied:

FIRST Look at the Field Controller CONDITION INDICATORS and refer to the Indicator Description Table.

SECOND Look at the Field Controller CONDITION INDICATORS and compare with the Reference Table.

THIRD Check the voltages indicated on the plug-in DIAGNOSTIC TEST UNIT and compare with the Diagnostic Test Table.

FIELD CONTROLLER CONDITION INDICATOR DESCRIPTIONS

LED 1 AUXILIARY SUPPLY ON/OFF

ON: Auxiliary supply connected, FS3 intact.

OFF: a) Auxiliary supply or fuse FS3 failed.

b) Preset PCB or Calibration PCB not fitted or plugged in correctly.

LED 2 MAIN SUPPLY ON/OFF

ON: Main supply connected, fuses FS1 and FS2 intact, (external contactor closed).

OFF: Main supply or fuses FS1 and FS2 failed or external contactor opened due to fault or STOP condition.

LED 3 AUX. ENABLE / INHIBIT

ON: Auxiliary enable input "high" (+24V).

OFF: Auxiliary enable input "low".

LED 4 START/DELAYED STOP

ON: START input "high" or turn off delay timer has to be initiated by START going "low".

OFF: START input "low", turn-off delay time elapsed.

LED 5 Va NORMAL/ALARM

ON: Over 'E' TRIP in normal (reset) condition.

OFF: a) Armature voltage has exceeded 150% of Va MAX setting.

b) Tacho and armature voltage of opposite polarity.

c) Shaft stationary input "high" whilst field weakening.

LED 6 CONTACTOR ON/OFF

ON: Main supply contactor driver relay activated.

OFF: a) Turn-off delay time has elapsed.

b) OVER E TRIP has been activated.

LED 7 If PRESENT/ZERO

ON: Field current passing in load.

OFF: Current below 5% nominal detect threshold.

LED 8 If READY/INHIBIT

ON: FIELD READY output in "high" state indicating that field current is present and that system INHIBIT is in the "low" state.

OFF: a) Field current is below 5% nominal detect level.

b) INHIBIT is high, INHIBIT low depends on:-

i) Aux. Supply on (LED 1)

ii) Main Supply on (LED 2)

iii) Aux Enable high (LED 3)

iv) Turn-off delay in run condition (LED 4)

v) Over 'E' TRIP reset (LED 5)

LED 9 POSITIVE SHAFT ROTATION

ON: Tach voltage on terminal B2 is positive.

OFF: Tacho voltage on B2 is negative.

LED 10 MINIMUM CURRENT (limit)

ON: Minimum current limit has been reached as set by potentiometer P3.

OFF: Extremity of field weakening not yet reached.

LED 11 MAXIMUM CURRENT (limit)

ON: Current demand is at the maximum level set by input terminal B3.

OFF: Field current is weakened from maximum level.

Diagnostic Condition Indicators - Status Recognition

CONDITION REFERENCE	AUX. SUPPLY ON/OFF	MAIN SUPPLY ON/OFF	AUX ENABLE/INHIBIT	START/DELAYED STOP	Va NORMAL/ALARM	CONTACTOR ON/OFF	If PRESENT/ZERO	If READY/INHIBIT	LED ON ● LED OFF ○
	1	2	3	4	5	6	7	8	CONDITION / CHECKS
A	●	○	●	○	●	○	○	○	NORMAL STOP
B	●	●	●	○	●	○	○	○	NORMAL STOP No external contactor fitted, main supply still connected
C	○	○	○	○	○	○	○	○	NO AUXILIARY SUPPLY CHECK:- 1. Auxiliary AC Supply between terminals D5 and D6 corresponds to auxiliary power supply transformer-tapping selected. 2. Auxiliary supply fuse FS3.
D	○	○	●	○	●	○	○	○	CAL OR PRESET BOARD NOT FITTED IN STOP CONDITION. 1. Calibration board is inserted correctly. 2. Preset board is inserted correctly.
E	●	○	○	○	●	○	○	○	AUXILIARY ENABLE LOW IN STOP CONDITION. CHECK:- 1. Link has been made between terminals A6 and A8. 2. External interlock to terminal A6 is active "high" (≥ 15V).
F	●	●	●	●	●	●	●	●	NORMAL RUN Field current passing normally.
G	●	●	●	●	●	●	○	○	NO FIELD CURRENT IN RUN CONDITION. CHECK:- 1. Field circuit (supplies off). 2. Field current calibration.
H	●	●	○	●	●	●	●	○	AUXILIARY ENABLE LOW, FIELD CURRENT STILL FREEWHEELING TOWARDS ZERO.
I	●	●	○	●	●	●	○	○	AUXILIARY ENABLE LOW, FIELD CURRENT ZERO.
J	●	○	●	●	●	●	○	○	NO MAIN SUPPLY IN RUN CONDITION. CHECK:- 1. Main AC supply between busbar L1 and L2. 2. Main supply fuses FS1 and FS2.

Diagnostic Condition Indicators - Status Recognition

CONDITION REFERENCE	AUX. SUPPLY ON/OFF	MAIN SUPPLY ON/OFF	AUX ENABLE/INHIBIT	START/DELAYED STOP	Va NORMAL/ALARM	CONTACTOR ON/OFF	If PRESENT/ZERO	If READY/INHIBIT	LED ON ● LED OFF ○
	1	2	3	4	5	6	7	8	CONDITION / CHECKS
K	●	○	●	●	○	○	○	○	ALARM IN RUN CONDITION CAREFULLY CHECK:- 1. Correct rotation of motor. 2. Correct polarity of armature sense leads to drive terminals. 3. For good tacho operation and connection to drive. 4. Interconnections between drive and field weakener. THEN 5. Adjust speed setpoint to zero then reset OVER 'E' TRIP and very carefully check correct voltage control operation of 5401 whilst field weakening.
L	●	●	●	●	○	○	○	○	ALARM IN RUN CONDITION No external contactor fitted. Action is same as in condition reference K.
M	●	○	●	○	○	○	○	○	ALARM IN STOP CONDITION After a trip condition has occurred and the 5401 has been stopped. Reset by either:- 1. Pressing reset button. 2. Applying external reset pulse. 3. Removing Main and Auxiliary supplies from 5401.

No.	DIAGNOSTIC TEST POINT DESCRIPTION	CONDITION	VOLTAGE
1	INTERNAL +15V SUPPLY	Aux. Power ON	+15V ± 0.7V
2	EXTERNAL +10V REFERENCE Note this supply is buffered from the internal reference and may be affected by external leads.	Aux. Power ON	+10V ± 0.1V
3	INTERNAL -10V REFERENCE	Aux Power ON	-10V ± 0.1V
4	INTERNAL -15V SUPPLY	Aux. Power ON	-15V ± 0.7V
5	ZERO SPEED INPUT From drive or other controller on terminal B3	High = shaft stationery Low = shaft moving	High ≥ 15V (typically +24V) Low ≤ 0V
6	BUFFERED TACHO INPUT From drive or other controller Analog input voltage representing speed and direction of motor on terminal B2.	Variable input 100% forward speed Zero speed 100% reverse speed	 +10V 0V -10V
7	BUFFERED FIELD CURRENT Monitor of field current meter drive output on terminal B5.	Variable output 100% current 10% current Zero current	 +10V +1.0V 0V
8	AUXILIARY ENABLE Monitor of external enable input on terminal A6	High = enable Low = inhibit	≥ 15V (typically +24V) ≤ 0V
9	START INSTRUCTION Monitor of start input on terminal A7	High = run Low = stop	High ≥ 15V Low ≤ 0V
10	+24V Monitor of unregulated "high" rail	Aux. Power ON	+24V +6V/-2V
11	SYSTEM INHIBIT Released when all 5 enables are satisfied:- i. Aux. Supply ON (LED 1 ON) ii. Main Supply ON (LED 2 ON) iii. Aux. Enable "high" (LED 3 ON) iv. Start/Delayed stop (LED 4 ON) v. Va Normal (LED 5 ON)	 Enable Inhibit	 -15V 0V
12	IaRa COMPENSATION Monitors level of armature resistance voltage drop compensation adjusted by Pot No. 8.	Variable signal Drive enabled, armature current passing.	 0 to ± 2.2V Average
13	ISOLATED Va (INVERTED) Monitors motor armature voltage feedback.	Variable signal Drive enabled, armature current passing.	 Scaled in V/100
14	COMPENSATED Va Monitors armature voltage less armature resistance voltage drop. The average of this signal corresponds to the back e.m.f. of the motor 'E'.	Variable signal Drive enabled, armature current passing, pot number P8 adjusted.	Scaled in V/100

No.	DIAGNOSTIC TEST POINT DESCRIPTION	CONDITION	VOLTAGE
15	LEAD COMPENSATION MAGNITUDE Monitors the amount of filtered (smoothed) back e.m.f applied for lead compensation of the voltage control loop. Useful for oscilloscope monitoring of back e.m.f. applied for lead compensation of the voltage control loop. Useful for oscilloscope monitoring of back e.m.f voltage closed loop response shape.	Variable signal Run Inhibit	Adjustable up to the maximum negative voltage seen on diagnostic position 16. 0V
16	MODULUS FEEDBACK VOLTAGE (INVERTED) Measures the closed loop summing junction feedback voltage of the voltage loop.	Variable Signal Drive enabled, armature current passing	Scaled in -V100
17	VOLTAGE DEMAND The voltage loop "setpoint"	Factory preset on pot No. 4	Scaled in V/100
18	VOLTAGE P + I OUTPUT Monitors output of the voltage "proportional + integral" controller before the current limit clamps are imposed.	Variable Signal Maximum field Minimum field	 -12V ± 1V +0.6V ± 0.1V
19	I_f MINIMUM Measures the minimum current limit level	No field weakening Full field weakening	10V = 100% 1V = 10%
20	I_f MAXIMUM Measure the maximum current limit level. Also monitors current demand on terminal A3 when 5401 is being used as a simple field regulator.	Variable Input 100% Current Limit 10% Current Limit	 10V 1V
21	SCALED CODING Monitors scaled, isolated measure of main supply.	Main supply on, contactor closed	Sinusoid of between 8 and 20V peak to peak.
22	CONSINE RAMPS Monitors ramps derived from SCALED CODING	Main supply on, contactor closed	Switched Consine of between 8V and 20V p/p
23	FIRE INSTRUCTION (INVERTED) Logical firing instruction to thyristor/diode bridge.	INHIBIT released "low" to fire.	High = 0V Low = -15V
24	CURRENT ERROR Error between CURRENT DEMAND and CURRENT FEEDBACK.	Run Inhibit	0.0V steady state +1.1V maximum
25	CURRENT DEMAND Measures current demand between I_f MAXIMUM and I_f MINIMUM clamp levels (Signal is negative)	Run 100% current 10% current Inhibit	-10V - 1V -10V } With +10V on A3
26	CURRENT FEEDBACK Measures current feedback as scaled internally. Diagnostic position 7 may be used preferentially.	Run 100% current 10% current Inhibit zero current	1.1V 0.1V 0.0V
27	PHASE ANGLE Monitors output of current loop controller. (This output is held against the CONSINE RAMPS to form the FIRE INSTRUCTION).	Run Variable signal Inhibit	± 11V ± 1V (saturation limits) + 11V ±1V

Chapter 6 Sales & Service

The product has no user serviceable parts and should be returned to Eurotherm Drives for repair. The product should be returned in the original packaging if possible or else reasonable care should be taken in the packing of the product to ensure that no transport damage be incurred.

Technical Support can be obtained by contacting Eurotherm Drives at the address given or your local supplier.

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FIRST USED ON	MODIFICATION RECORD 5401 Field Controller
EUROTHERM DRIVES	DRAWING NUMBER ZZ464436

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