VERY LARGE TELESCOPE

ESO VME4ST
4-CHANNEL STEPPER
MOTOR DRIVER

TECHNICAL MANUAL

VLT-MAN-ESO-17130-0991
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1. INTRODUCTION

The VME4ST is a four-channel stepper-motor power translator/amplifier (hereafter referred to as amplifier) designed by ESO for low power stepper motors. It is capable of driving 4 bipolar stepper motors (2, 4 or 5 phase motors) with a maximal current of 1A/phase. Input signals from the motor controller are direction, step, enable and power level signals, and output signal to the motor controller is a drive fault signal.
Other input signals are limit switch signals, and motion inhibit (interlock) signals.
The amplifier is designed primarily for use together with the MAC4/STP 4-axes motion controller, forming a complete motion control system housed in a VME-crate. The two VME-units must be interconnected by a special P2 backplane. For detailed description about the backplane and the connection between VME4ST and the MAC4/STP motion controller, see backplane documentation VLT-MAN-ESO-17130-0992. In this document there is also information about how to connect external units such as motors, encoders and limit switches.

For higher power outputs an external (not integrated into the VME-crate) power amplifier must be used.
A block diagram of the VME4ST amplifier is shown in appendix 1.

2. HARDWARE DESCRIPTION

For reference, see board block diagram in appendix 1 and board schematics in appendices 3 and 4.

2.1 VME bus connection

The amplifier is designed for use in VME-bus systems. Board size is 6HE (double height). It can only be used in a VME P1-only system. A special connector is mounted on the VME P2 (board lower) connector location. If a VME P2 (DIN 96-pin) connector is present in the VME-chassis, it has to be removed, or it will not be possible to use the VME4ST amplifier.

Warning : Don't attempt to insert the board in a chassis with VME P2 (DIN 96-pin) connector. This could result in damage to your VME-system and the VME4ST board.

The power amplifier has ***no*** VME interface. The only connections to the VME-bus are +5V supply and GND.

2.2 Amplifier working modes

The amplifier has two working modes :

- Handset mode
- Normal mode

When a handset is plugged into the front panel handset connector, the selected channel (select with the handset channel selector) automatically goes into handset mode. This axis can now be controlled from the handset, and a "drive fault" status is signalled to the motion controller.
The handset mode is used for testing and setting up of motorised functions. See sect 2.7. for a description of the handset.

2.3 Amplifier power modes

During motor rotation, the amplifier works in PWM current control to achieve maximal motor torque even at high motor speed. When the motor has reached its final position, there are three possibilities :

a) Keep position with full current (PWM regulated). See sect 2.3.1.
b) Keep position with reduced current (Linearly regulated). See sect 2.3.2.
c) Shut off motor current. See sect 2.3.3.

The switching between amplifier power modes are controlled for each channel individually by input control signals (channel enable -EN signal and channel HPWR signal) and channel PWR jumper settings. See also sect. 2.8 for jumper settings.

2.3.1 Full power hold mode

In this mode motor position is maintained by the motor under full current (motor current constant during motor running and motor stopped).

PWR Jumper setting : 2-3
Enable input signal : Always on
HPWR input signal : Don't care

Advantages :

- Maximal motor torque available to maintain motor position

Disadvantages :

- Electrical noise from motor windings and cabling due to PWM regulation
- Higher motor heat dissipation

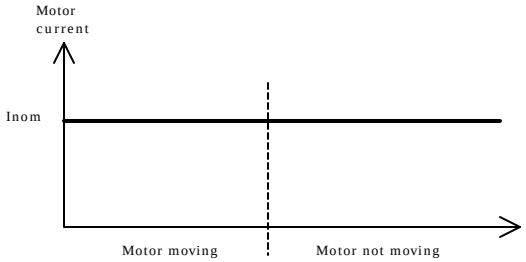


Fig 2.3.1. Motor current in full power hold mode

2.3.2 Reduced power hold mode

In this mode motor position (at final position) is maintained by the motor under lower current (approximately 25% of nominal motor current).

PWR Jumper setting : 1-2
Enable input signal : Always on
HPWR input signal : Controls high or low power mode

Advantages :

- No electrical noise from motor windings (when motor not moving) and cabling due to PWM regulation
- Low motor power heat dissipation

Disadvantages :

- Lower torque available to maintain motor position in final position.

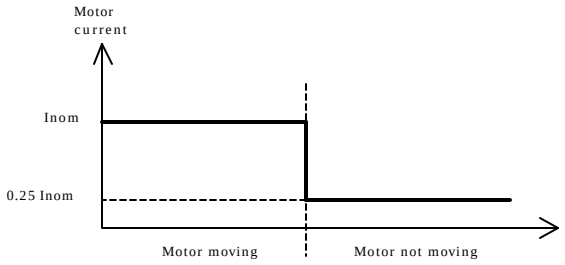


Fig 2.3.2. Motor current in reduced power hold mode

2.3.3 Current shut-off mode

In this mode motor current is completely switched off between motor movements. It will be used for motors driving mechanically self-locking functions, or where no position hold is required.

PWR Jumper setting : 2-3
Enable input signal : Controls current on or off
HPWR input signal : Don't care

Advantages :

- No electrical noise (when motor not moving) from motor windings and cabling due to PWM regulation
- No motor power heat dissipation (when motor not moving).

Disadvantages :

- No motor torque available to maintain motor position at final position.

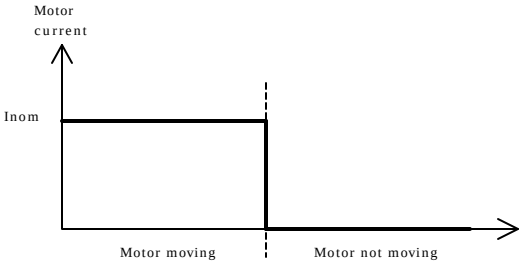


Fig 2.3.3. Motor current in reduced power hold mode

2.4 Step modes

The amplifier is capable of operating in two jumper selectable modes :

* Full-step mode (Jumper position 1-2)
* Half-step mode (Jumper position 2-3)

Each channel can be set individually, see sect 2.8 for jumper settings. The two modes have the following characteristics :

2.4.1 Full-step mode

In full-step mode, motor is operating with nominal step count, speed and torque.

2.4.2 Half-step mode

In half-step mode, the double step count of the motor is achieved. This is done on the cost of maximal motor speed (steps/sec), which will be reduced. Maximal motor tourque differs only slightly between the two step modes. Half-step mode is used where maximal motor step resolution is of primary importance. Also, half-step mode normally gives a smoother motor run.

2.5 Motor supply voltage

The voltage supplies for the output amplifiers (motor power supply) are only supplying the output stages. One or two supplies are required, depending on whether the amplifier is operated in low-power mode or not.
Output stages and motor power supply are galvanically isolated from other circuitry.

2.5.1 Power-down mode voltage supply

If a motor is operated in power-down mode, two power supplies are required:

- VMH - motor high voltage (nominally 24 VDC)
- VML - motor low voltage (nominally 12 VDC)

Both power supplies are supplied from the P2 connector. They share the same reference, motor ground, which is galvanically isolated from VME (logic) ground. The motor is supplied from VMH when running, and from VML when it has stopped.
The reason of having two power supplies is to have a high motor drive voltage during motor movement for best motor performance, and use a lower supply voltage to reduce heat dissipation when the motor has stopped and current regulation is done by a current limit resistor.

Supply requirements :

	Minimum	**Recommended**	**Maximum**
VMH	8 VDC or VML	24 VDC	45 VDC
VML	8 VDC	12 VDC	24 VDC or VMH

2.5.2 High power mode voltage supply

If all motors are operated in high power (or current shut-off) mode only one power supply is required:

- VMH - motor high voltage

Power is supplied from the P2 connector. The motor ground is galvanically isolated from VME (logic) ground. The motor is supplied from VMH.

Supply requirements for VMH as in sect 2.5.1.

2.6 Motor current setting

In PWM operation - during motor movement - the current through each phase of the motor is controlled by a PWM current controller that uses a current sensing resistor R_{hp}. The phase (winding) current versus resistor value is calculated as follows :

$I_{phase} = 0.25 / R_{hp}$

The R_{hp} resistors are

Motor 1 : R19-R23 (Phases 1 thru 5)
Motor 2 : R119-R123 (Phases 1 thru 5)
Motor 3 : R219-R223 (Phases 1 thru 5)
Motor 4 : R319-R323 (Phases 1 thru 5)

In low power mode PWM regulation is inhibited, and motor current is set by a series resistor R_{lp} in each phase. The value of these resistors are calculated as follows :

$I_{phase} = VML / (R_{lp} + R_{winding})$

where $R_{winding}$ is the motor winding resistance.

The R_{lp} resistors are

Motor 1 : R9-R13 (Phases 1 thru 5)
Motor 2 : R109-R113 (Phases 1 thru 5)
Motor 3 : R209-R213 (Phases 1 thru 5)
Motor 4 : R309-R213 (Phases 1 thru 5)

In appendix 2 the location of current setting resistors is indicated.

2.7 Handset

For set-up and test purposes, a handset is supplied with the VME4ST stepper motor amplifier. With this handset the user can run the connected motor at a selectable speed (without using a MACCON motion controller). On the handset there are three elements :

- *Direction selector* : Three position rocker switch. Selects between reverse - stop - forward motion.
- *Speed adjust* : Four position adjustment of motor speed.
- *Motor selector* : Four position switch, selects which one of the four motors to drive.

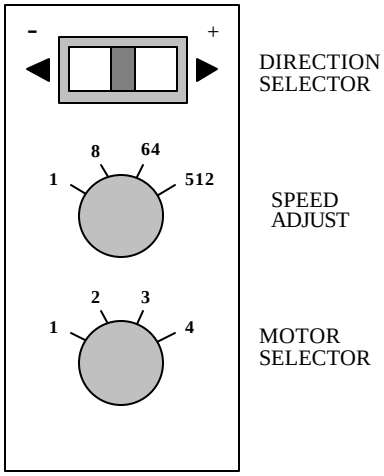


Fig 2.9. Handset.

The handset connects to the front panel of the servo amplifier, see fig 4.2. Note that the selected channel will signal "Drive Fault" to the connected controller when the handset is connected. High and low power operation remains active as set by the corresponding jumpers. The speed values selectable on the handset are not absolute speeds, but their relations are 1:8:64:256 where 1 is the lowest and 256 is the highest selectable speed. However, these values correspond roughly to steps/sec.

2.8 Jumper settings

For each channel two jumpers must be set correctly. These are :

Jumper identifiation (Ch1 - Ch4)	**Pos 1-2**	**Pos 2-3**
STEP (CN4, CN104, CN204, CN304)	Full step operation	Half step operation
PWR (CN5, CN105, CN205, CN305)	Auto motor power	High power only

Please note that a jumper ***must*** be inserted in one of the positions, otherwise the amplifier will not work properly. For location of jumpers, please refer to appendix 2.

3. EXTERNAL CONNECTIONS

3.1 CN2 configuration

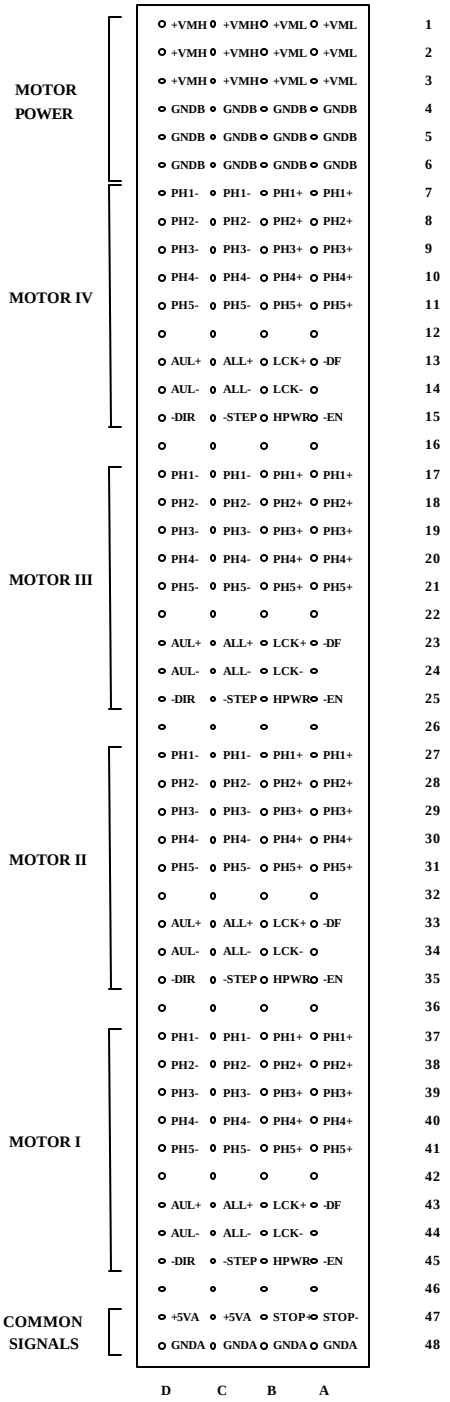


Fig 3.1. P2 (CN2) pin assignment (pin side view).

3.2 Signal names

For external signal connections and wiring see also VME4ST backplane manual.

+5VA : Logic supply (VME +5V) from VME4ST to VME4ST backplane. Fused 1 amp.
GNDA : Logic supply ground (VME ground) from VME4ST to backplane.

+VMH : Motor high power positive power supply. See sect. 3.9.
+VML : Motor low power supply. See sect. 3.9.
GNDB : Motor supply ground.

PHx+ : Motor channel I-IV winding x positive output. See sect. 3.4.
PHx- : Motor channel I-IV winding x negative output. See sect. 3.4.

AUL+ : Positive limit channel I-IV optocoupler diode anode. See sect. 3.3.
AUL- : Positive limit channel I-IV optocoupler diode cathode.

ALL+ : Negative limit channel I-IV optocoupler diode anode. See sect. 3.3.
ALL- : Negative limit channel I-IV optocoupler diode cathode.

LOCK+: Channel interlock optocoupler diode anode. See sect. 3.6.
LOCK-: Channel interlock optocoupler diode cathode.

-DIR : Motor direction input. TTL-level input with pull-up resistor. See sect. 3.7.
-STEP : Motor step input. TTL-level input with pull-up resistor. See sect. 3.7.
HPWR : High power channel I-IV. TTL-level input with pull-up resistor. See sect. 3.7.
-EN : Enable input channel I-IV. TTL-level input with pull-up resistor. See sect. 3.7.

-DF : Drive fault channel I-IV. TTL-level output. See sect. 3.5.

STOP+: Main interlock optocoupler diode anode. See sect. 3.6.
STOP- : Main interlock optocoupler diode cathode.

3.3 Limit switch inputs AUL+/- , ALL+/-

Signal abbreviations :

AUL+ : Amplifier Upper Limit positive terminal.
AUL- : Amplifier Upper Limit negative terminal.
ALL+ : Amplifier Lower Limit positive terminal.
ALL- : Amplifier Lower Limit negative terminal.

The limit switch inputs are the anode and the cathode of the input optocouplers. There is no internal current limit, the current must be limited *externally* by a resistor within 4-30 mA. Current flowing through opto-coupler indicates ***off*** limit (normal operation), no current through opto-coupler means ***on*** limit.
The status of limit signals are displayed on front panel LED's, one for each limit. A lit LED indicates ON limit; a dark LED indicates OFF limit. All LED's can be disabled by setting the LED on/off switch (see appendix 2) in the OFF position.

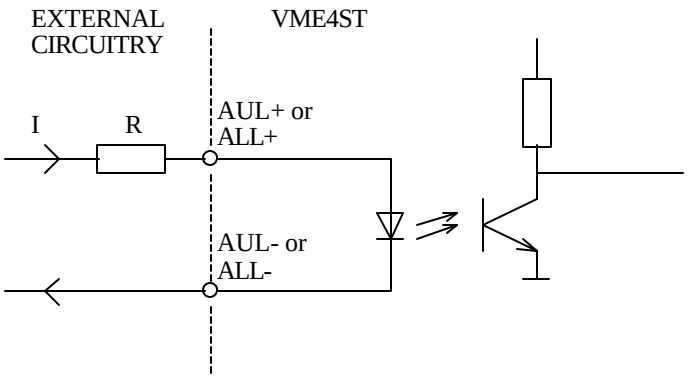


Fig 3.3. Limit switch input.

3.4 Motor outputs PH1 - PH5

The VME4ST amplifier is capable of driving 2-5 phase (windings) bipolar stepper motors. However, the different motor types require different board configurations. The following types are possible :

Type	Motor
1	5-phase (Berger-Lahr)
2	
3	

Table 3.4 Amplifier types

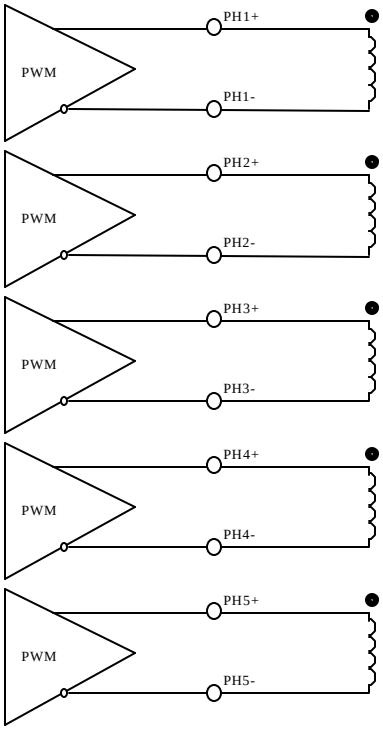


Fig 3.4. Motor connection.

Motor connection is illustrated in fig 3.4.
Only the applicable number of motor windings shall to be connected.
Motor outputs and supply are galvanically isolated from GNDA (VME GND).

The different board types are identified by a label located on connector P1.

3.5 Drive fault -DF

Output from VME4ST amplifier. These signals indicate the drive status for each channel. The signal is TTL low when the corresponding channel is not in handset mode, and no error condition is present. Output driver is CMOS logic totem-pole, relative to GNDA (logic/VME ground).

3.6 STOP+/- , LOCK+/-

Interlock inputs to the amplifier. Optocoupler inputs that, when not activated (no current), disable motor drivers. *The user must supply these inputs with current to operate the motor*. Inputs are floating w.r.t. motor and logic grounds.
The interlock inputs are the anode and the cathode of the input optocouplers. There is no internal current limit, the current must be limited *externally* by a resistor within 4-30 mA. For reference, see fig. 3.3. The status of interlock signals are displayed on front panel LED's for each channel individually. A lit LED indicates interlock situation (= motor disable); a dark LED indicates normal operation (= motor enable). All LED's can be disabled by setting the LED on/off switch (see appendix 2) in the OFF position.

Note that the LOCK input acts on ALL four motors, whereas the STOP inputs act on only one motor each.
When either LOCK (global signal) or STOP (channel individual signal) are activated, the corresponding motor is disabled (no motor current). If this happens, the amplifier output drive fault (-DF) for the corresponding axis becomes active.

3.7 -DIR, -EN, HPWR, -STEP inputs

Inputs to VME4ST amplifier. These signals (individual for each motor) control motor rotation. Inputs are all CMOS/TTL level compatible, with input pull-up resistor to interface to open collector drivers, relative to GNDA (logic/VME ground). Their respective function is indicated in table 3.7.

Signal	TTL low	TTL high or unconnected
-DIR	Motor moves forward	Motor moves backwards
-EN	Motor is enabled	Motor is disabled
HPWR[1]	Low power mode	High power mode

Signal	TTL H-L flange	TTL L-H flange
-STEP	-	Motor performs one step

Table 3.7. Amplifier inputs.

[1] Note that Low or High power mode is also dependent of jumper setting, see sect 2.8.

3.8 +5VA, GNDA

VME bus power supply and ground are available at the P2 connector. The 5V output line is fuse protected.

3.9 VMH, VML, GNDB

Motor power supply input. See also sect 2.5. Galvanically isolated from VME GNDA.

4. MECHANICAL DESCRIPTION

4.1 Cooling system

A steel-plate covers the component side of the board. It serves two purposes :

- Electrical shielding[1]
- Output amplifier cooling

The amplifier is working in PWM-mode so only little heat is dissipated. Nevertheless, to ensure reliable operation, it must be cooled.
Normal forced air-flow convection cooling system is used. The specified cooling capacity requires vertical mounting position, and a forced air flow of minimum 0.5 m/s directed from lower to upper end of card. A typical configuration would be a crate with 3 fans dia. 120mm mounted under the chassis. Other mounting positions are allowed, but the user must make sure that a continouos airflow is secured.

[1] Please note that for electrical shielding, the cover plate is connected to VME ground.

4.2 Front panel

On the front panel there are LED's for indication of limit switch status (LED on = on limit) interlock status (see also sect. 3.6), and high/low power mode of operation (LED on = active mode, see also sect. 2.3). All LED's can be disabled with the LED on/off switch. See fig 4.2.

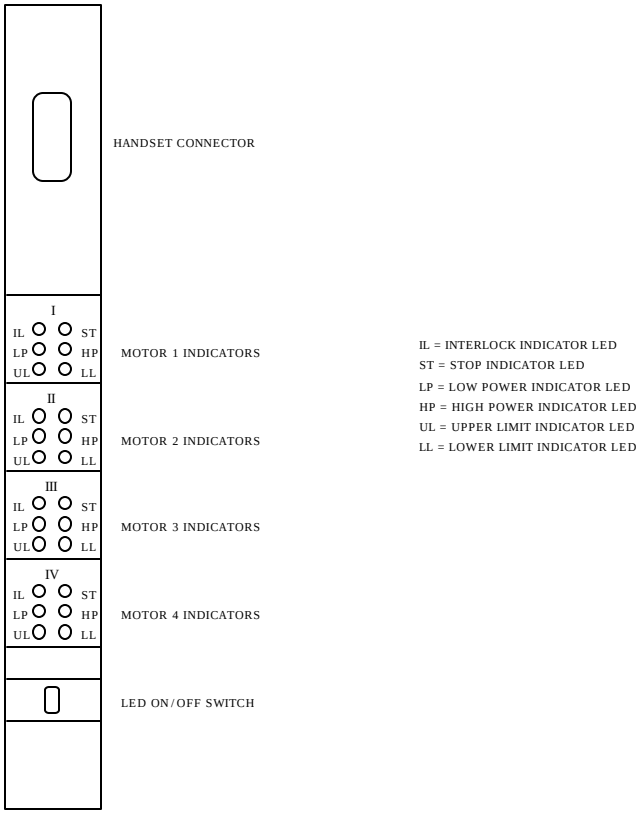


Fig 4.2. Front panel.

5. TECHNICAL SPECIFICATIONS

5.1 Electrical specifications

VME interface : None, VME +5V and GND only

Power supply : VME supply : +5V @ 1.0 A typ.

Motor supply : VMH nom. +24 VDC @ 0 mA typ.*
VML nom. +12 VDC @ 100 mA typ.*

Output current capability : I_{omax} = 1A / phase

PWM frequency : Fixed off-time interval 10 us

Power consumption : 6.1 W*

* : No motor connected.

5.2 Physical specifications

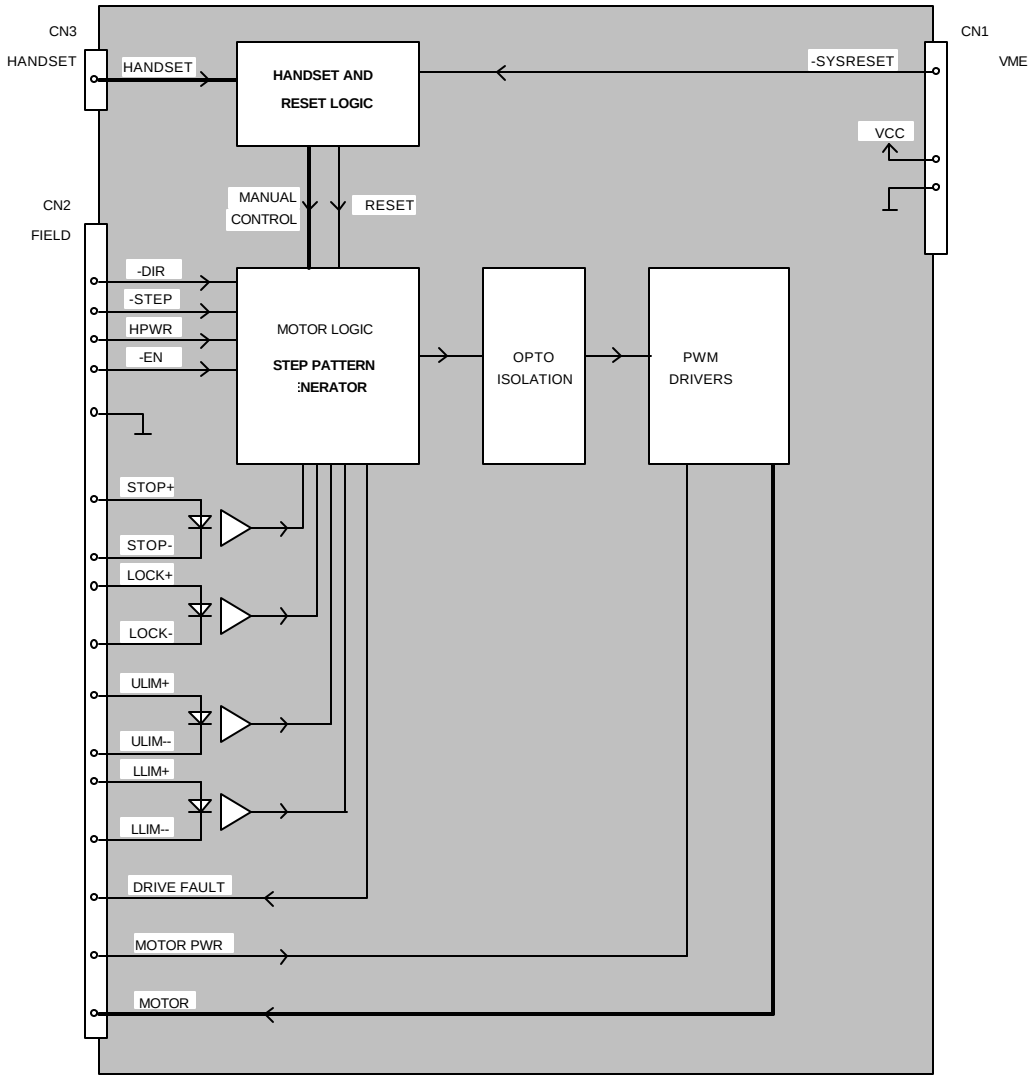
Size : Double-height 6 HE, single slot 4 TE

Weight : 800 g.

Ambient temp : Storage : -20C - +70C
Operation : 0C - +45C

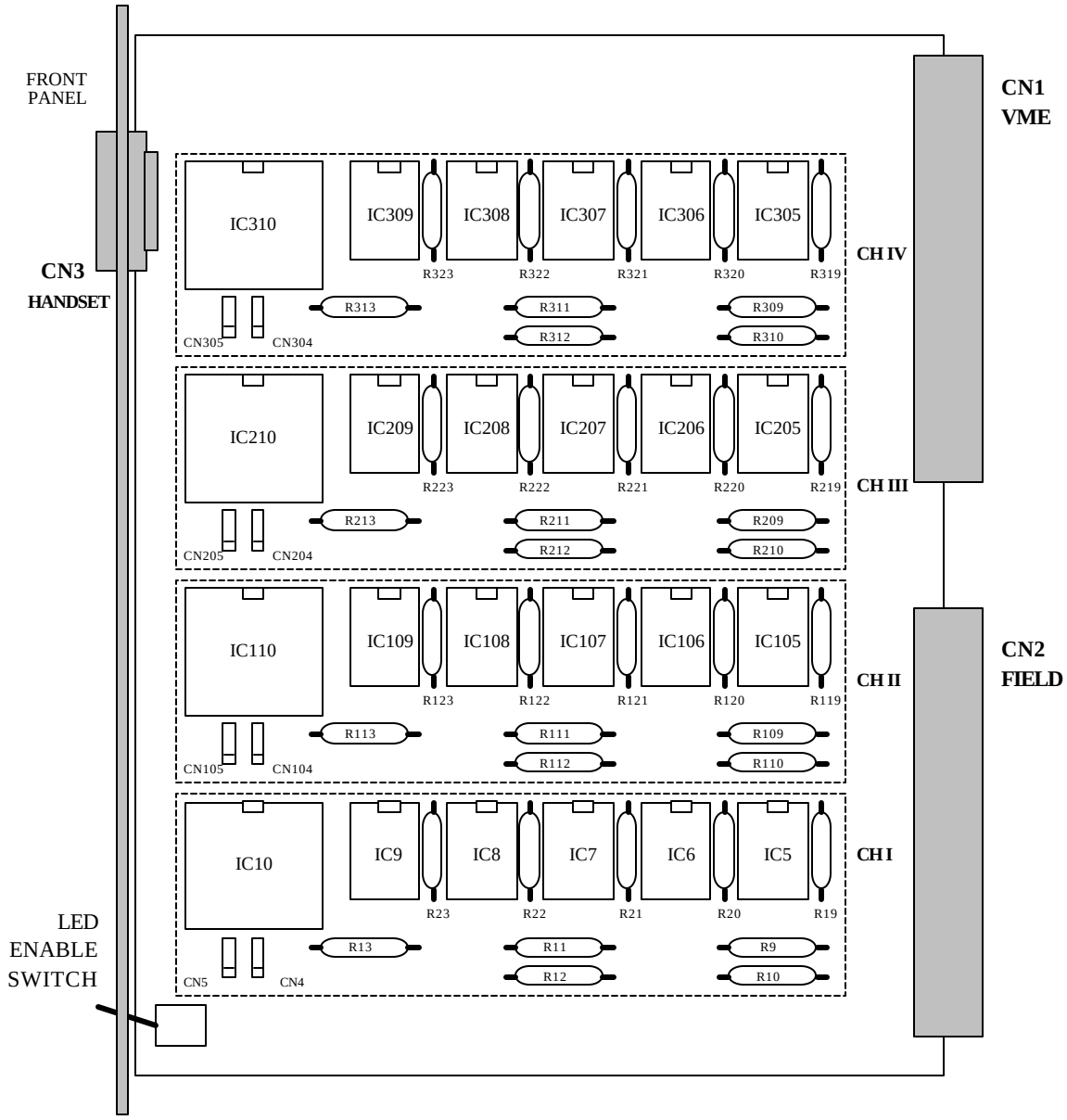
Connectors : VME (P1) : DIN 41 612, 96-pin
Field (P2) : Cannon CBC20 Z08-176FDS1 (176 pin)
Handset : D-Sub, female 9-pin

Appendix 1 : Amplifier block diagram.



Note : Only one channel shown.

Appendix 2 : Board layout.



Appendix 3 : Schematics pages 1-10.

Appendix 4 : Component list.