VERY LARGE TELESCOPE

ESO VME4SA-X1
4-CHANNEL DC SERVO AMPLIFIER

TECHNICAL MANUAL

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1. INTRODUCTION

The VME4SA-X1 is a four-channel linear DC-motor power amplifier designed by ESO for low and medium power DC-servo motors. The amplifier is designed primarily for use together with the MAC4/INC or MAC4/SSI 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. Because of its integrated VME-interface, the amplifier can operate in a stand-alone mode (i.e. without the MAC4 motion controller). For detailed description about the backplane and the connection between VME4SA-X1 and the MAC4 motion controller, see backplane documentation VLT-MAN-ESO-17130-0274. In this document there is also information about how to connect external units such as motors, tachos and limit switches.

The VME4SA-X1 is available in two versions, the -01 and the -11, differing in output current capability and cooling system for the output amplifiers.
For higher power outputs an external (not integrated into the VME-crate) power amplifier must be used.
A block diagram of VME4SA-X1 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 interface

The power amplifier has a VME slave interface to enable data exchange over the VME-bus. The purposes of the VME interface are to:

- Set amplifier mode (see sect 2.2 and 4.1)
- Read back amplifier status (sect 4.1 and 4.4)
- Read the output current (sect 2.6 and 4.2)
- Set the output voltage in DAC mode (sect 2.2.3 and 4.3)
- Read card insertion slot identification number (sect 2.7 and 4.4)

The VME-interface is 8-bit of A16:D08(O) slave type and the VME-address is switch settable within the 64-kB short I/O-range. The card occupies 256 bytes of address space. A switch setting "ON" corresponds to logical low, a switch setting "OFF" corresponds to logical high. At delivery all switches are set to "OFF". This setting corresponds to address FFXXh. An example of switch setting for address 20XXh is shown in fig. 2.1.

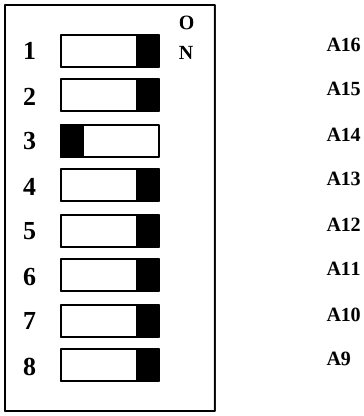


Fig 2.1. Address selection switch.

The switch location on the board is shown in appendix 2.

2.2 Amplifier working modes

The input to the PID-filter, i.e. speed set value, is selectable by a multiplexer. see fig. 2.2.

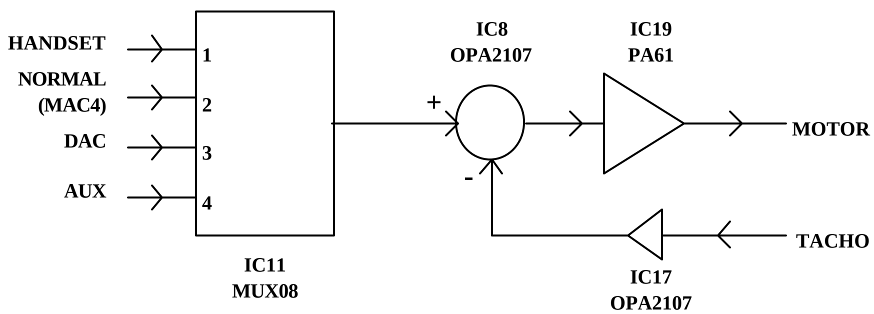


Fig 2.2. Input selector.

The multiplexer channel selection is made through the VME-interface, thus giving the VME bus master the control over the working mode of the amplifier. The selection is made individually for each channel. There are four working modes :

- Handset mode
- Normal mode
- DAC mode
- Aux mode

For a detailed description of the different modes, see sect 2.2.1 - 2.2.4.

Note : After power-on, after manual or VME-bus reset the amplifier always goes to handset mode.

2.2.1 Handset mode

This mode is always automatically selected after reset. In this mode the control is given to a handset that connects to the front panel of the amplifier, thus enabling manual operation of the motor. This mode can also be activated via a VME-bus write into the status register (see sect 4.1) for the corresponding channel.
This mode is used for testing and set-up. See sect 2.9. for a description of the handset.

2.2.2 Normal mode

When this mode is selected, motor speed control is given to the MAC4 motion controller. It is the normal working mode of the amplifier. The input sensitivity is ±10V. This mode can only be activated via a VME-bus write into the status register (see sect 4.1) for the corresponding channel.

2.2.3 DAC mode

The DAC mode is a way of giving direct control of the motor speed to the CPU-card (or any VME-bus master) rather than the MAC4 motion controller. It can be used for motor jog operation, or for applications without MAC4 motion controller (for instance a motor function that goes from limit to limit only). The VME bus master controls the speed set value (SV) by writing a byte to an 8-bit DAC (see sect 4.3). This mode can only be activated via a VME-bus write into the status register for the corresponding channel (see sect 4.1).

2.2.4 Aux mode

In this mode, an external unit is given control of amplifier speed set value (SV). The external SV signal input (range ±10V) is connected to the SP connector on VME4SA backplane.

Note : On the first circuit board revision (marked "CSP1750" close to P1 connector) this input is connected to ground. The Aux mode is NOT available on the "CSP1750" revision.

2.3 PID-filter

Each amplifier channel has a speed-loop filter of PID-type with discrete component programmable parameters and DC tacho feedback. The positive input to the filter comes from a multiplexer as described in fig. 2.2 and the negative feedback comes from the DC tacho generator input. The programmable parameters are:

- P,I,D constants and
- DC tacho gain.

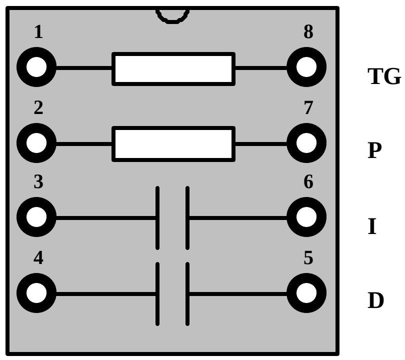


Fig 2.3. Component adapter.

The programming components are mounted on a socket that can be removed easily for parameter adjustment, see fig 2.3. For location of sockets, see appendix 2.

2.3.1 P - filter constant

The P filter constant sets the overall speed loop gain. It must be set to a proper value according to the mechanical properties of the driven function, motor type etc. The gain is set by a resistor connected between pin 2 and 7 on the component adapter. The gain resistor value is calculated with the formula :

R_p (KOhms) = 341 / Gain (times).

The resistor should be of 1/16W size, carbon or metal film type.
Upon delivery the component adapters are fitted with R_p = 20 KOhms.

Note : This resistor must be mounted, otherwise the amplifier will not work.

2.3.2 I - filter constant

The integration constant is set by a capacitor connected between pin 3 and 6 on the component adapter. The integration time constant is approximated with the following formula :

C_i (nF) = T_i (ms) * 10 ;

Where T_i = integration time constant. A typical range of value would be 50nF to 500nF.
The capacitor should preferably be of miniature multi-layer type due to its small size.
Upon delivery the component adapters are fitted with C_i = 100 nF.

Note : If no integration is required, pin 3 and pin 6 on the component adapter must be shorted, i.e. interconnected with a piece of wire.

2.3.3 D - filter constant

The derivation constant is set by a capacitor connected between pin 4 and 5 on the component adapter. The derivation time constant is approximated with the following formula :

C_d (nF) = T_d (ms) * 45 ;

Where T_d = derivation time constant. The capacitor should preferably be of miniature multi-layer type due to its small size.
The board is delivered with NO C_d mounted.

Note : If no derivation is required, leave pin 4 and pin 5 on the component adapter open; do not connect those pins.

2.3.4 DC-tacho generator gain

The tacho input is buffered and low-pass filtered with a cut-off frequency at nominally 200 Hz. The input resistance is 200 kOhms and maximal tacho voltage is ±20V. The input is over-voltage protected up to ±100V.
The tacho gain is set by a resistor between pin 1 and pin 8 on the component adapter. The resistor value is selected according to the tacho output voltage at maximal desired speed. The resistor value is calculated with the following formula:

R_{tg} (kOhms) = V_{tmax} (V) / 2 ;

where V_{tmax} represents the tacho output voltage at maximal desired motor speed.
The recommended range of value is from 100 Ohms to 10 kOhms.
The resistor should be of 1/16W size, carbon or metal film type.
Upon delivery the component adapters are fitted with R_t = 3 KOhms.

Note : This resistor must be mounted, otherwise the amplifier will not work, unless operating without tacho (see sect 6.1).

2.4 Amplifier status register

Each channel has a status register that can be read or written from the CPU-card. The register controls/provides information about :

- Amplifier working mode
- Upper limit switch status
- Lower limit switch status
- Output stage status (overheat).

For more detailed description of the status register, see sect 4.1.

2.5 Motor supply voltage

The voltage supply for the output amplifiers (motor power supply) is only supplying the output stages. **Note that the motor supply ground is connected to VME ground**, see also block diagram in appendix 1.

Motor power supply voltage V_{sm} requirements are :

Absolute minimum	V_{sm} : ± 10V
Nominal	V_{sm} : ± 24V
Absolute maximum	V_{sm} : ± 45V

V_{sm} ripple : < 10% p-p

Output current capability (electronically limited due to board maximal heat dissipation) :

VME4SA-01 (single width) : I_{omax} = 2A
VME4SA-11 (double width) : I_{omax} = 5A

Maximal total heat dissipation :

VME4SA-01 (single width) : P_{dmax} = 50W
VME4SA-11 (double width) : P_{dmax} = 175W

Notes :

1. The figures above refer to power dissipation, not motor drive power.
2. These ratings are valid only under the condition that the unit is mounted and cooled according to the specification in section 5.1.
3. Be sure not to exceed the maximally allowed total heat dissipation.
4. The output stages are thermally protected.
5. The output current is internally limited to a resistor programmable maximal value. If the maximal output current needs to be adjusted, change the **two** R_{cl} R17 and R51 resistors (see appendix 2) for the appropriate channel. The resistor value is calculated with the formula :

R_{cl} (Ohms) = 0.65 / I_{omax} (A)

The output stage can be disconnected from the motor with the limit switch relays. The relays are opened (disconnecting the motor) if any of the following cases occur :

- Motor limit switch activated
- Output stage overheat
- During reset
- On CPU-card request (see sect 4.1)

2.6 Motor current read back

In order to provide a means of output current measurement, a four-channel 8-bit ADC is included on the board.

VME4SA-01 (single width) : Measuring range : ± 2.5A   Resolution : 20 mA
VME4SA-11 (double width) : Measuring range : ± 6.3A   Resolution : 50 mA

The readout is normally done with one VME-bus read cycle in wait mode, that is, the DTACK signal is delayed until the conversion is ready (conversion time = 2.5us). In applications where this is not acceptable, the card can be jumpered to operate without wait mode. In this case the readout has to be started by reading the ADC register (see sect 4.2), and the result can be read out at any time after the conversion time (2.5 us). The second read-out starts the next conversion, which in turn could be read out after another 2.5 us. The ADC status (conversion ready) can be monitored by reading the BCKPLID register (see sect 4.4).

Note : The first readout after power-up of the board must be disregarded, as it is invalid due to AD converter internal structure.

2.6.1 Readout mode jumper setting

CN4 1-2 : Wait mode (factory setting)
CN4 2-3 : Two-byte readout

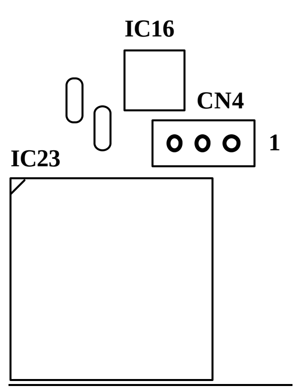


Fig 2.6.1. Readout mode jumper.

2.7 Card position read back

This function gives the VME bus master a possibility to examine the VME-system set-up. It provides the software with information about which amplifier card is installed in which slot, thus preventing an accidental mix-up of cards. The information is given by comparing the VME-address of the power amplifier card with the backplane address (see sect 4.4). This is important if there are multiple sets of MAC4/VME4SA-X1 cards installed in the same VME-system.

See also "VME4SA backplane technical manual", VLT-MAN-ESO-17130-0274.

2.8 Card reset facility

The internal reset signal is generated by a logical combination of the following signals :

1. VME-bus reset
2. Power-up reset (300 ms)
3. Output amplifier overheat
4. Front-panel local reset

As long as any of these signals are active the motor outputs are disconnected (by the limit relays) and the channels go into handset mode. When the reset is released (for instance when temperature goes down to normal after overheat) the board goes into handset mode with the motor outputs connected.

The front panel reset (manual reset) is activated by short-circuiting the two terminals on the front panel lower part (see fig. 5.2).

Notes:

1. The signal status can be monitored by reading the BCKPLID register (see sect 4.4).
2. The VME4SA-X1 unit can be put in reset mode by plugging in a shorting plug in the front panel reset connector, thereby making sure that none of the motors can move as long as the plug remains in position.

2.9 Handset

For set-up and test purposes, a handset is supplied with the VME4SA servo amplifier. With this handset the user can run the connected motor at a selectable speed. On the handset there are three elements :

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

The handset connects to the front panel of the servo amplifier, see sect 5.2. Note that the handset is only working when the servo amplifier is in handset mode (see sect.2.2.1).

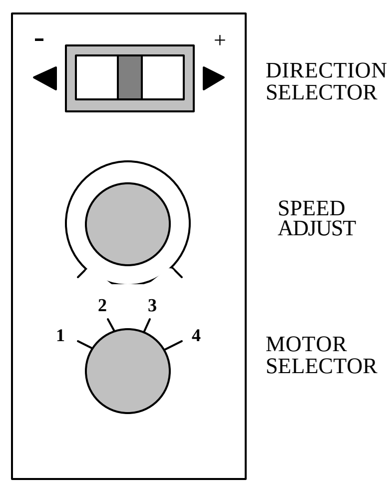


Fig 2.9. Handset.

3. EXTERNAL CONNECTIONS

3.1 CN2 configuration

Pin	E	D	C	B	A
38	M4+				
37	M4+	GND	GND		
36	M4-	GND	GND		
35	M4-				
34	GND	MN4	MP4		
33	T4+	N4+	P4+		
32	T4-		+5V		
31	GND	PC0	DF4	AIN1	
30	+VM	+VM	+VM		+VM
29	GND	PC1	DF3	AIN2	
28	M3+				
27	M3+	GND	GND		
26	M3-	GND	GND		
25	M3-				
24	GND	MN3	MP3		
23	T3+	N3+	P3+		
22	T3-		+5V		
21	GND	PC2	DF2	AIN3	
20	GND	GND	GND		GND
19	GND	PC3	DF1	AIN4	
18	M2+				
17	M2+	GND	GND		
16	M2-	GND	GND		
15	M2-				
14	GND	MN2	MP2		
13	T2+	N2+	P2+		
12	T2-		+5V		
11	GND	AU1	AU2		
10	-VM	-VM	-VM		-VM
9	GND	AU3	AU4	+12V	
8	M1+				
7	M1+	GND	GND		
6	M1-	GND	GND		
5	M1-				
4	GND	MN1	MP1		
3	T1+	N1+	P1+		
2	T1-		+5V		

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

3.2 Signal names

For external signal connections and wiring see also VME4SA backplane manual.

+5V : Logic supply from VME4SA-X1 to VME4SA backplane. Fused 1 amp.
+12V : Supply from VME4SA-X1 to VME4SA backplane. Fused 1 amp.
+VM : Motor positive power supply. See sect. 2.5.
-VM : Motor negative power supply. See sect. 2.5.

M+ : Motor channel I-IV positive output. See sect. 2.5.
M- : Motor channel I-IV negative output. See sect. 2.5.

T+ : Tacho channel I-IV positive input. See sect. 2.3.
T- : Tacho channel I-IV negative input. See sect. 2.3.
TSH : Tacho shield

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

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

PC : Backplane address bit 0-3. Input to amplifier. See sect. 4.4.

DF : Drive fault channel I-IV. Output from amplifier. See sect. 3.5.

AIN : Analogue input channel I-IV. Input to amplifier. See sect. 2.2.2.

AU : Auxiliary input channel I-IV. Input to amplifier. See sect. 2.2.4.

3.3 Limit switch inputs

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.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.

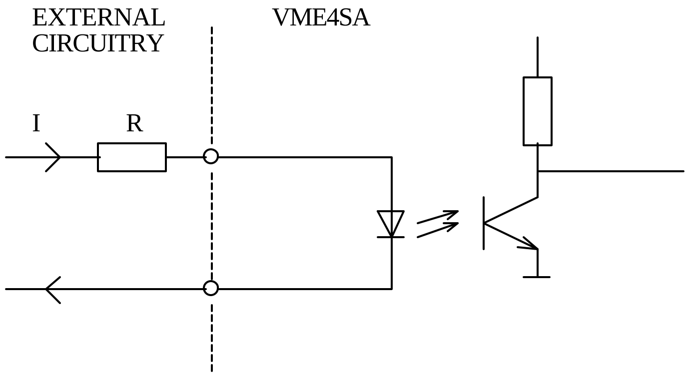


Fig 3.3. Limit switch input.

3.4 Backplane address inputs PC0-PC3

Four bits of TTL-level data input to the amplifier. Data can be read back over the VME-bus.

3.5 Drive fault DF1-DF4

Output from VME4SA amplifier. These signals indicate the drive status for each channel. The signal is TTL low when the corresponding channel is in normal mode, and no error condition is present.

3.6 Analogue input AIN1-AIN4

Speed set value for the motor, when the amplifier is in normal mode. Analogue range ±10V. The input is protected and can withstand input voltages up to ±50V.

4. PROGRAMMING REFERENCE

4.1 Status register

Address ChI : XX01H
Address ChII : XX03H
Address ChIII : XX05H
Address ChIV : XX07H

The status register is a read/write byte controlling/giving information about the amplifier working status. The bits are configured as follows:

Bit	7	6	5	4	3	2	1	0
Read	X	X	LimU	LimL	ReU	ReL	A1M	A0M
Write	X	X	X	X	ReU	ReL	A1M	A0M

Where :

LimU,LimL (R) : Limit switch status Upper/Lower limit.

1 = On limit.
0 = Off limit.

ReU,ReL (R/W) : Amplifier relay Upper/Lower.

1 = Relay open (Motor disconnect).
0 = Relay close (Motor connect).

Notes :

1. Writing 1 into the ReU,ReL bits means motor disconnect, regardless of other signals. A written 0 in this position (motor connect) will be overridden by an eventual limit or error condition.

2. The ReU,ReL bits are always cleared to 0 (motor connect) upon reset or error condition.

A1M,A0M (R/W) : Multiplexer input selector bits. Sets the working mode of the corresponding channel (see sect 2.2).

00 : Handset mode
01 : Normal mode
10 : DAC mode
11 : Aux mode

Note: The A0M,A1M bits are always cleared to 0 (handset mode) upon reset or error condition.

4.2 Motor current read back

Address ChI : XX09H
Address ChII : XX0BH
Address ChIII : XX0DH
Address ChIV : XX0FH

A VME-bus read on any of those addresses starts the amplifier output current read back A/D conversion (see sect 2.6). The output code (one byte) corresponds to a signed byte :

Output code	Output current
FFH	$+I_{max}$
.	.
.	.
80H	0
.	.
.	.
00H	$-I_{max}$

where I_{max} is a value depending on amplifier type (see sect 2.6).

Note :

1. Depending on jumper setting, the readout can be either one or two VME-bus read cycles (see sect 2.6).

2. A write to any of these addresses has no effect.

3. The first readout after power-up of card must be disregarded, as it is invalid due to AD converter internal structure.

4.3 Set value register

Address ChI : XX19H
Address ChII : XX1BH
Address ChIII : XX1DH
Address ChIV : XX1FH

A VME-bus write on any of those addresses sets the motor speed set value for the corresponding channel (if the amplifier channel is set to DAC mode). The input code (one byte) corresponds to a signed byte :

Input code	Speed set value
FFH	$+V_{max}$
.	.
.	.
80H	0
.	.
.	.
00H	$-V_{max}$

Note : After power-up the DAC output is undefined.

4.4 BCKPLID register

Address : XX21H

This register provides channel independent status information about the power amplifier.

Bit	7	6	5	4	3	2	1	0
Read	CR	ERR*	HOT*	X	PC0	PC1	PC2	PC3
Write	X	X	X	X	X	X	X	X

Where :

CR : Conversion ready. ADC status (see sect 2.6).

0 : Conversion running
1 : Conversion ready

ERR* : General error signal.

1 : Card OK
0 : Card locally in reset (see sect 2.8) and/or
card overheated and/or
VME-bus reset signal activated

HOT* : Amplifier overheat.

1 : Temp normal
0 : Overtemp (Card goes in reset, see sect 2.8)

PC0-PC3 : Backplane address.

5. MECHANICAL DESCRIPTION

5.1 Cooling system

Normal forced air-flow convection cooling system is used. The specified cooling capacity requires vertical mounting position, and a forced airflow of minimum 1 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. Any other mounting position or cooling system is allowed, but with corresponding derating of total power dissipation.
The VME4SA-01 version is intended for low power dissipation (maximally 50 watts dissipated totally for four channels), while the VME4SA-11 version can dissipate up to 175 watts in total. The two versions are electrically identical (same PCB is used for both versions), but because of the different cooling systems the low power version occupies one slot (= 4 TE), and the medium power version needs two slots (= 8 TE).
Due to carefully selected components, the board quiescent power consumption is as low as 4.5 watts.

5.2 Front panel

On the front panel there are LED's for indication of limit switch status (LED on = on limit) and output stages temperature (LED on = overheat). The limit LED's can be disabled with the LED on/off switch. See fig 5.2.

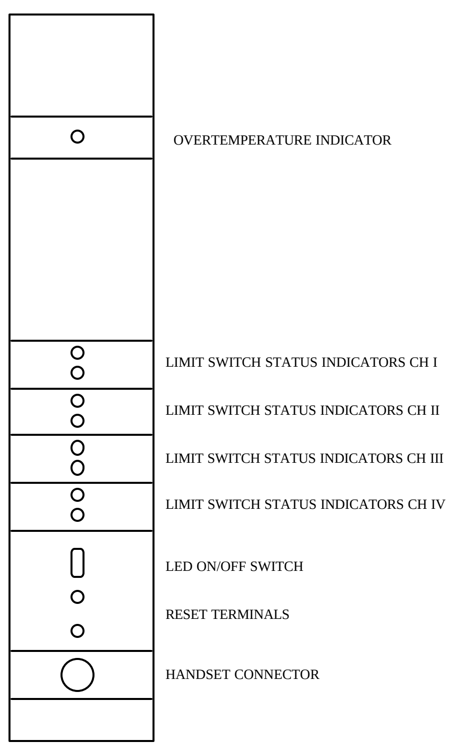


Fig 5.2. Front panel.

6. SPECIAL APPLICATIONS

6.1 Operating without tacho

The VME4SA-X1 can also be operated without tacho generator. Possible applications would be a motor running from end-to-end position only, or driving an other type of device such as a heater resistor or incandescent light source.
The amplifier then will work as a voltage amplifier without feedback.

In such a case, note:

- Remove the tacho gain resistor R_{tg} (open circuit).
- Replace the I-capacitor C_i with a 0-Ohm resistor (short circuit).
- Remove the D-capacitor C_d (open circuit).
- Limit switch inputs and handset will also work in this application.
- Adjust the P resistor R_p value according to :

$$V_{out} / V_{in} = 341 \text{ kOhm} / R_p$$

6.2 Operating without MAC4

Due to its integrated VME-interface, the VME4SA-X1 could also be operated in stand-alone mode. Possible applications would be as above. In this case, a special backplane must be used for the external connections.

7. TECHNICAL SPECIFICATIONS

7.1 Electrical specifications

VME interface : P1 slave short I/O A16/D08(o)

Address space : 256 bytes

Power supply : VME supply : +5V @ 400mA typ.
+12V @ 110mA typ.
-12V @ 70mA typ.

Motor supply : +24 VDC @ 10 mA typ.*
-24 VDC @ 10 mA typ.*

Absolute minimum ± 10 VDC
Nominal ± 24 VDC
Absolute maximum ± 45 VDC

Output current capability : -01 (single width) : I_{omax} = 2A
-11 (double width) : I_{omax} = 5A

Maximal total heat dissipation : -01 (single width) : P_{dmax} = 50W
-11 (double width) : P_{dmax} = 175W

Power consumption : 4.5 W*

* : No motor connected.

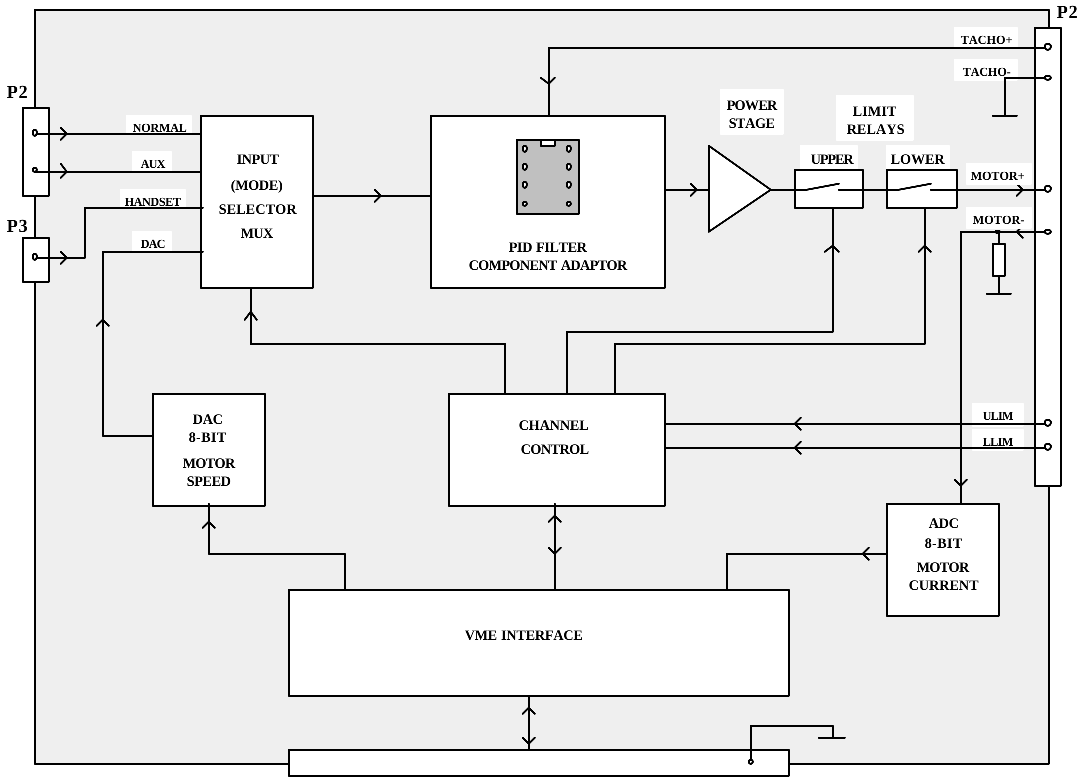
7.2 Physical specifications

Size : -01 : Double-height 6 HE, single slot 4 TE
-11 : Double-height 6 HE, two slots 8 TE

Weight : -01 : (4 TE) 600 g.
-11 : (8 TE) 1300 g.

VME (P1) : DIN 41 612, 96-pin
Field (P2) : DIN 41 642, 148-pin
Handset : LEMO series B, 6-pin

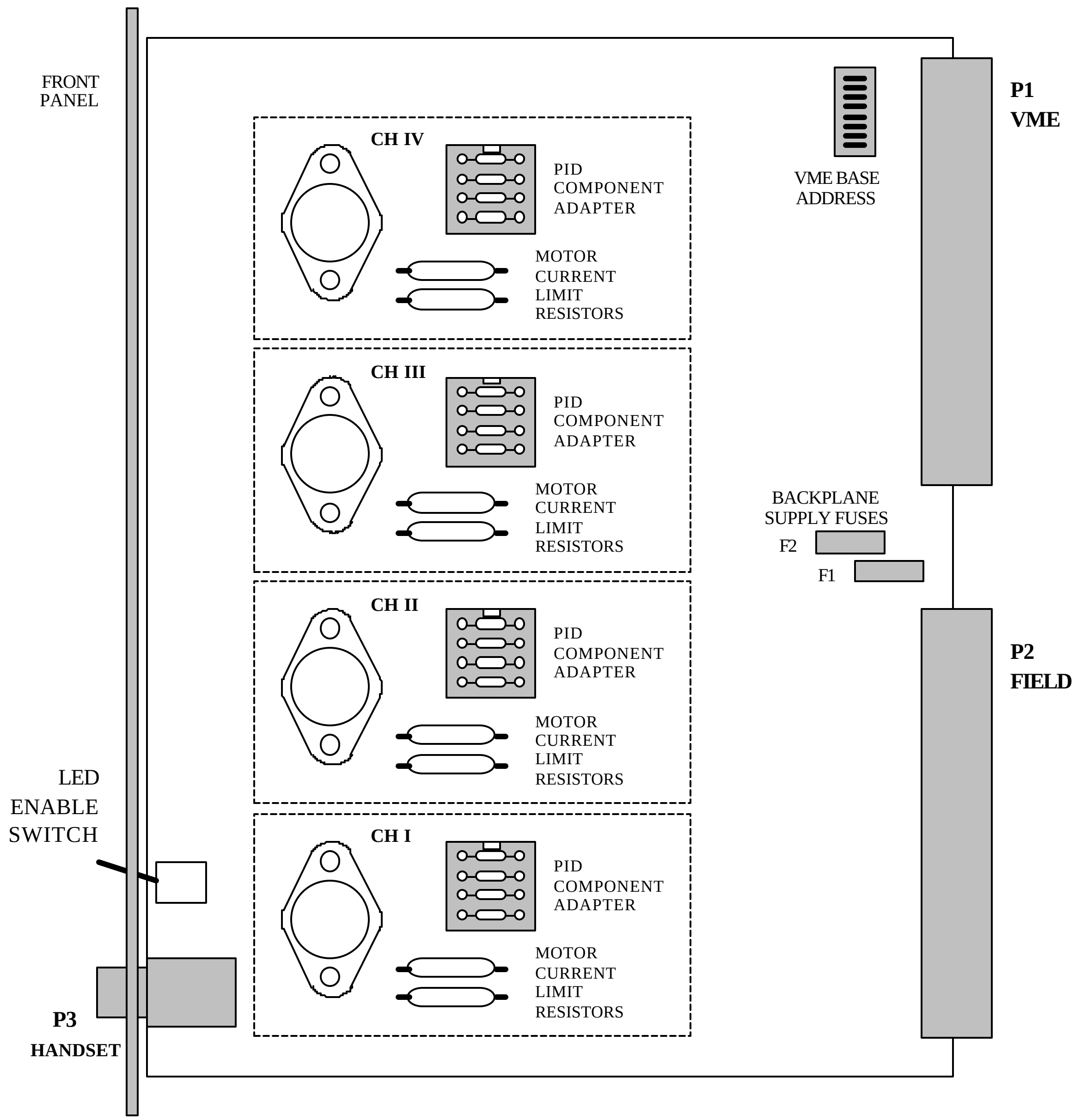
Appendix 1 : Amplifier block diagram.



P1 (VME) CONNECTOR

Note : Only one channel shown.

Appendix 2 : Board layout.



Appendix 3 : Schematics page 1.

Appendix 4 : Schematics page 2.

Appendix 5 : Component list.

***** COMPONENT LIST ******

VME DC motor power amplifier

(4x)	C1	100NF	Multilayer
(4x)	C2	100NF	Multilayer
	C3	100NF	Multilayer
(4x)	C4	10UF-50	Electrolytic
(4x)	C5	470PF	Ceramic
(4x)	C6	100NF	Multilayer
	C7	10NF	Multilayer
	C8	100NF	Multilayer
	C9	100NF	Multilayer
(4x)	C10	100NF	Multilayer
(4x)	C11	100NF	Multilayer
(4x)	C12	100NF	Multilayer
(4x)	C13	10UF-50	Electrolytic
	C14	220UF-15	Electrolytic
	C15	220UF-15	Electrolytic
	C16	220UF-15	Electrolytic
	C17	4UF7-10	Tantalum
	C18	100NF	Multilayer
	C19	100NF	Multilayer
	C20	100UF-50	Electrolytic
	C21	100UF-50	Electrolytic
	C22	100PF	Ceramic
	CN1	96-PIN DIN MALE	
	CN2	HAR-PAK	
	CN3	6-POL LEMO B	
	CN4	Wire 1-2	
(4x)	CN5	8-PIN ADAPTER (DIL SOCKET)	
(4x)	D1	BAT42	Shottky diode
(4x)	D2	BAT42	Shottky diode
(4x)	D3	IR 7F-50WF10	Power silicon diode
(4x)	D4	IR 7F-50WF10	Power silicon diode
(4x)	D5	IR 7F-50WF10	Power silicon diode
(4x)	D6	IR 7F-50WF10	Power silicon diode
(4x)	D7	4148	
	D8	LED_3MM RED	
	D9	LED_3MM YELLOW	
	D10	LED_3MM YELLOW	
	D11	LED_3MM YELLOW	
	D12	LED_3MM YELLOW	
	D13	LED_3MM YELLOW	
	D14	LED_3MM YELLOW	
	D15	LED_3MM YELLOW	
	D16	LED_3MM YELLOW	
(4x)	D17	BAT42	Shottky diode
(4x)	D18	BAT42	Shottky diode
(4x)	D19	4148	
	F1	PICOFUSE F1A	
	F2	PICOFUSE F1A	
	IC1	74ALS521	SO package
	IC2	74ALS521	SO package
	IC3	74ALS74	SO package

	IC4	74ALS04	SO package
	IC5	74ALS574	SO package
	IC6	74HCT645	SO package
	IC7	74HCT645	SO package
(4x)	IC8	OPA2107AU	SO package
(4x)	IC9	OPA2107AU	SO package
(4x)	IC10	AD7524	SO package
(4x)	IC11	MUX08	SO package
(4x)	IC12	EP610	DIL, "VMEPA610-1"
	IC13	OPA2107AU	SO package
	IC14	PC3Q15	SO package
	IC15	PC3Q15	SO package
	IC16	REF02	SO package
(4x)	IC17	OPA2107AU	SO package
	IC18	DS1233	TO-92
(4x)	IC19	PA61	POWER TO-3
	IC20	OPA2107AU	SO package
	IC21	MX7824	SO package
	IC22	74ALS38	SO package
	IC23	EP910-25	PLCC, "VMEPA910-2"
(4x)	P1	P10K-8T	
	P2	P10K-8T	
(4x)	P3	P2K-8T	
	R1	S8X10K	
	R2	S4X10K	
	R3	S8X10K	
(4x)	R4	20K-2%	
(4x)	R5	20K-2%	
(4x)	R6	10K-2%	
	R7	1K-2%	
(4x)	R8	1K-2%	
(4x)	R9	5K1-2%	
(4x)	R10	100K-2%	
(4x)	R11	10K-2%	
(4x)	R12	10K-2%	
(4x)	R13	5K1-2%	
(4x)	R14	4K7-2%	
(4x)	R15	27K-2%	
(4x)	R16	100K-2%	
(4x)	R17 :		-01 : 0R33 3W -11 : 0R12 3W
(4x)	R18	10K-2%	
(4x)	R19	10K-2%	
	R20	10K-2%	
	R21	10K-2%	
(4x)	R22	100K-2%	
(4x)	R23	100K-2%	
(4x)	R24	100K-2%	
(4x)	R25	100K-2%	
(4x)	R26	100K-1%	
(4x)	R27	100K-1%	
(4x)	R28	22K-2%	
(4x)	R29	4K7-2%	
(4x)	R30	4K7-2%	
(4x)	R31	100K-2%	
	R33	4K7-2%	
	R34	680-2%	
	R36-R39 :		-01 : 1R0 3W -11 : 2 X 0R8 3W in parallell
(4x)	R40	1M-2%	
	R41	20K-2%	
	R42	20K-2%	
	R43	20K-2%	
	R44	20K-2%	
	R45	20K-2%	
	R46	20K-2%	

	R47	20K-2%	
	R49	20K-2%	
	R50	4K7-2%	
(4x)	R51	:	-01 : 0R33 3W
			-11 : 0R12 3W
	R52	390-2%	
	R53	390-2%	
	R54	390-2%	
	R55	390-2%	
	R56	390-2%	
	R57	390-2%	
	R58	390-2%	
	R59	390-2%	
(4x)	RE1	DK1a-5V	
(4x)	RE2	DK1a-5V	
	SW1	8-POLE SMD	
(4x)	T1	BC337	
(4x)	T2	BC337	