Observatoire de Paris (ODP)

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VERY LARGE TELESCOPE

MULTIPLE APPLICATION CURVATURE ADAPTIVE OPTICS

MACAO-VLTI - TIP TILT MOUNT

FINAL DESIGN REPORT

Doc.No. VLT-TRE-ODP-11640-0002

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CHANGE RECORD

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1 SCOPE

In this technical report, we describe the concept design and the servo controller design for a Tip Tilt Mount dedicated to receive a Bimorph Deformable Mirror in purpose to be installed onto the MACAO-VLTI project. We describe the fabrication of the TTM assembly and we include at the end of this report, the electrical schematics, the mechanical drawings and the data sheets of the main components.

The prototype mount will be built to confirm the expected performances and after will be used as a spare.

2 ACRONYMS AND ABBREVIATIONS:

AO	Adaptive Optics
DM	Deformable Mirror
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
FEM	Finite Element Modeling
CRIRES	VLT High-Resolution IR Echelle Spectrometer
MACAO	Multiple Application Curvature Adaptive Optics
SINFONI	SINgle Far Object Near-ir Investigation
NAOS	Nasmyth Adaptive Optics System
TT	Tip Tilt
TTM	Tip Tilt Mount
TTM-FE	Tip Tilt Mount Front End
TTM-DEU	Tip Tilt Mount Drive Electronic Unit
IC-LCU	Instrument Control-Local Control Unit
RTC	Real Time Computer

3 APPLICABLE AND REFERENCE DOCUMENTS

[1] Technical Specification and Statement of Work, Doc N° VLT-SPE-ESO-11640-2149

[2] MACAO-VLTI- Tip Tilt Mount Preliminary Design Report, Doc N° VLT-TRE-ODP-11640-0001 Issue 1.3, October 30, 2000.

[3] MACAO-VLTI-TTM INTERFACE with Deformable Mirror, N° VLT-IDW-ODP-15600-0-312000-0102, November 30, 2000.

4 TIP TILT MOUNT SPECIFICATIONS:

4.1 Tip Tilt Mount Specifications

- Optical aperture clearance of the deformable mirror: 150 mm
- Overall diameter of the DM: 180 mm
- Deformable mirror weight: 813 g
- Overall dimension of the TTM: 290 mm
- Optical surface of the DM in the same plane than the TTM axes
- Lateral and longitudinal displacements of the central point of the DM less than ± 0.2 mm

4.2 Drive electronic dynamic specifications

- Bandwidth of the TTM controller (- 3 dB) at small signal level: 100 Hz
- Phase shift at 15 Hz: < - 20 °
- Tilt angle range on the sky: 6 arc sec. pp
- Tilt mechanical angle range: 240 arc sec. pp (1.16 mrad)
- Angular resolution on the sky: 1 mas
- Mechanical angle resolution (noise equivalent angle): 0.04 arc sec. rms
- Inter-channel cross-talk: 0.1%
- Channel assignment: each channel simultaneously and individually addressable
- Input signal voltage: ± 10 V
- Output monitoring for each channel (± 10 V)
- Cable length between the TTM and the controller: 18 m
- The local closed loop should be tunable in order to avoid possible interface between the TTM closed loop performed and the DM loop.

4.3 Environmental specifications

- Functional air temperature range:- 10 °C to + 30 °C
- Operational air temperature range: 0 °C to + 15 °C
- Typical air temperature gradient at night: 0.4 °C / hour
- Operational altitude: 0 to 2700 m
- Humidity: < 95% non condensing

5 DEFORMABLE MIRROR INTERFACE SPECIFICATIONS

The best performances will be obtained if the center of gravity of the moving part (central ring of the gimbal mount with the deformable mirror) is placed at the crossing point of the two rotating axes. As the optical surface of the DM should be in the plane defined by the tip tilt axes, the center of gravity position of the DM has been requested to be on the optical surface.

5.1 Deformable Mirror Specifications

Hereafter, we remind the DM specifications after the DM FDR.

- External diameter of the DM body: 180 mm
- Weight: 813 g
- Position of the connector with respect of the fixing surface: 62 mm
- Position of the centre of gravity: on the mirror surface < 0.2 mm
- DM connectors: 2 connectors 851-41 aligned with one TTM axis.

The bimorph DM body is assumed to be delivered with an interface ring for its installation into the tip tilt mount and with an interface plate for the connectors.

5.2 DM Mechanical Interface:

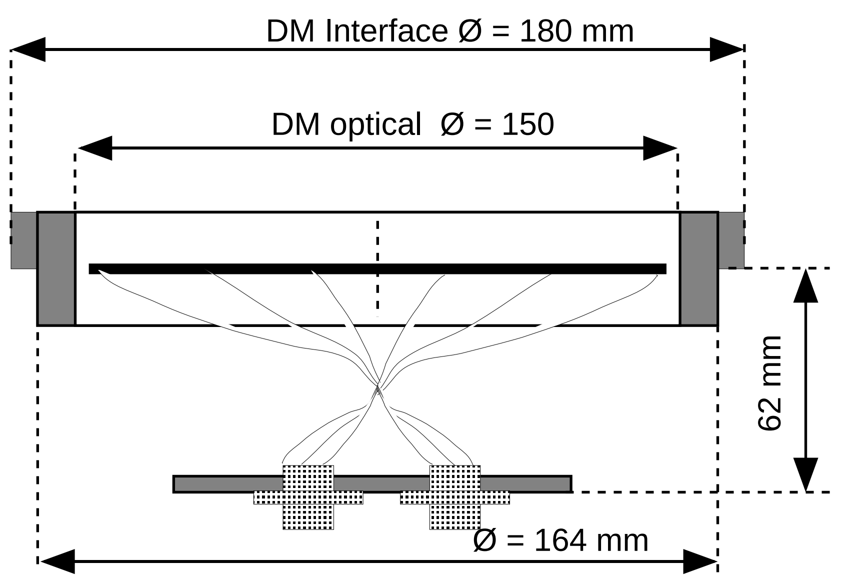

Figure 1: Deformable Mirror overall dimensions

The mechanical interface between the TTM and the DM is defined by the drawing VLT-IDW-ODP-15600-0-312000-0102. (3).
The accurate positioning of the DM onto the TTM is made with two precise pins implemented on the TTM -DM interface ring.
The DM high voltage wires between the DM and its connectors will be twisted in order to produce symmetrical and low torque between the TTM inner and its chassis.
A mounting-dis-mounting procedure of the DM onto the TTM will be written.

6 TTM GENERAL OVERVIEW

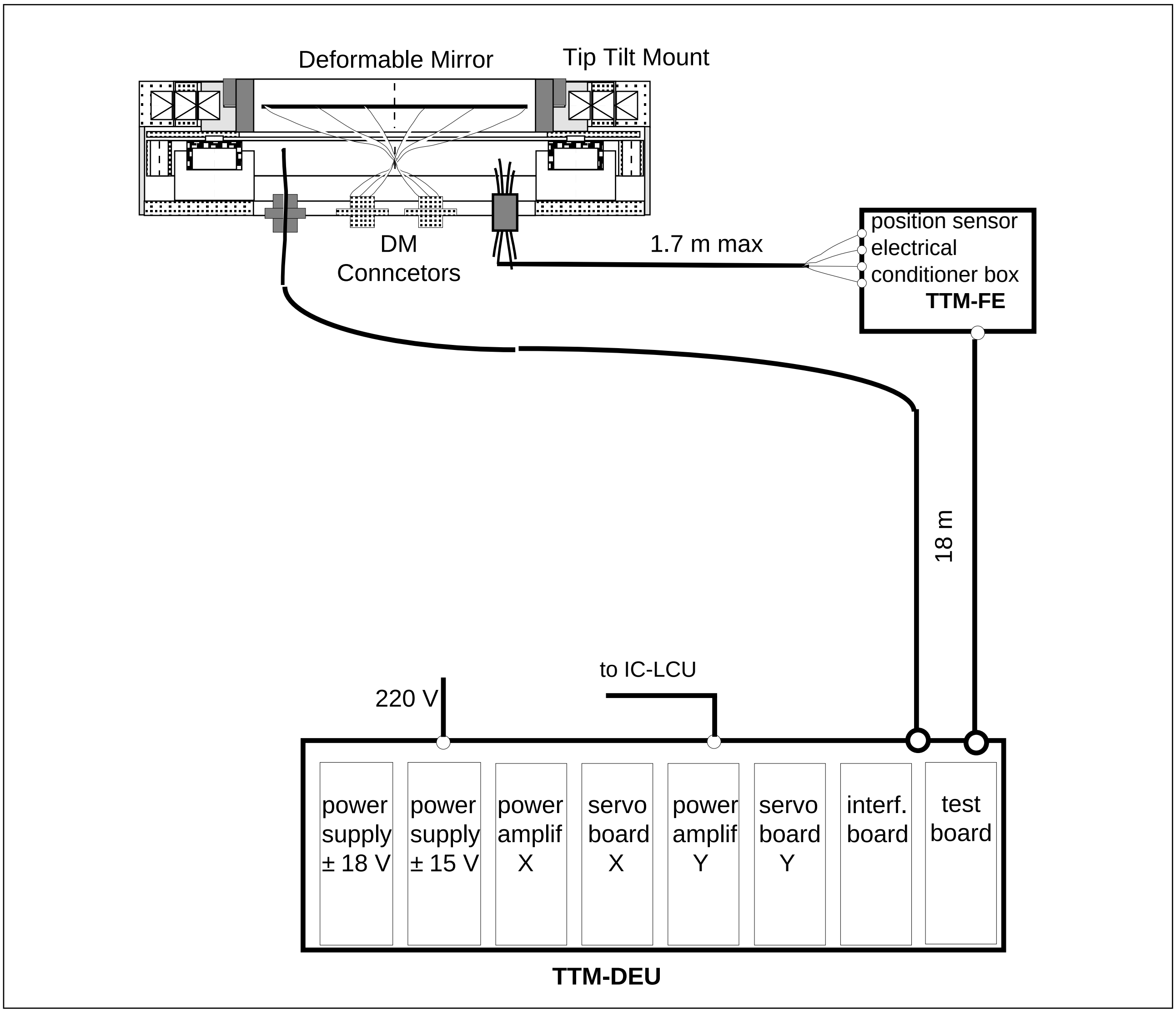

Figure 2: Tip Tilt Mount Assembly

This overview fig # 2 shows the main components of a Tip Tilt Mount Assembly which contains:

- The Tip Tilt Mount itself (TTM) equipped with the Deformable Mirror.
- The position sensor electrical conditioner (TTM-FE) should be close to the TTM. (less than 1.7 m) in order to keep the highest resolution.
- The Tip Tilt Mirror Drive Electronics Unit (TTM-DEU) which contains the two local servo loop components.

The TTM-DEU could be a few meters far from the Tip Tilt Mount, but, for a distance more than 6 m, we have to implement the line drivers for each analog signals and a dedicated power supply (+/- 18.5 V) for the TTM-FE in the TTM-DEU.
The TTM-DEU contains the power supplies, the servo cards and the interface card.
The control of the Tip Tilt Mount Drive Electronic Unit is done through the IC-LCU interface, with two analog signals.

7 TIP TILT MOUNT CONCEPT

7.1 Design concept:

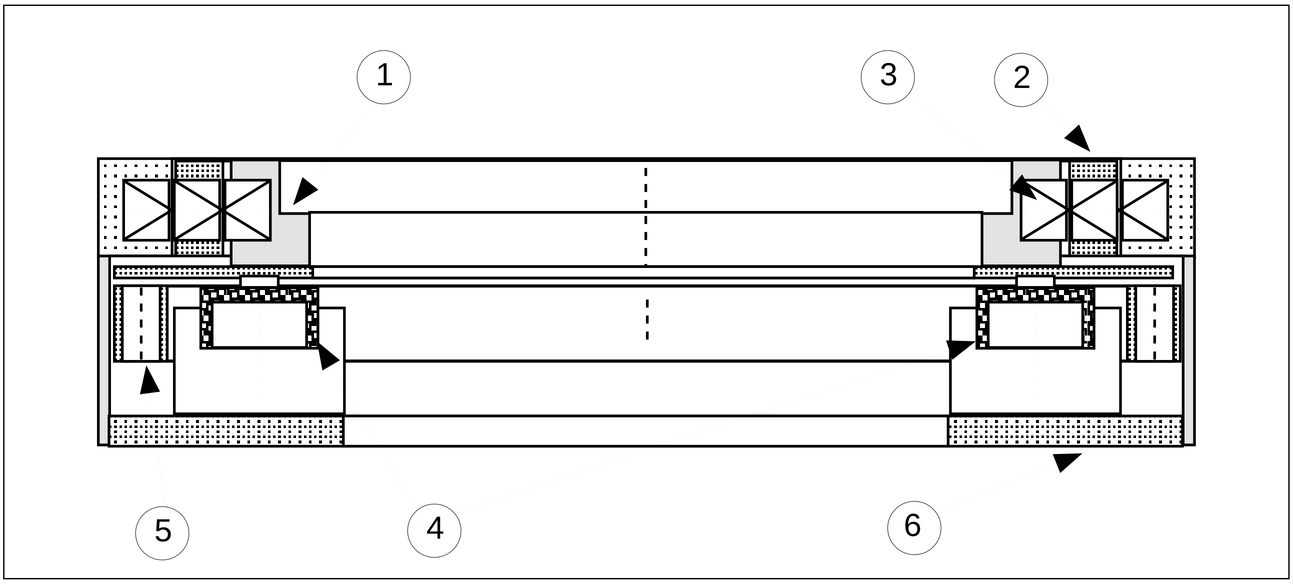

Figure 3: Tip Tilt Mount Concept

Legend fig # 3:

1. Central ring of the gimbal mount receiving the DM interface
2. Intermediate ring of the gimbal mount
3. Flexible pivots
4. Actuators, voice coil type
5. Position sensors
6. Fixing interface surface.

The Tip Tilt mount is based on a gimbal mount concept which allows the two axes to tip and tilt. The internal ring (1) receives the DM interface. The actuators (4) and the position sensors (5) take place around the Deformable Mirror in order to allow to get enough room for the DM interface and to permit the tip tilt axes to be exactly onto the optical surface.

On both axes, we implement a pair of position sensors (5) which measure the central ring position with respect to the chassis, in differential mode. This concept gives a real angular measurement.

The central ring is activated by four linear motors (4) working by pair in push-pull mode, which produce smooth torque on both axes.

All the moving part of the gimbal mount equipped of the DM should be weight balanced with respect to the axes in order to dissipate the lowest power when the mount takes any orientation.

7.2 TTM and DM Assembly

The deformable mirror is sitting on the central ring interface (1) and the DM connector is clamped on the center of the TTM bottom (6) in order to limit the coupling of the central ring with the TTM

chassis through the DM wires.
If the coupling is too important, the main power dissipation into the actuators will be due to the torque coupling. Smooth and light wires should be used for the DM connections.
The connector supplying the actuators and the position sensor cable clamp for the DM will be implemented on the bottom surface (Fig # 4).

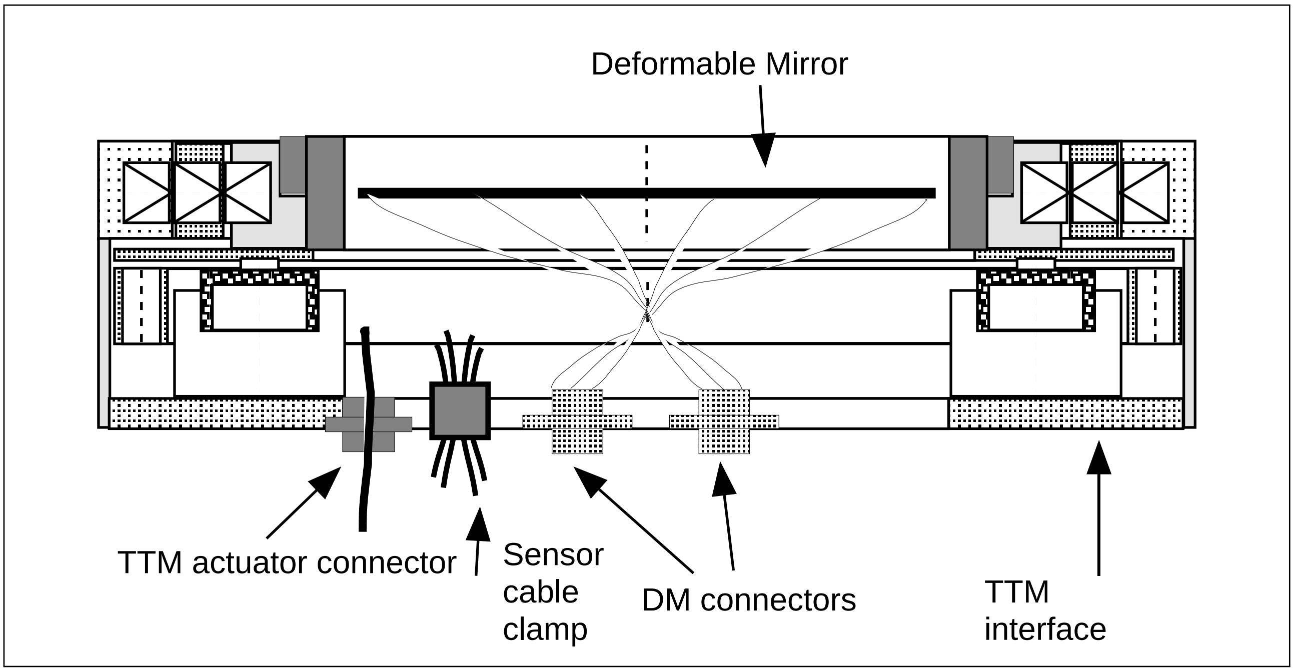

Figure 4: Deformable Mirror and TTM Assembly

The bottom of the TTM (6 Fig # 3) is foreseen to be used as a mechanical interface and electrical interface with the MACAO-VLTI support

7.3 TTM dimensions:

- Overall dimensions of the Tip Tilt mount: 287 mm
- Total height: 90 mm
- The estimate total weight of the mount: 8 to 9 Kg
- Inertia estimate of the moving part: 2×10^{-2} Kg/m ^{2}

7.4 Flexion

ESO will make the FEM for mechanical dynamic analysis from our design. The purpose of this analysis is to get a good approach of the first eigen mode frequencies in the 50 Hz to 500 Hz band. Special care will be on the modes which could disturb the performances of the servo loop. This analysis will be confirmed by the measurements made on the prototype.
The maximum lateral and longitudinal displacements of the DM surface is mainly due to the flexure of the flexible pivots.
Assuming the total moving mass is 2 kg, the radial rigidity of one pivot is: $5.7\ 10^{6}$ N/m
Assuming that there is no gimbal ring deformation and the lateral displacement is due only to the flexion of the pivots, the flexion estimate for 90 ° orientation change is: < 2 µm

7.5 Mechanical repeatability

The design has been made to provide the repositioning of the DM between dis-mounting and re-assembly within ± 0.1 mm. Two location pins will be implemented in the internal ring for the DM repositioning, one is bigger than the other one to keep the same orientation of the DM with respect to the TTM.

7.6 TTM Prototype

A Tip Tilt Mount Prototype will be manufactured to confirm the expected dynamic performance (frequency response and resolution). The FEM analysis will bring some information to improve our TTM prototype.

The TTM prototype will be equipped with a dummy DM with equivalent mass, inertia, center of gravity and interface.

8 SERVO CONTROL

8.1 Servo diagram

The servo loop components will be mainly the same than the ones we have used for the NAOS-Tip Tilt Mirror control system. This electronics will benefit of the same NAOS-TTM reliability.
The mirror accurate position is performed through two independent analogue local closed loops.
The power supplies and electronics boards will be installed into a 3 U, 19" EMC Europe standard chassis.

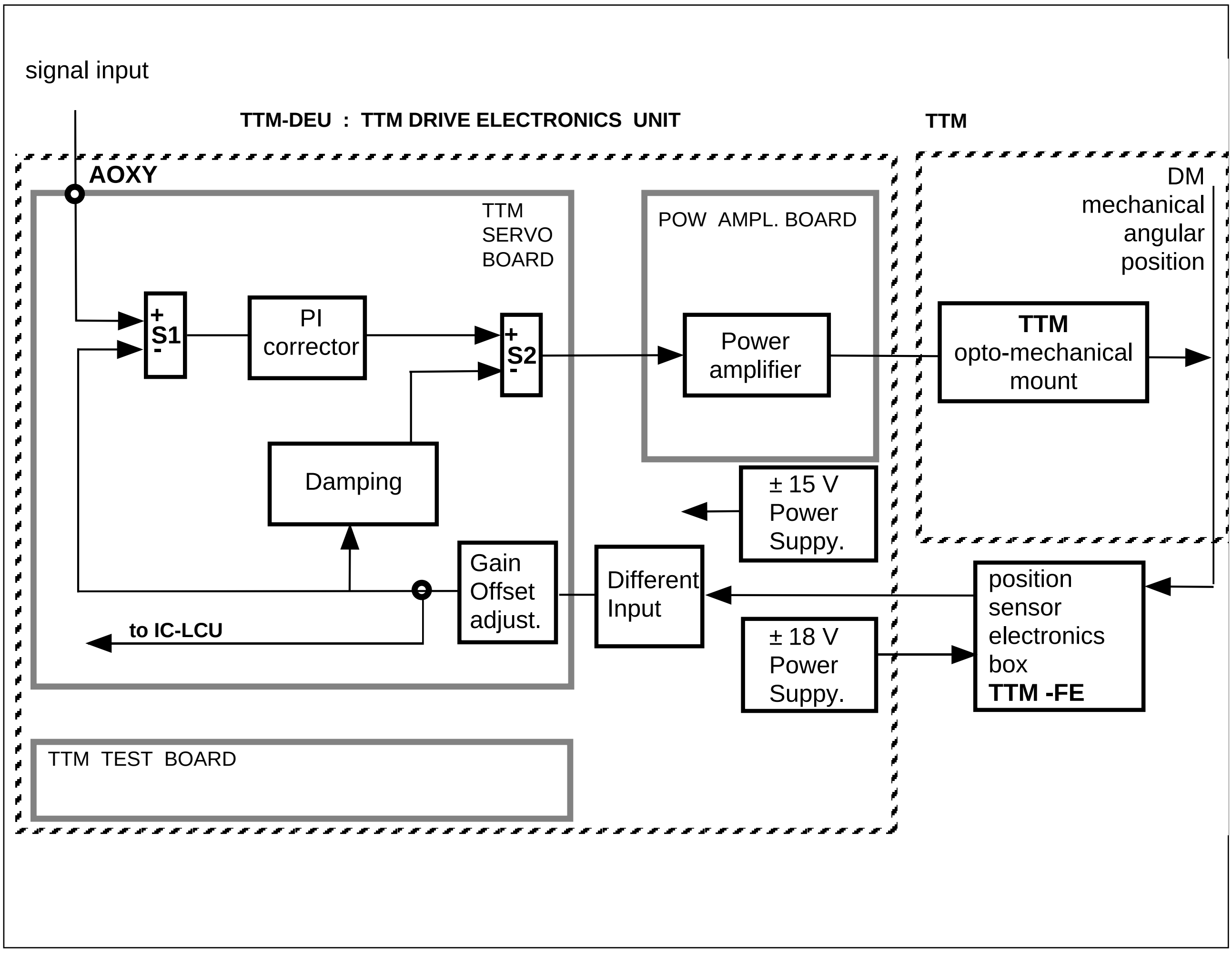

Figure 5: One axis servo concept

On Fig # 5 for both axes, the mirror position signal is received from the TTM-FE (position sensor electronic conditioner) by an interface board through differential amplifiers. After the adjustment of the gain and the offset, the position signal is compared to the drive signal in the summing junction “S1”. The proportional and intregal (PI) corrector and the position derivative come to stabilize the loop through the summing junction S2 which drives the power amplifier.
The parameters of the corrector will be adjustable in order to adapt the TTM servo loop behavior when the DM is in place.

8.2 Bandwidth analysis

On figure # 6, we represent the analog servo loop that we have simulated with MATLAB software.

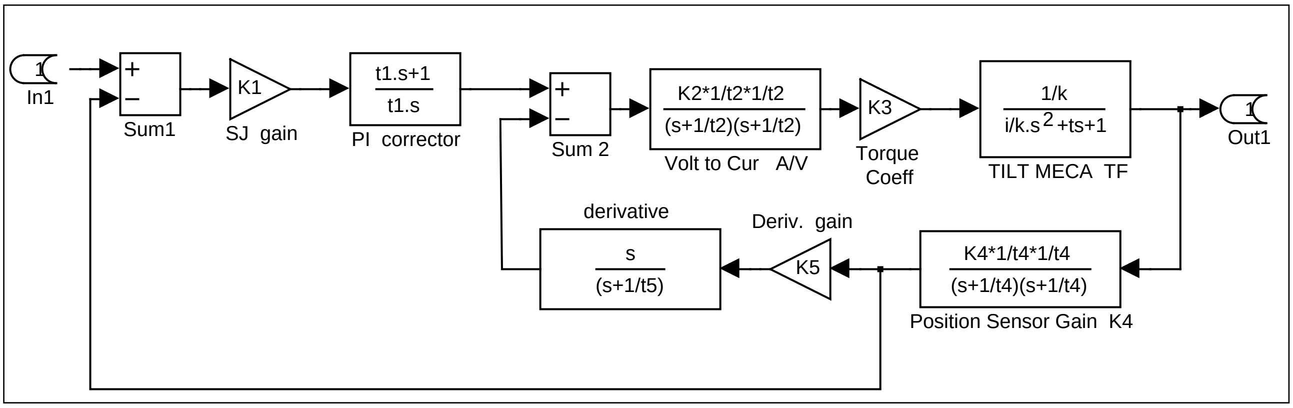

Figure 6: Diagram of one axis servo loop

From the current design, the tilting part (Dummy Deformable Mirror + central ring + intermediate ring) the inertia estimate is: 13 x 10^{-3} Kg.m^2
The flexible pivots (5020-400) torsional rate is 12 Nm / rad.
This mechanical approach gives the first eigen modes of the mechanism (Tip Tilt modes) around 6.8 Hz which is two times lower than the NAOS Tip Tilt Mirror eigen modes (12 Hz). We remind that the NAOS-TTM local closed loop has 350 Hz bandwidth at - 3 dB.
This approach is consistent with the objective of 100 Hz bandwidth specification.

A simulation of the servo closed loop as shown on the Fig # 6 gives a phase shift of - 16 ° at 15 Hz with 100 Hz of bandwidth of the local closed loop and less than 10% overshoot in the step response, for small signal, which is in agreement with the specification for this Tip Tilt Mount.

8.3 Mass and Inertia table

DESCRIPTION	Mass	Inertia Iyy	PDR estimate
VLTI - DM	813 gr	2,17 e- 03 kg.m ^{2}	5 e- 03 kg.m ^{2}
Dummy DM	787 gr	2,2 e- 03 kg.m ^{2}	
TTM with dummy DM	2683 gr	13 e- 03 kg.m ^{2}	2 x 10^{-2} kg.m ^{2}
Torsional rate			24 Nm / rd.
First eigen mode (tilt)			6.8 Hz

Table 1: Mass / Inertia of Dummy DM and TTMount

8.4 Power Dissipation

We propose to calculate the power dissipation into the TTM for one axis with two different hypothesyses, with the assumption that no perturbation is introduced by the DM.

8.4.1 Power dissipation for full range static angular deviation

Torsional rate, two pivots, one axis: Kt: 24 Nm/rad
Maximum tilt angle: An: 5.8×10^{-4} rad (120 arc sec)
Torque needed: T= Kt . An = 1.40×10^{-2} Nm
Lever arm: l: 192 /2 = 96 mm
Force: F = T/l = 0.145 N
Actuator coefficient Ac: 12 N/A
Actuator resistance: R = 15 Ohms
DC current needed for full stroke deviation: I = F/ Ac = 0.145 / 12 = 12×10^{-3} A
Power dissipation for one axis: RI^2 = 2 mW

8.4.2 Power dissipation with control signal

We propose to calculate the power dissipation into the TTM when we are applying a control signal at 10 Hz with an amplitude of 1/10 of the range:
Control signal: S = An sin wt
- Signal amplitude (1/10 of the range): An: 5.8×10^{-5} rad (12 arc sec.)
- Signal Frequency: 10 Hz (w = 62.8 rd/s)
Total estimated Inertia: J= 2×10^{-2} kg.m ^{2}
Actuator coefficient Ac: 12 N/A
Actuator resistance: R = 15 Ohms
Torque amplitude:
$T = J. An . w^2 = 2 \times 10^{-2} \times 5.8 \times 10^{-5} \times (10 \times 6.28)^2 = 4.5 \times 10^{-3}$ Nm
Lever arm: l = 96×10^{-3} m
Force amplitude: $F = T / l = 4.3 \times 10^{-3} / 96 \times 10^{-3} = 4.7 \times 10^{-2}$ N
Current amplitude at 10 Hz: I = F / Ac = 4×10^{-3} A
Power consumption: $RI^2 < 1$ mW

9 TTM DRIVE ELECTRONICS UNIT

9.1 TTM Drive Electronics Unit:

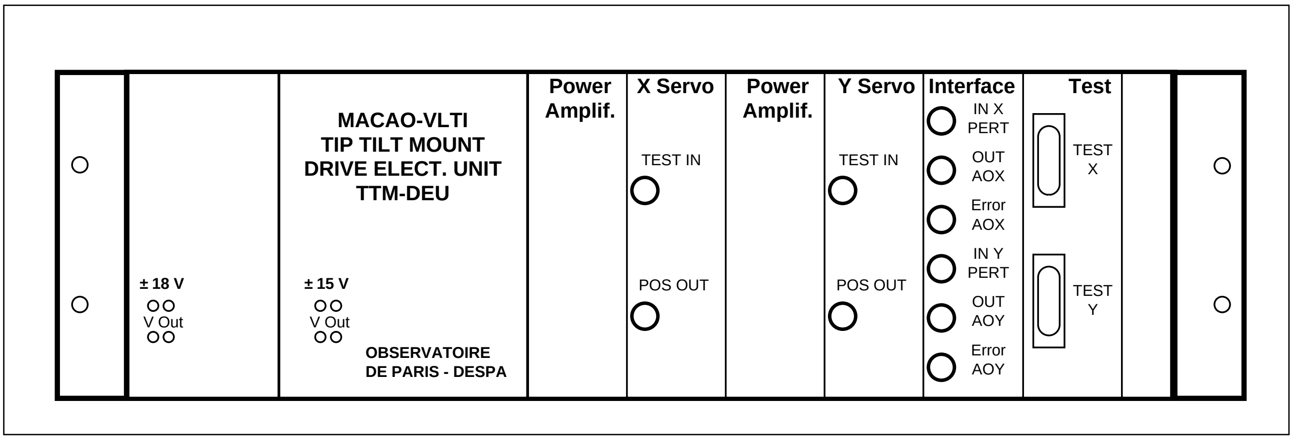

Figure 7: TTM-DEU Front panel

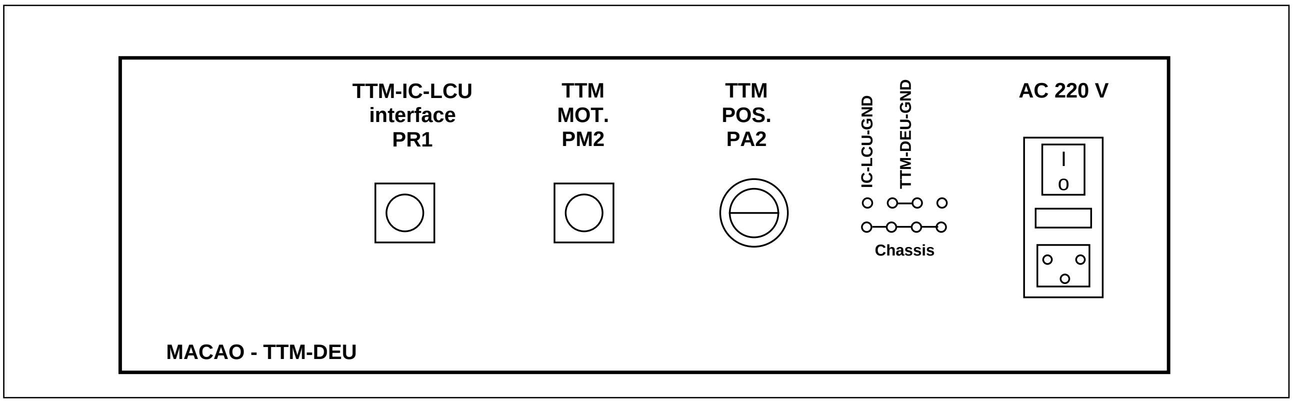

Figure 8: TTM-DEU rear panel

9.2 TTM-DEU Description:

We will pay attention to the EMC in order to reject the AC power and to reach the resolution of the system. (see chapter on EMC concept).

The TTM Drive Electronics Unit (Fig # 7 and 8) will be housed into a 19”, 3U, EMC chassis. This unit includes the control of the two TTM axes:

- the two servo boards
- the two power amplifier boards
- the interface board
- the testing board
- the two power supplies ± 15 V, ± 18 V.
- The +5V is generated from the +15V on the X servo board.

Each board is a printed circuit board 160 x 100 mm with edge connectors DIN 41612

This TTM servo electronic will be built to accept a 18 m cable length between the TTM-DEU and the TTM.
Especially, the signals coming from the sensor electronics will be received through a differential instrumentation amplifier (interface board).
The full power consumption estimate of this unit is less than 80 W.

9.2.1 X & Y servo boards:

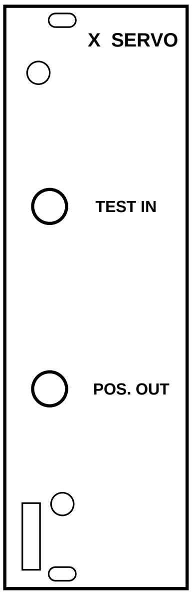

Figure 9: TTM Servo board front panel

Detail design is described in the schematic: VLT-SCH-ODP-15600-0-314000-0003 (or 0004)
For each axis, the analog servo board has to achieve the damping closed loop and the position closed loop.
This servo board includes some other functions such as test points and relays to make different servo loop configurations.
Two connectors will be implemented on the front panel to make easier the tests or maintenance: one connector "TEST INPUT" to apply directly any analog signal to the servo loop, one connector "POS. OUT" which gives the TTM position signal of the axis.
We will use two identical servo boards but as the two tilting axes do not have the same dynamic behavior, the tuning of each servo board is different. Consequently, the two servo boards will not be inter-changeable after their tuning.

9.2.2 Power amplifier boards:

Detail design on schematic: VLT-SCH-ODP-15600-0-314000-0005
The power amplifier Burr Brown 541 implemented on the board has to drive the two linear actuators in parallel. The maximum output current will be limited to provide the OP AMP protection against the short circuits.

9.2.3 Interface board:

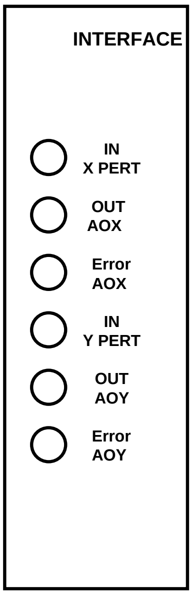

Figure 10: TTM Interface Board front panel

Detail design on schematic: VLT-SCH-ODP-15600-0-314000-0006
This interface board has three purposes:

- Receives in differential mode the two analog signals coming from the RTC.
- Receives the four position sensor signals coming from the TTM-FE.
- Gives the possibility to measure the adaptive optics frequency response of the Tilt correction. Some connectors are implemented on the front panel as shown on the fig # 10.

As we need a very high common mode rejection, specially at 50 Hz, we have chosen the instrumentation amplifier Burr Brown INA114. which has a very high Common Mode Rejection (90 dB for gain = 1).

9.2.4 Test board / Test Tools:

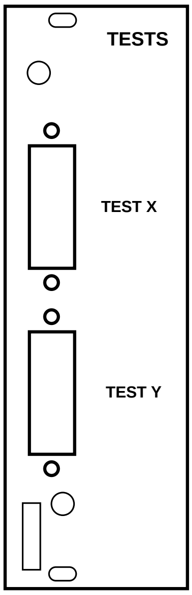

Figure 11: TTM Test board front panel

Detail design on schematics: VLT-SCH-ODP-15600-0-314000-0007 and 0008
To avoid any mistake during the test period or trouble-shooting such as short circuit or loading any amplifiers in the closed loop, we have designed an interface testing board which is mainly equipped with follower amplifiers with unit gain +1. This board stands a testing front edge connector where the main signals are accessible on two edge connectors. We can plug a “Test Box” on these test connectors (X &Y channel) to have access to test points into the local closed loop with three possible configurations without any hand change on the TTM servo boards.
As soon the test box is disconnected, the servo board returns in the previous configuration.
For for information, see the section: “Test and Maintenance”.

9.2.5 Power supplies:

To reach the high angular resolution required for the TTM system, we will use only the linear regulated power supplies with low noise level output: ± 15 V, ± 18 V.
The power supply (± 15 V) will feed all analog circuits of the TTM-DEU, mainly, the power amplifiers and the sensor electronics conditioner, while the ± 18.5 V power supply is dedicated to feed the TTM-FE, due to the long cable.
We will procure the power supplies from KNIEL, with over-voltage protection as recommended by ESO.

9.3 TTM Cable set:

9.3.1 Cables

Detail design on schematic: VLT-SCH-ODP-15600-0-314000-0001

As shown on the general overview on the TTM assembly fig # 2 the TTM has two cables coming out of the mount.

- The first wrap-cable “TTM-SENS” is composed of the four sensor cables which are connected into the TTM to the position sensors. This set of cables are clamped to the mount. These four sensor cables go to the TTM-FE box where they are connected. The wrap-cable can not be longer than 170 cm.
- The actuator power cable “TTM-ACT” disconnectable from the bottom of the TTM and going to the TTM-DEU. Length: 18 m
- The sensor cable “TTM-FE-SENS” for the 4 position signals and the ± 18.5 V, connected to the TTM-FE and to the TTM-DEU. Length: 18 m.

The interface cable with the IC-LCU will not be made, only the connector “PR1” will be provided to ESO.

9.4 TTM Electrical Schematics table

NUMBER	FORMAT	TITLE
VLT-SCH-ODP-15600-0-314000-000	A3	GENERAL WIRING
VLT-SCH-ODP-15600-0-314000-0001	A3	CABLE SET
VLT-SCH-ODP-15600-0-314000-0002	A3	TTM-DEU WIRING
VLT-SCH-ODP-15600-0-314000-0003	A3	SERVO BOARD X
VLT-SCH-ODP-15600-0-314000-0004	A3	SERVO BOARD Y
VLT-SCH-ODP-15600-0-314000-0005	A4	POWER AMPLIFIER
VLT-SCH-ODP-15600-0-314000-0006	A3	INTERFACE BOARD
VLT-SCH-ODP-15600-0-314000-0007	A3	TEST BOARD
VLT-SCH-ODP-15600-0-314000-0008	A3	TEST BOX

Table 2: MACAO-VLTI-TTM Electrical Schematics table

10 PRODUCT TREE

10.1 Product tree

The Tip Tilt Mount Assembly (TTMAs) has the product number:
This product three gives the list of the parts that will be delivered for one TTM Assembly.

Main TTM parts	Parts number	Comments or spares
312000 TTM: Tip Tilt Mount	Mechanical Mount Assembly: - Dummy Deformable Mirror - 4 actuators - 4 flexible pivots - 4 position sensors - sensor cable set	Tools: cover and locking system for transport
313000: TTM-FE: Sensor Electronics	TTM-FE: Front End Sensor Electronics	
314000: TTM-DEU	- power supplies - servo boards - power amplifier board - interface board - test board - test box - TTM-FE-SENS: sensor cable from TTM-FE to TTM-DEU - TTM-ACT: actuator cable from TTM to TTM-DEU - TTM-IC-LCU Cable: command and status cable from the TTM-DEU to the IC-LCU (RTC): provided by ESO - AC 220V power cable	
TTMAs box	TTM transport and storage box	

Table 3: Tip Tilt Mount Assembly product tree for one TTM set

For the MACAO-VLTI - TTM, we expect to fabricate:

- one complete TTM Assembly prototype: TTM + cables +TTM-FE + TTM-DEU (see above the product tree)
- four complete TTM Assemblies: TTM + cables +TTM-FE + TTM-DEU and one “Test Box”.
- Spare parts: We will deliver one cable spare set, one TTM-FE, one complete TTM-DEU

10.2 main components

10.2.1 Flexible pivots:

Manufacturer: Lucas Aerospace

- Free flex pivot reference: 5020-400
- Torsional spring rate: 12.Nm/rd

- Radial stiffness rate: 5.7 10^6 N / m
- Axial stiffness rate: 11 10^6 N / m
- Capacity load: 283 kg
- Life time: infinite life due to the low load and to the small angular stroke
- No friction and no maintenance

10.2.2 Actuators:

The four actuators are home-made.

- Actuator type: linear motor or voice coil type.
- Stroke range: 1 mm
- Coil resistance: 15 Ohm
- Motor coefficient: 12 N / A
- Force peak with 10V: 8 N
- Coil weight: 22 g
- Magnetic body weight: 280 g

The magnetic housing is made in a specific steel and is protected again rust before assembling.
The coils are sub-contracted and made with thermal bonding in order to have a very good reliability and a high stiffness.

10.2.3 Position sensors:

Manufacturer: FOGALE-nanotech

- Sensors type: capacitor. They are robust and present a very high resolution.
- Reference: MCC 10
- Displacement range: 500 µm
- Bandwidth: 0 to 10 kHz
- Resolution: 4 x 10^{-5} mm with a 1 kHz bandwidth

The manufacturer delivers the sensors with their cable and the electronic conditioner. One has to notice that the electronic conditioner is calibrated with the delivered sensors. For this reason, the delivery of sensor spare does not make sense.
We find the position sensor and their electronics data sheets in appendix.

10.2.4 TTM Front End Electronics (TTM-FE):

The TTM-FE is the sensor electronics box which comprises four conditioner channels. Each channel is tuned with its dedicated sensor and its own cable.
The four sensors have been labelled C1, C2, C3, C4 with the sensor cables labelled 1, 2, 3, 4. These four sensor cables will be put into a protective sheathe.
In order to get the best signal to noise ratio for the resolution of the sensors and to minimize the power dissipation is this box, two voltage regulators (±15V) have been implemented.
This electronics box should be powered with ± 18.5 V DC (18 V DC minimum). This power supply is integrated into the TTM-DEU.
The consumption is 0.290 mA. The power dissipation of the TTM-FE box is 10,75 W.
The sensitivity of the module is calibrated by the manufacturer at: 10 V for 500 µm with the load of

500 Ohms.

MCI 4930 Specification:

- Module for 4 synchronous capacitive sensor conditioners
- Low pass filter at 3 KHz
- Power supply ± 18,5 V, with internal ±15V DC voltage regulator.
- Resolution: 0.04 µm
- Calibration: 10 V for 500 µm with the load of 500 Ohms
- Option: current line driver, 2 wires, 10 V = 20 mA / 500 Ohms.
- Output connector LEMO FFA 3S 316

11 EMC CONCEPT

11.1 EMC Schematic:

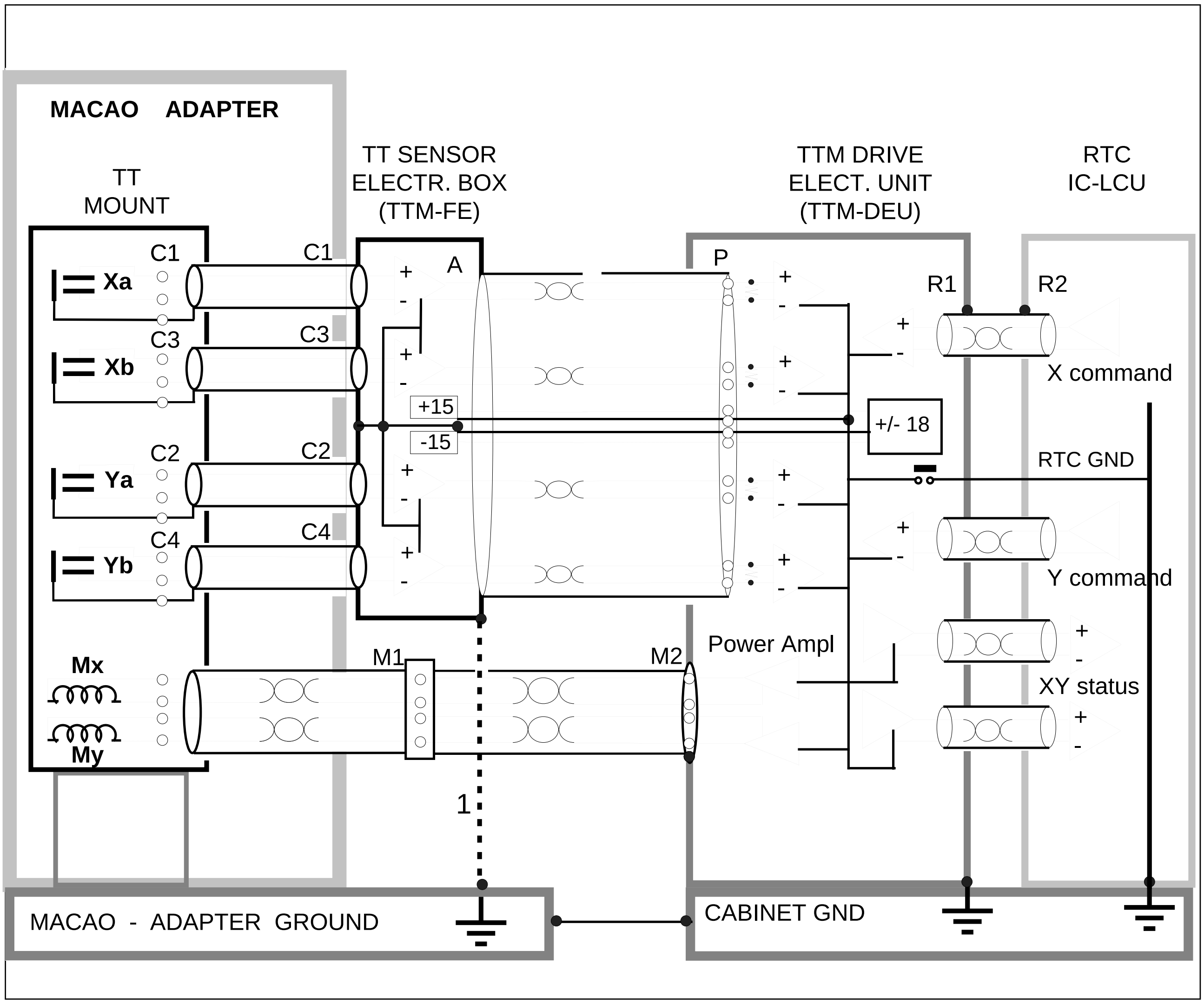

Figure 12: EMC concept schematic

11.2 TTM EMC Concept:

In order to reach the high resolution required for the TTM system, we have to pay attention to the protection against the Electro-Magnetic Interferences into the TTM system and with respect to the external interfaces such as the IC-LCU interface.
As the TTM system is a full analog servo loop which has a bandwidth about 100 Hz that includes the AC 50 Hz frequency and some harmonics, we should not have any GND closed loop for the low frequencies and we should have the best protection against the high frequencies EMI too.

Starting from the position sensor conditions imposed by the manufacturer in order to keep the sensor resolution, we have designed the EMC principle schematics (fig #12) keeping the EMC rules following as:

- no GND loop through any electrical wire at low frequency.

- use of shielded twisted pair wires.

Constraints:

- The four position sensor shields are connected to their support.
- The four position sensor shields are connected to the sensor electronics box (TTM-FE).
- The sensors power supply GND is connected to the TTM-FE chassis.
- The sensor electronics box is powered with ± 18 V coming from the TTM-DEU.

We have figured out the connection principle represented in the fig #12:

- The four sensors are insulated locally from the TTM chassis
- The four sensor signal reception is done with an instrumentation amplifier which has a high common mode rejection (90 dB CMMR at G=1).
- We use a twisted pair shielded cable for the sensor signal between the TTM-FE box and the TTM-DEU.
- The sensor cable shield is continuous all along the cable from the TTM-FE box to the TTM-DEU.
- The sensor cable shield is open on the TTM-DEU chassis in order to avoid the GND loop through the chassis.
- The motor drive cable is a twisted pair shielded cable with the shield connected to the TTM-DEU chassis.
- The TTM-DEU receives the two TTM command signals (X & Y) coming from the IC-LCU through a differential instrumentation amplifier. Nevertheless, a jumper is expected to be implemented if the IC-LCU GND is required (lab or site tests). (see fig # 13 &14)
- The only one TTM system GND connection to the MACAO GND is expected through the TTM-FE box.

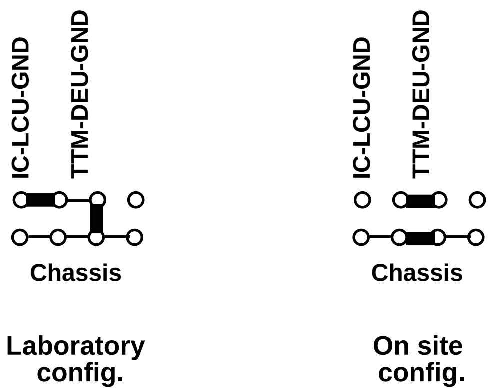

Figure 13: TTM -DEU Grounding Configuration

12 TTM INTERFACES

The electrical interface give hereafter the general concept

12.1 TTM Drive Electronic Interface:

The TTM Drive Electronics Unit receives the two analog signals through two differential amplifiers. Maximum voltage +/- 10 V.
The TTM-DEU returns two analog signals +/- 10 V which give the tilt angle position with respect to the chassis.
The electrical interface concept is shown on the fig # 14:

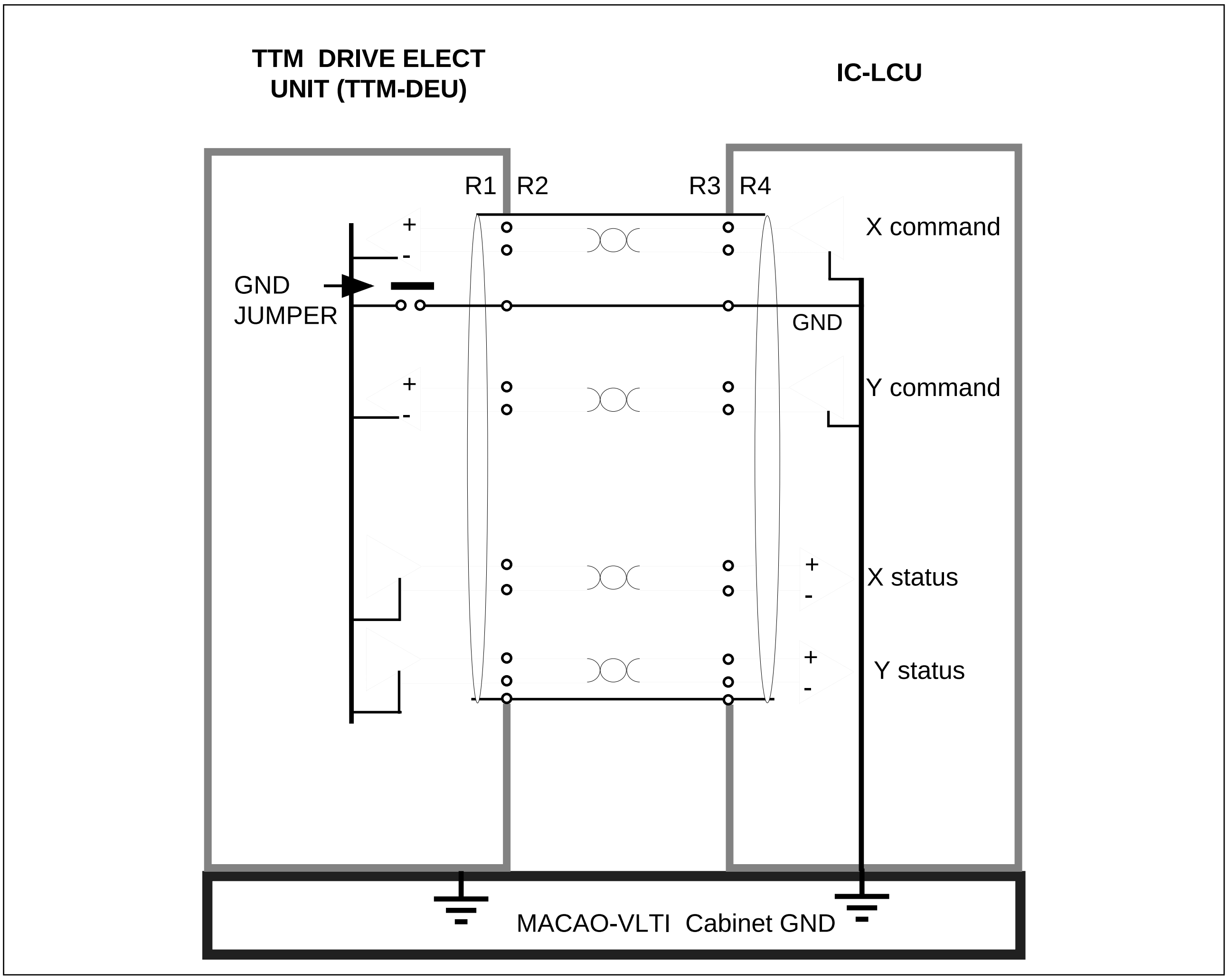

Figure 14: TTM Drive Electronic Interface Concept

In this concept, the all signals are received through differential amplifier.
A jumper connection between the IC-LCU-GND and the TTM DEU-GND is foreseen on the rear panel when it is needed for the test period in the laboratory.

12.2 TTM-FE Interface:

This electronics box has its own ± 15 V regulator and is powered from TTM-DEU with a dedicated linear power supply +/- 18.5 V.
This box should be implemented close to the TTM (less than 1.7 m)
TTM-FE box dimensions: 160 x 160 x 90 mm
<u>This TTM-FE box is a referential electrical ground</u>
As this box dissipates about 11 W, a convenient place should be find in order to not generate any turbulence into the optical beam but close to the TTM due to the sensor cable length (+/ 1.7 m).

12.3 TTM Drawings table:

Basic VLTI-TTM numbering: VLT-DWG-ODP-156000-0-312000-0000

Items #	Drawing #	For-mat	Title	Material	Mass
	0102	A3	MACAO-VLTI-TTM-DM I/F drawing		
	0116	A0	SUPPORT BARILLET (VLT-TTM I/F drawing)		
	0000	A2	TTM ASSEMBLY 1/2 & 2/2		
3	0111	A0	ANNEAU BOITIER	Fortal Hr	
20	0112	A3	ANNEAU INTERMEDAIRE	2618A	
19	0113	A2	ANNEAU INTERIEUR	2618A	
21	0114	A4	CENTRE-DM-DIA6	Z10CN18-10	
22	0115	A4	CENTRE-DM-DIA4	Z10CN18-10	
4	0130	A4	ENTREFER-AIMANT	ARMCO	
5	0131	A4	MOTEUR-BOBINE	2618A ou2017	
6	0132	A4	SUPPORT-CAPTEUR	2017	
7	0133	A4	SUPPORT-CIBLE-CAPTEUR	Z10CN18-10	
8	0134	A4	CIBLE-CAPTEUR	LAITON UZ9	
10	0136	A4	PONT-ELECTRIQUE-CAPTEUR	LAITON UZ39PB2	
11	0137	A4	RD-ISOLANTE-SUPPORT-CAPTEUR	ARMODUR	
28	0211	A3	BARRE-CENTRAGE	FORTAL	
29	0212	A4	BARRE-CENTRAGE	Z10CN18-10	
30	0213	A3	FAUX-MIROIR	FORTAL HR	
31	0214	A4F	IXATION-TRANSPORT	2017	
32	0215	A4	PROTEGE-MIROIR-TRANSPORT	2017	
33	0216	A4	COLONNETTE-PROTEGE-MIROIR	2017	

Table 4: VLTI-TTM DRAWINGS TABLE

Items #	Drawing #	Format	Title	Material	Mass
62	0217	A4	IMITE-PIVOT	Z10CN17-10	

Table 4: VLTI-TTM DRAWINGS TABLE

13 MAINTENANCE AND TESTS FACILITIES:

13.1 Reliability

The technology of this Tip-Tilt Mount is identical to the one used on the Canada-France-Hawaii adaptive optics tip-tilt mirror, and ADONIS field selector mirror (Chile, 3.6 m ESO). These components have been in service since 1992 and 1989 respectively without any failure. Maintenance has also been minimal on these components which illustrates their robustness.
The critical components: power supplies, power amplifiers, flexible pivots and actuators are chosen with large security margins with respect to the manufacturers quoted performances.

13.2 Criteria of maintenance for the TTM Assembly:

- Easy access to the TTM. The TTM shall be relatively easily accessible; meaning no particular prowess are necessary to access it and its surrounding.
- The TTM has a positioning system on its interface for repositioning.
- The parts of the TTM are mounted all together with location pins for repositioning. This makes the re-assembly much easier.
- The TTM is dismounted with the cables section going from the mirror unit to the TTM-FE box unit
- All cables will be clearly labeled to allow the operator no possible error in cabling.
- The connectors used are different size, swap connections are not possible

13.3 Preventive Maintenance Operations

- All operations on TTM Assembly requires the operator to wear a grounded bracelet (sensitive to electrical static discharges)
- Check test points on TTM-FE box are implemented
- The DM can be dismounted easily from the TTM for maintenance operation if required.

13.4 Maintenance and tool: test box

Everyone knows that it not easy to make a trouble shooting of a servo system closed loop. Sometime, we need to open the loop to test any elementary function. When someone does a configuration change into a closed loop for trouble shooting, the return into the previews configuration may be the cause of a new trouble.

We have designed a “Test Box” (Fig # 15) which could be connected anytime to the TTM local servo loop to check it without any others change. This “Test Box” gives access to many test points of the connected axis. It gives three configurations of the servo loop with the choice of one internal generator calibrated signal or one external generator. As soon as the “Test Box” is disconnected, the servo loop gets back to its previous configuration.
All signals accessible from the “Test Box” have been buffered with a follower amplifiers on the “Test Board” which gives protection of the servo circuit against the short circuit or static discharges.

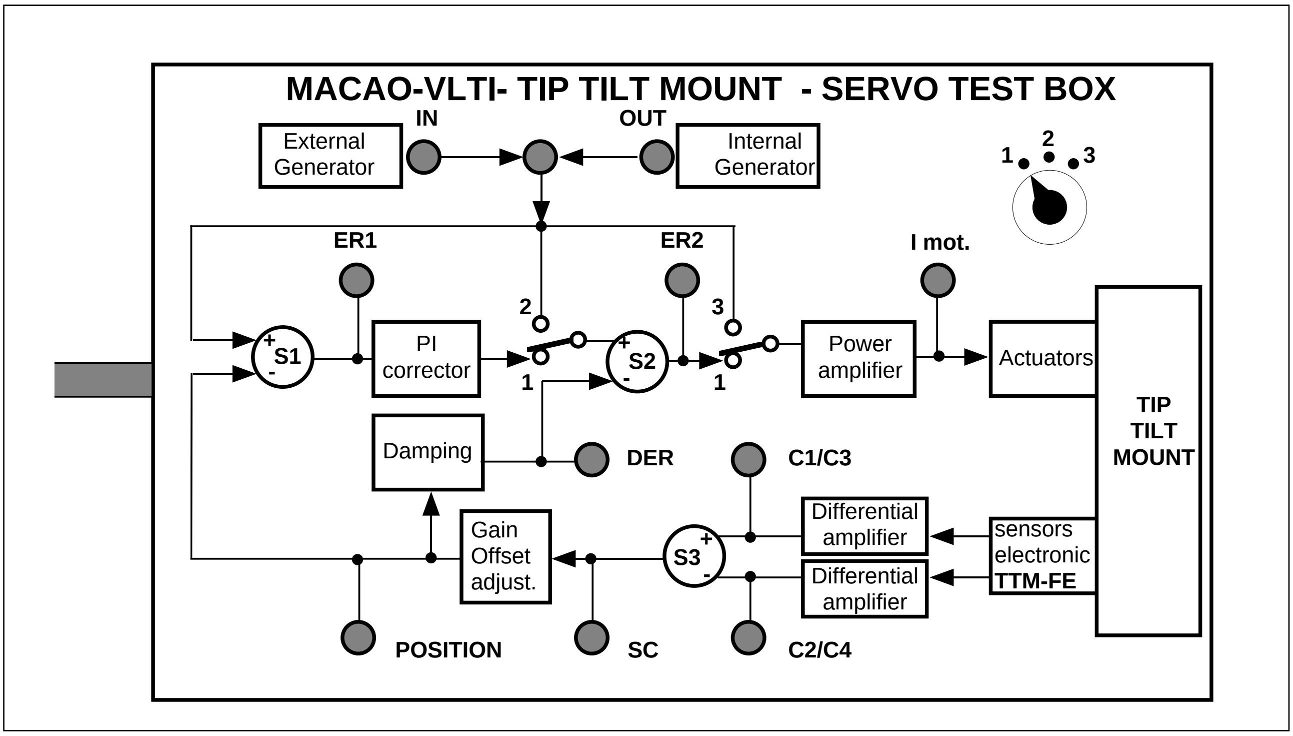

Figure 15: TTM - Servo Test Box

The schematic of the servo loop has been represented on the top of the "Test Box" (Fig # 15) with the test connectors which give access to the basic analog function of the local servo loop. All connectors give an output signal except the external generator "IN" which is an input connector for the external generator.
The "Test Box" can be connected either to the "TEST X" or "TEST Y" connector of the test board front panel.

The "Test Box" allows with the rotating switch three servo loop configurations:

- Configuration (1) makes the system work in normal position local closed loop.
- Configuration (2) makes the system work in damped closed loop only, the position feed back is opened.
- Configuration (3) makes the servo in open loop, and the signal is directly applied to the input of the power amplifier.

The switch selector gives the choice between the internal generator or the external generator.

14 ACCEPTANCE TESTS

The dynamic and static tests will be performed with a dummy Deformable Mirror.

The tests will be conducted at room temperature and at - 10 ° C.
They will include for both axes:

- All static voltage measurements in the vertical position of the optical axis.
- The power consumption measurement.
- The angular sensitivity calibration with an autocollimator.
- The frequency response which gives the bandwidth at - 3 dB
- The step response at 1 / 10 of the tilting full amplitude range. This test shows the rise time and the stability of the local servo loop.
- The cross-talk frequency response between each axis.

A test document will report all the records and measurements.

15 APPENDICES

- The TTM Electrical Schematics
- The TTM-FE data sheets
- The main component data sheets
- The TTM Mechanical Drawings

NO TEXT