VLT PROGRAMME

VERY LARGE TELESCOPE

VLTI - UT Vibration Monitoring System

Doc. No.: VLT-SPE-ESO-15400-4013

Issue: 1

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CHANGE RECORD

ISSUE	DATE	SECTION/PAGE AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
1.0 / prep 1	18/07/2006	All	First Preparation
1.0 / prep 2	06/09/2006	All	After lab tests in Garching
1	09/11/2006	All	After sky tests Paranal

	VLTI - UT Vibration Monitoring System	Doc. Issue Date Page	VLT-SPE-ESO-15400-4013 1 09/11/2006 3 of 27

ESO

TABLE OF CONTENTS

ESO

VLTI - UT Vibration Monitoring System

Doc.   VLT-SPE-ESO-15400-4013
Issue   1
Date   09/11/2006
Page   4 of 27

1 INTRODUCTION

1.1 Purpose

The purpose of this document is to specify the system of sensors in the Unit Telescope main structure to measure vibrations. The signals from these sensors are used by the VLTI fringe tracking loop to improve the performance. The project is code named Manhattan2[1].

1.2 Scope

This document is applicable to the design, installation, commissioning and maintenance of the UT Vibration Monitoring System.

The current version reflects the "as-built" status after first sky tests using UT3 and UT4 in October 2006. The document shall be updated after full deployment on all UTs.

The documentation is kept under configuration control in the cmm module named VLT-SPE-ESO-15400-4013.

1.3 Applicable Documents

Ref	Document Number	Issue	Date	Title

1.4 Reference Documents

Ref	Document Number	Issue	Date	Title
1	VMIC	E		VMIVME-3123 Product Manual
2	Brüel & Kjaer			Product Data Nexus 2690-2693

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[1] For an explanation of this name, please contact the author.

1.5   Abbreviations and Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

AD	Applicable Documents
ADC	Analogue to Digital Converter
AT	Auxiliary Telescope
cmm	Configuration Management Module
CPU	Central Processing Unit
DL	Delay Line
DLCS	Delay Line Control Software
FSU	Fringe Sensor Unit
I/O	Input/Output
LCU	Local Control Unit
OPD	Optical Path Difference
OPL	Optical Path Length
PPC	Power PC
PSD	Power Spectral Density
RD	Reference Document
RMN	Reflective Memory Network
S/N	Serial number
SCP	Service Connection Point
TBC	To Be Confirmed
TBD	To Be Defined
TIM	Time Interface Module
TRS	Time Reference System
UT	Unit Telescope
VLT	Very Large Telescope
VLTI	VLT Interferometer
VME	Versa Module Europe

2 OVERVIEW

The purpose of Manhattan2 is to provide sensors (accelerometers) to measure vibrations, which introduce OPD perturbations, in the UT telescopes structure. The sensor signals are acquired, processed and published on the reflective memory network and made available to the fringe tracking loop algorithms. Using the delay lines as actuators the system can attenuate the OPD residuals seen by the interferometric instruments.

Manhattan2 consists of a new local control unit (LCU), named *ltXvib*, in each of the UT's. This new LCU is located inside the mirror cell in order to interface to accelerometers mounted on the optical surfaces on the moving part of the telescope. The LCU is expandable to interface up to 12 accelerometers. The final number and exact locations of accelerometers are expected to be determined during the cause of tests in 2006 and 2007. This is supported by the finite element model of the telescope as well as local measurements. Interface to the outside world is implemented using the SCP in the mirror cell. The signal path is illustrated in Figure 2.1.
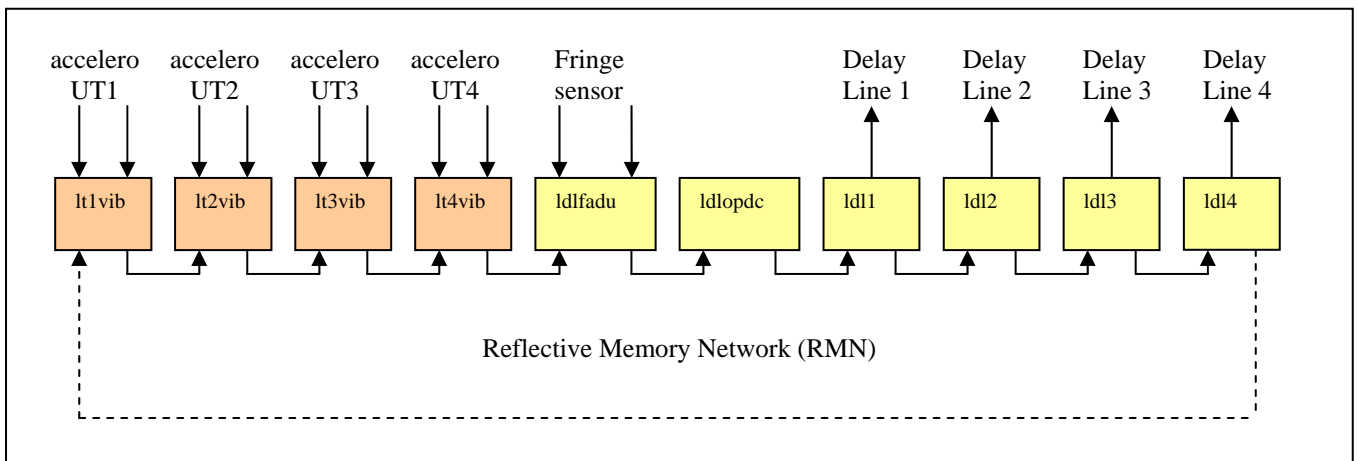

Figure 2.1. Signal path for using accelerometers in the fringe tracking loop

2.1   Principle of Operation

In the baseline scenario the system is used for feed forward control. The accelerometers on each optical surface are scaled to m/s^2, averaged, band pass filtered, double integrated and scaled again depending on the geometrical relation between optical surface and OPL. Finally all optical surfaces OPL are added together to generate one telescope OPL signal written on the RMN at the location corresponding to the associated delay line. The delay line reads the OPL correction signal from the associated telescope and adds this to its setpoint. All nodes on the RMN are synchronized by the VLT time reference system and the sampling rate is 2 kHz. Taking into account the system delays, in particular the delay line actuation, it is possible to achieve a good coherence in the frequency range of interest (~10-30 Hz) and therefore a decent attenuation with these parameters.

2.2   Demonstration of Feasibility

On October 9, 2006 the feasibility of the system was demonstrated using UT3 and UT4 and two accelerometers mounted on each M3. Figure 2.2.1 shows the relevant signals during fringe tracking.
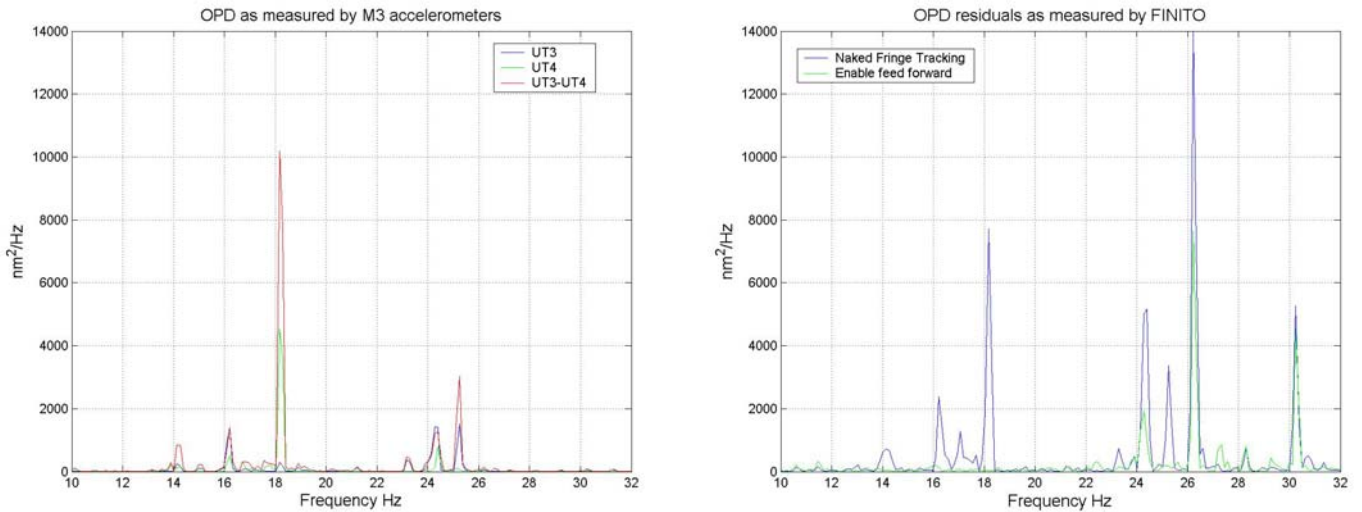

Figure 2.2.1. To the left the PSD of the OPL signals of UT3 and UT4 as well as the difference as generated by Manhattan2. To the right the OPD as measured by FINITO with and without feed forward enabled. The peaks detected by Manhattan2 are effectively attenuated by switching on feed forward. The total OPD residuals was in this case reduced from 465 to 374 nm RMS.

3 EXTERNAL CONNECTIONS

The electronics cabinet with LCU mounted in M1 cell connects to the M1 cell SCP. The external connections are power, liquid coolant and fiber optics.

The fiber optic connections are illustrated in Figure 3.1. Each LCU uses 5 fibers; 2 for RMN, 2 for network and 1 for TIM. The network is connected to the Ethernet fiber optic hub in the UT NAP. The TIM connects to the time distribution system in the UT NAP. The RMN is patched through to the VLTI computer room. Here it terminates in the RMN patch panel located to the right in the front row of cabinets in the VLTI computer room. The patch panel allows connecting and disconnecting (bypass) the node from the RMN ring network. The required changes to Paranal fiber optic network have been documented in PPRS-020299 and PPRS-020300.
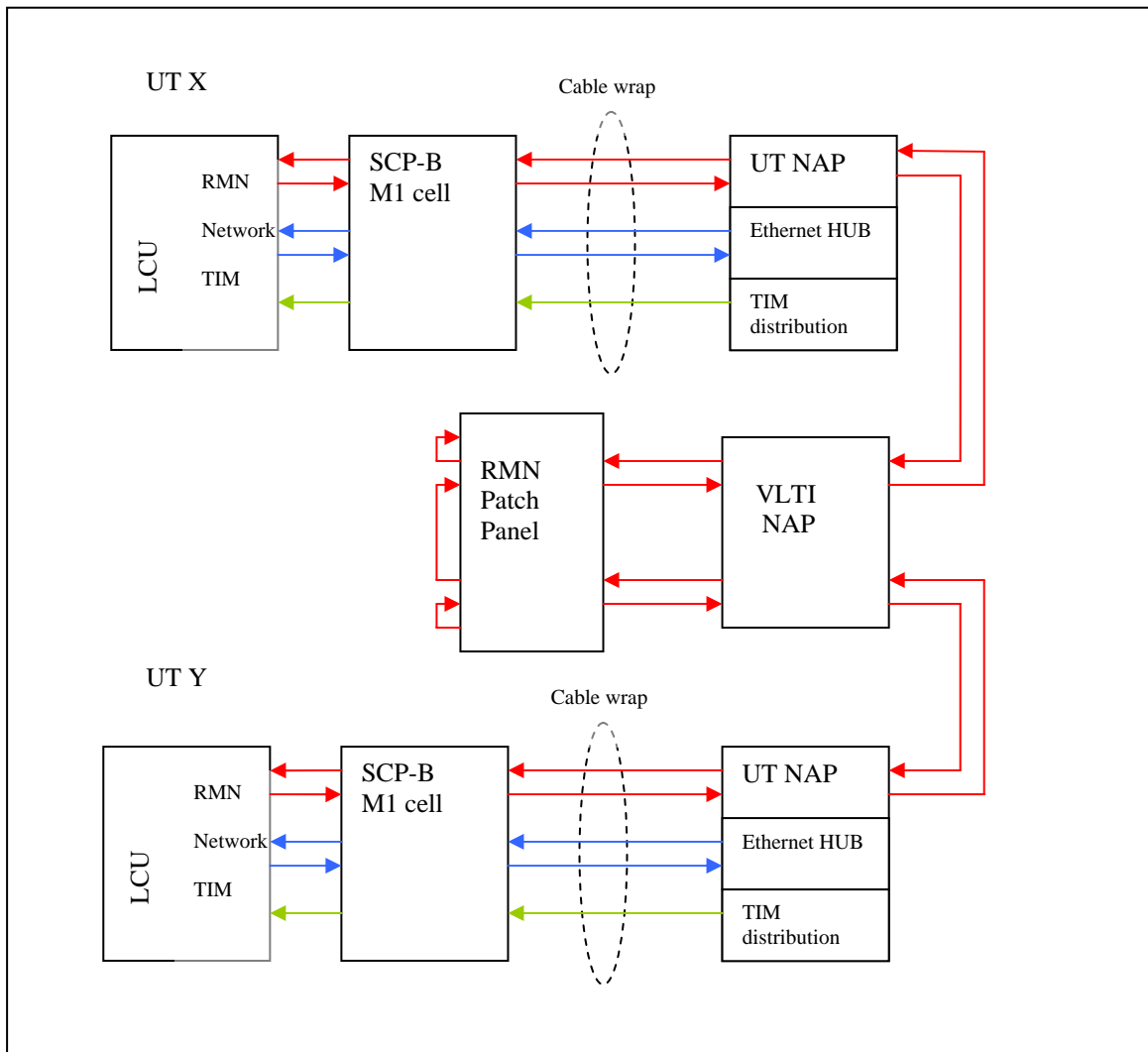

Figure 3.1. Fiberoptic interconnections (only 2 UTs are shown for simplicity)

4 ELECTRONICS CABINET

The LCU requires four VME boards; PPC CPU, RMN, TIM and ADC, plus the standard transition module for serial port and network. The first two VME boards require access to P2 backplane (ADC board is configured to use short I/O, e.g not use P2).

A 19" 6HE standard VME crate is shared between a 5 slot VME and accelerometer amplifiers, type Nexus 2692. A maximum of three amplifiers can be mounted in the allocated volume and each amplifier has four channels, e.g. the total system can support a maximum of 12 accelerometers. Initially only two amplifiers will be installed (max 8 accelerometers). The input from accelerometer uses connectors 10-32 UNF (compatible with Microdot) and adapters to TNC connectors and the output to ADC uses BNC. The internal wiring from amplifiers to ADC is provided inside the cabinet. The fans are of good quality in order not to induce vibrations.
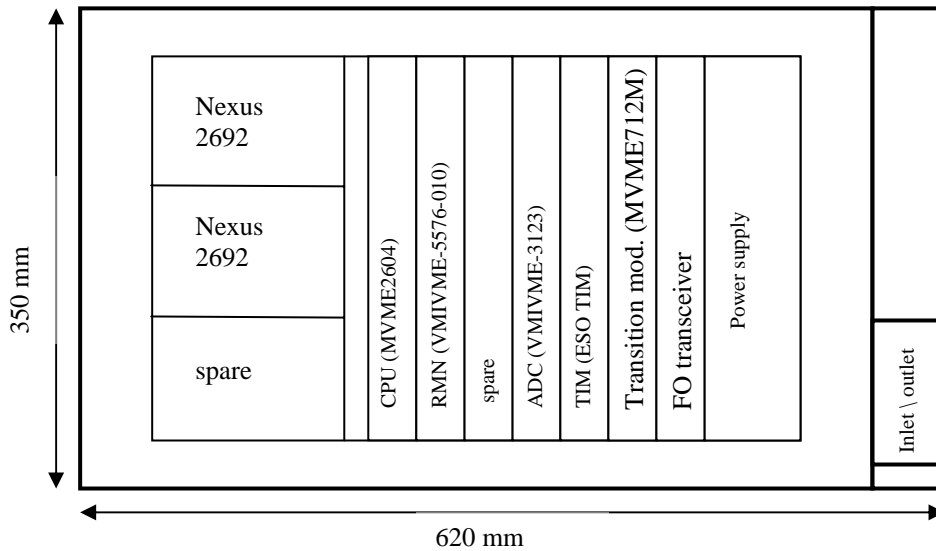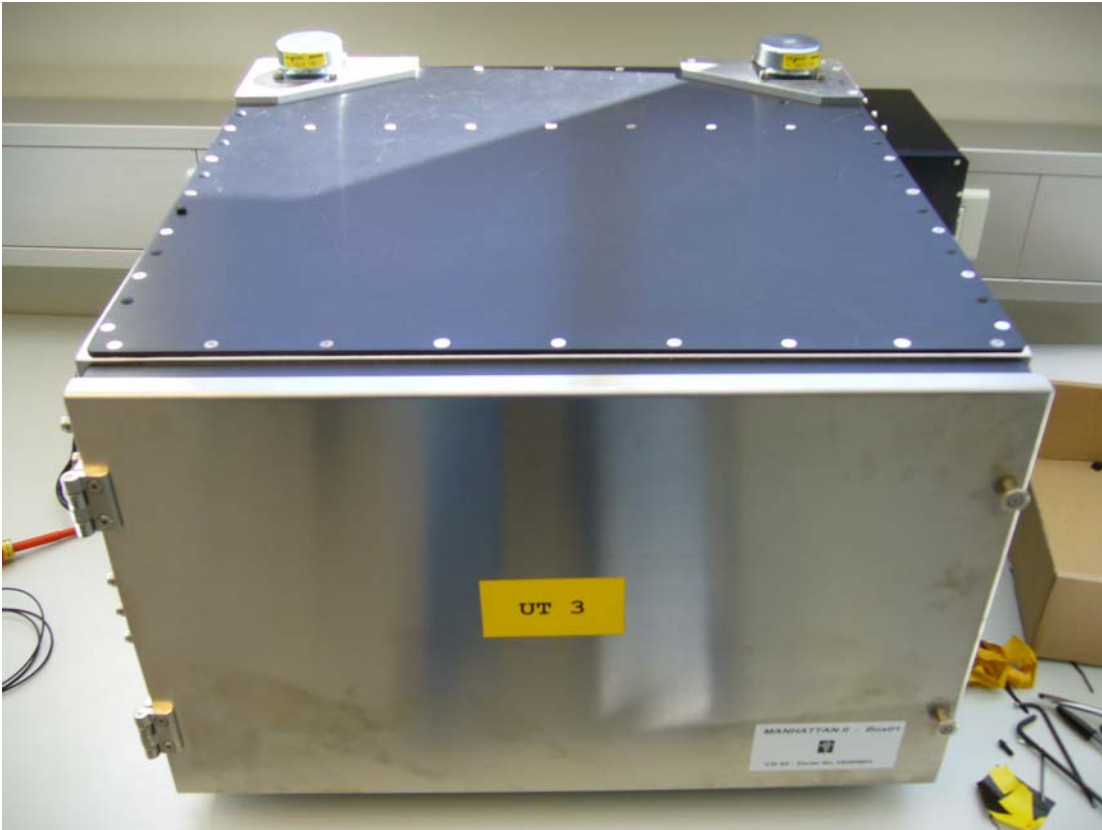
Figure 4.1. Front view of cabinet
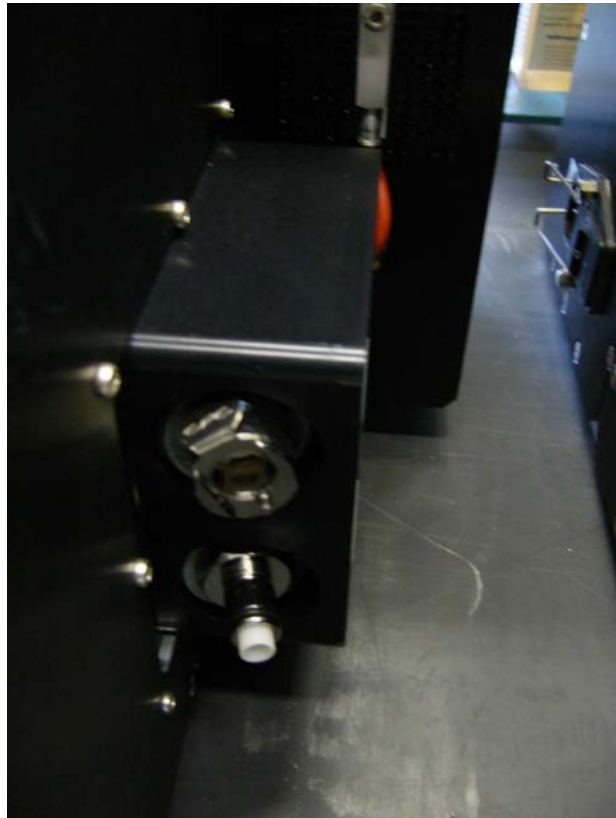
Figure 4.2. Picture of cabinet.

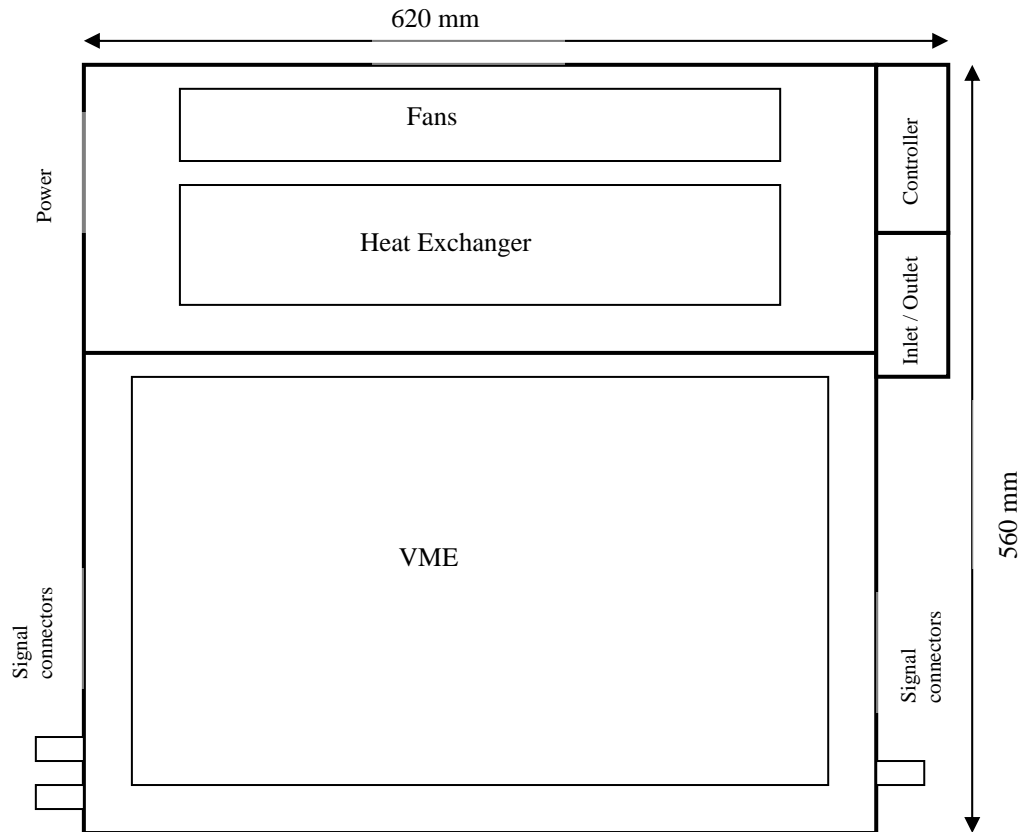*Figure 4.3. Detail of cooling liquid interface*

Figure 4.4. Top view of cabinet

The complete cabinet is closed. It is a reuse of cooled cabinet developed by the Infrared group for CRIRES and future IR instruments. All I/O connections to VME boards are done from the front. Therefore the distance between cabinet front panel and VME must be sufficiently large (> 5 cm). All external connections are made at the side; power, 2 fiber network, 2 fiber RMN, 1 fiber TIM, 12 accelerometers and liquid coolant inlet and outlet.

The liquid cooling supply from M1 cell SCPs have the following characteristics
- Maximum Delta Pressure: 1.1 Bar (without flow)
- Maximum Flow: 11 l/m, with a delta pressure of 0.3 Bar

Cabinets have been tested in the lab using a small portable cooling system (~3 l/m, ~0.3 Bar). Infrared camera was used to verify surface temperature compliance.
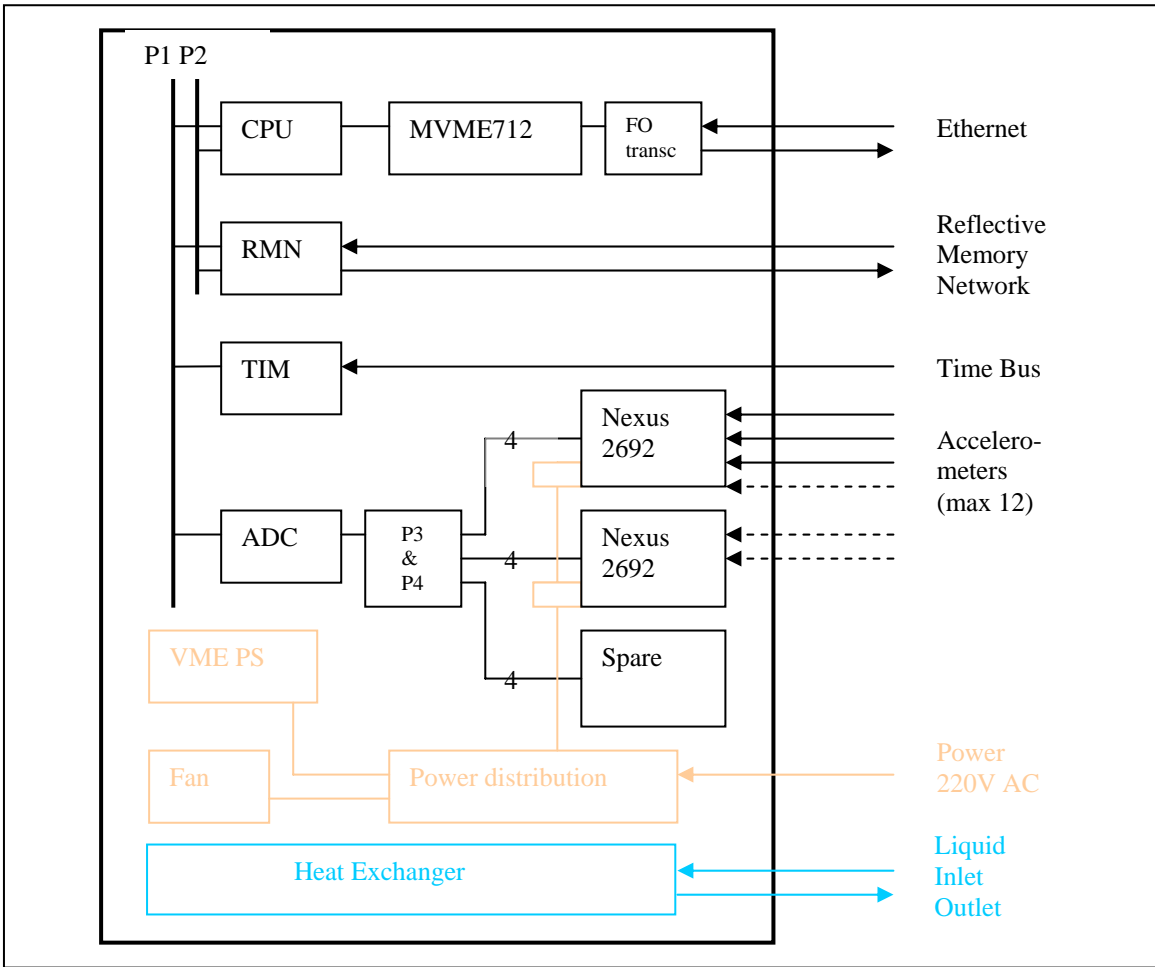
ESO

VLTI - UT Vibration Monitoring System

Doc.   VLT-SPE-ESO-15400-4013
Issue   1
Date   09/11/2006
Page   13 of 27

Figure 4.5. LCU interconnections

Item	Number	Description	Comment
1	1	VME crate	5 slot horizontal
2	1	Backplane P1	5-slot P1 backplane
3	1	Backplane P2	3-slot P2 backplane
4	1	Power Supply	Kniel
5	1	FO Transceiver	AUI - FO
6	1	Transition module	MVME712M Motorola Transition Module
7	1	CPU	MVME2604
8	1	RMN	VMIVME-5576 reflective memory
9	1	TIM	ESO Time Interface Module
10	1	ADC	VMIVME-3123 analogue to digital converter
11	2	Cooling fans	
12	1	Heat Exchanger	
13	1	Power distribution	
14	Max 3	Nexus 2692	Amplifiers to I/F accelerometers
15	Max 3	Power adapters	Adapters for Nexus 2692

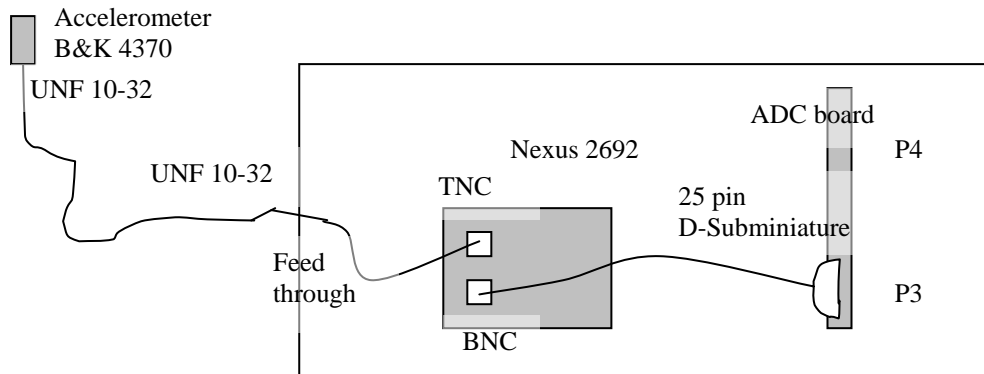*Table 4.1. Specification and list of components*

Figure 4.6. Wiring of I/O. Accelerometers are using cables with UNF 10-32 connectors. Feed through to the cabinet is currently being re-design most likely using UNF 10-32 connectors. To connect to the amplifier a UNF 10-32 to TNC adapter is used. Internally TNC connectors are used to connect to amplifier input. Amplifier connects to ADC board with BNC to 25 pin D-subminiature connectors.
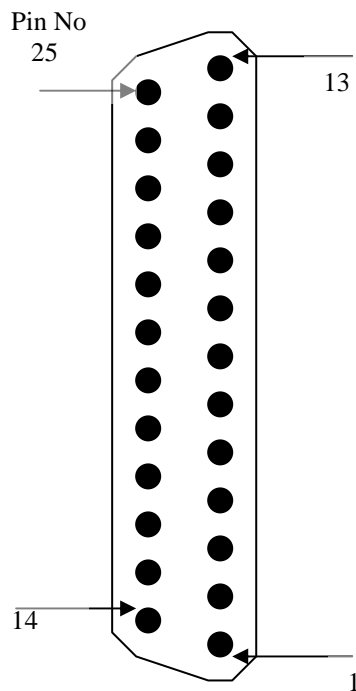
| Pin NO.	Signal P3	Signal P4
13	Analog (GND)	Analog (GND)
25	Channel 7 LO	Not used
12	Channel 7 HI	Not used
24	Guard (GND)	Not used
11	Channel 6 LO	Not used
23	Channel 6 HI	Not used
10	Guard (GND)	Not used
22	Channel 5 LO	Not used
09	Channel 5 HI	Not used
21	Guard (GND)	Not used
08	Channel 4 LO	Not used
20	Channel 4 HI	Not used
07	Guard (GND)	Not used
19	Channel 3 LO	Channel 11 LO
06	Channel 3 HI	Channel 11 HI
18	Guard (GND)	Guard (GND)
05	Channel 2 LO	Channel 10 LO
17	Channel 2 HI	Channel 10 HI
04	Guard (GND)	Guard (GND)
16	Channel 1 LO	Channel 9 LO
03	Channel 1 HI	Channel 9 HI
15	Guard (GND)	Guard (GND)
02	Channel 0 LO	Channel 8 LO
14	Channel 0 HI	Channel 8 HI
01	Guard (GND)	Guard (GND)

Figure 4.7. ADC P3 and P4 Connector and Pinout. As recommended in Ref[1] unused analogue signals (ch 12-16) are grounded, e.g. HI, LO and GND are connected in the connector. For used signals LO and GND pins are connected)

5   BOARD CONFIGURATION

The following host names, IP addresses and RMN node addresses have been allocated (SPR20060184)

Host name	IP address	RMN node address	Comment
lt1vib	134.171.216.56	0x61	UT1 vibration monitor
lt2vib	134.171.217.56	0x62	UT2 vibration monitor
lt3vib	134.171.218.56	0x63	UT3 vibration monitor
lt4vib	134.171.219.56	0x64	UT4 vibration monitor

*Table 5.1. Host names, IP addresses and RMN node addresses*

P1   P2

J10   J8   J9

J6   J7
J5
J3   J4
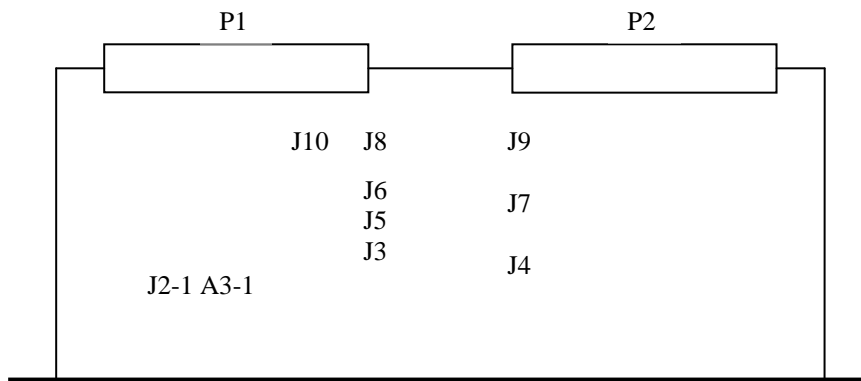
J2-1 A3-1

J2-1 A3-1	All 8 installed	J9 lt1vib	0::0 000:
J3	Installed	J9 lt2vib	0::0 00:0
J5	Empty	J9 lt3vib	0::0 00::
J6	Empty	J9 lt4vib	0::0 0:00
J8	Installed 2-3 (top)		from bottom to top
J10	Installed		
J9	Node address		
J7	All 8 installed		
J4	From bottom to top 000: 00:0	0=installed, :=empty	

Figure 5.1. Jumper setting RMN board (see man rmn for description)
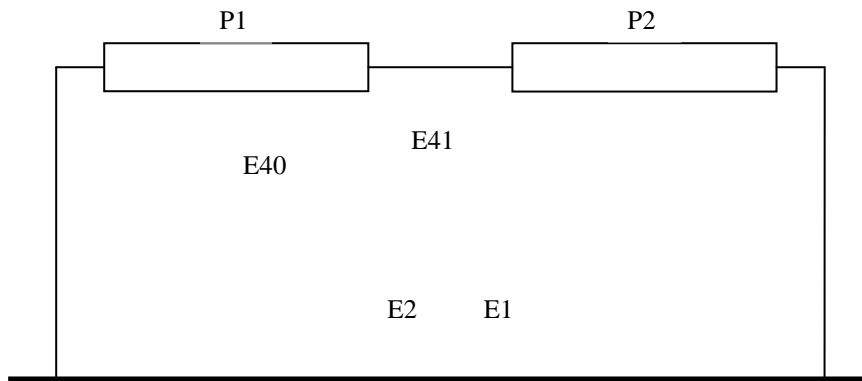
E1	Empty	Termination resistor for external trigger input
E2	Empty	P5 connector digital ground
E40	All installed	Access mode
E41	:0:00000	Short I/O address (from bottom to top, 1-2,5-6 empty)

Figure 5.2. Jumper setting ADC board
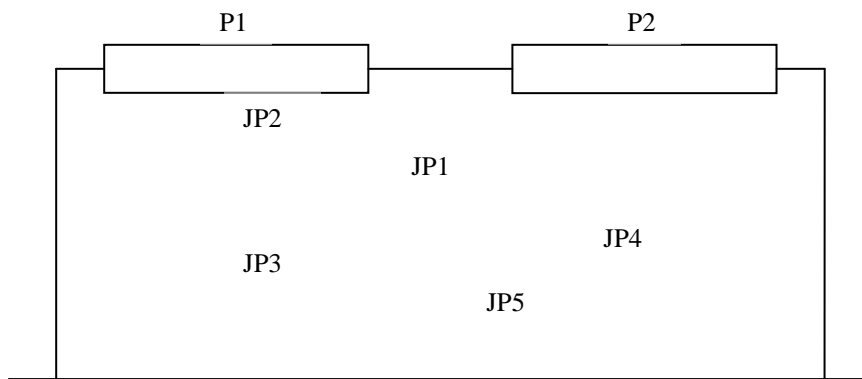
JP1	: 0::: ::::	Base address setting 0x0100
JP2	:0: ::::	IRQ-Level 6
JP3	:00	IRQ-Level 6
JP4	Bottom installed	Non standard. Time bus signal source via front
JP5	Empty	No termination of time bus signal on the TIM board

Figure 5.3. Jumper setting TIM board (see man tim for details)

6   NEXUS AMPLIFIER CONFIGURATION

The Nexus conditioning amplifier is programmable (Ref 2) from the front panel (there is also a RS-232 interface which could be used from the LCU, but this has not been implemented at this time).

Each individual accelerometer is delivered with a calibration sheet. The sensitivity value (pC/ms^{-2}) has to be entered in the amplifier for the corresponding channel. Further, a gain value (V to m/s^2) has to be entered. Finally the cut-off frequencies for built-in filters must be specified. The accelerometer assignment and amplifier settings, as of October 2006, are summarized in tables below.

Accelerometers with SN 10662-10664 do not belong to Manhattan2, but were borrowed.

6.1   UT 4

Serial Number	Sensitivity /pC/ms-2	
30063	9.97	assigned to UT4 Channel 1
10664	9.92	assigned to UT4 Channel 2

Table 6.1.1. Accelerometers installed on M3 UT4

Serial Number	Location in rack	Accelerometric Channels
2500458	Top	1-4
2551135	Middle	5-8

Table 6.1.2. Amplifier assignment on UT4

Acceler. Channel	High pass / Hz	Low pass / kHz	Gain / V/ms-2	Sensitivity / pC/ms-2	Input / Output floating Correction
1	0.1	1	100	9.97	Yes / Yes
2	0.1	1	100	9.92	Yes / Yes
3	Not used				
4	Not used				
5	Not used				
6	Not used				
7	Not used				
8	Not used				

Table 6.1.3. Nexus conditioning amplifier setup on UT4

6.2   UT 3

Serial Number	Sensitivity /pC/ms-2	
10663	9.89	assigned to UT3 Channel 1
10662	9.89	assigned to UT3 Channel 2

Table 6.2.1. Accelerometers installed on M3 UT3

Serial Number	Location in rack	Accelerometric Channels
2551134	Top	1-4
2551136	Middle	5-8

Table 6.2.2. Amplifier assignment on UT3

Acceler. Channel	High pass / Hz	Low pass / kHz	Gain / V/ms-2	Sensitivity / pC/ms-2	Input / Output floating Correction
1	0.1	1	100	9.89	Yes / Yes
2	0.1	1	100	9.89	Yes / Yes
3	Not used				
4	Not used				
5	Not used				
6	Not used				
7	Not used				
8	Not used				

Table 6.2.3. Nexus conditioning amplifier setup on UT3

7   MECHANICAL INTERFACE

The cabinets are mounted in sector "+Y" of the mirror cell in a position foreseen for future cabinets. The mechanical interface is implemented according to specification in Figure 7.1. The weight of the cabinet is 60 kg, e.g. four counter weight bars below the interface must be removed to maintain telescope balance.
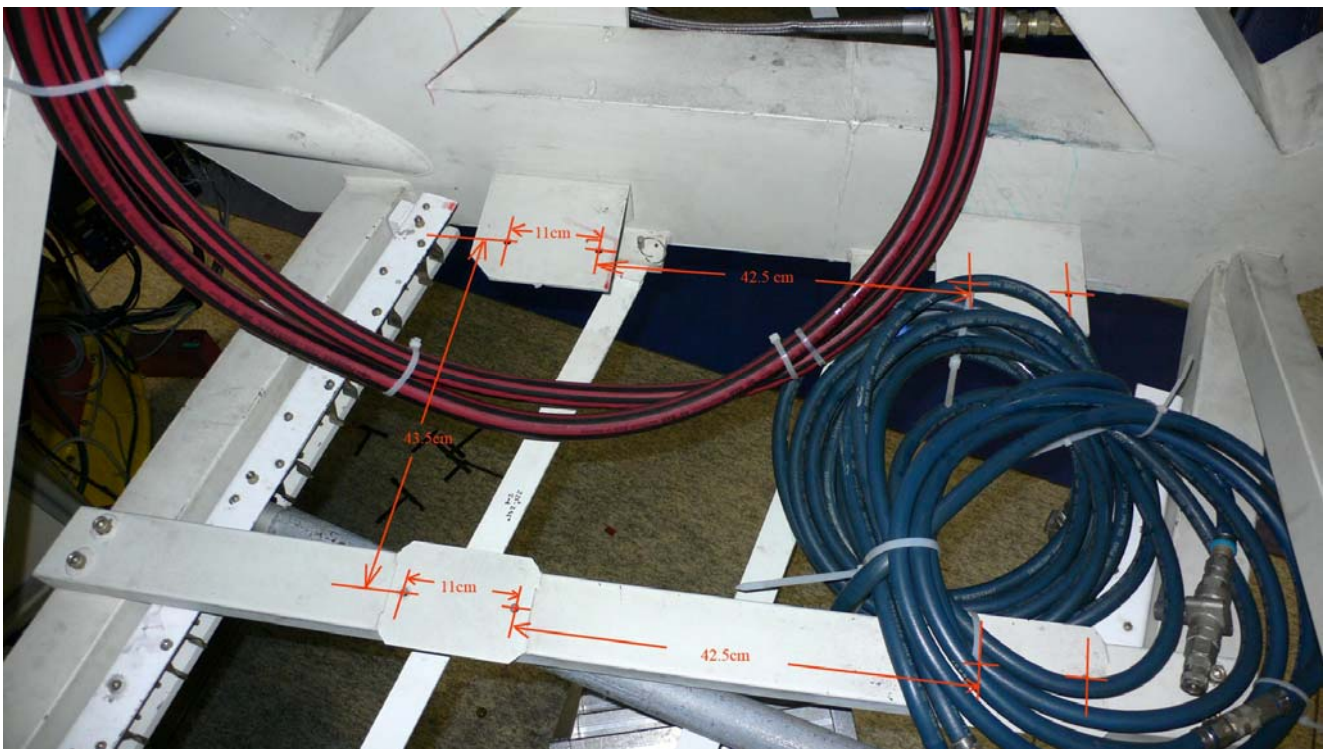

Figure 7.1. Mechanical interface in M1 cell before mounting cabinet.

Interface plates are attached to the bottom four corners of the cabinet. Rubber dampers (Sahlberg cup-mount element C1015 Art.Nr. 541-402, max load 40 kg) are mounted on the interface plates.

In addition two identical interface plates with rubber dampers are provided at the back two corners on the top of the cabinets. These are used for two additional attachment points.

8   LOCATION OF HARDWARE AS OF OCTOBER 2006

8.1   UT 4

Cooling Box with 2 amplifiers (thus 8 accelerometer capacity) mounted in the M1 cell, Power, cooling liquid, RMN, TIM and network connected.
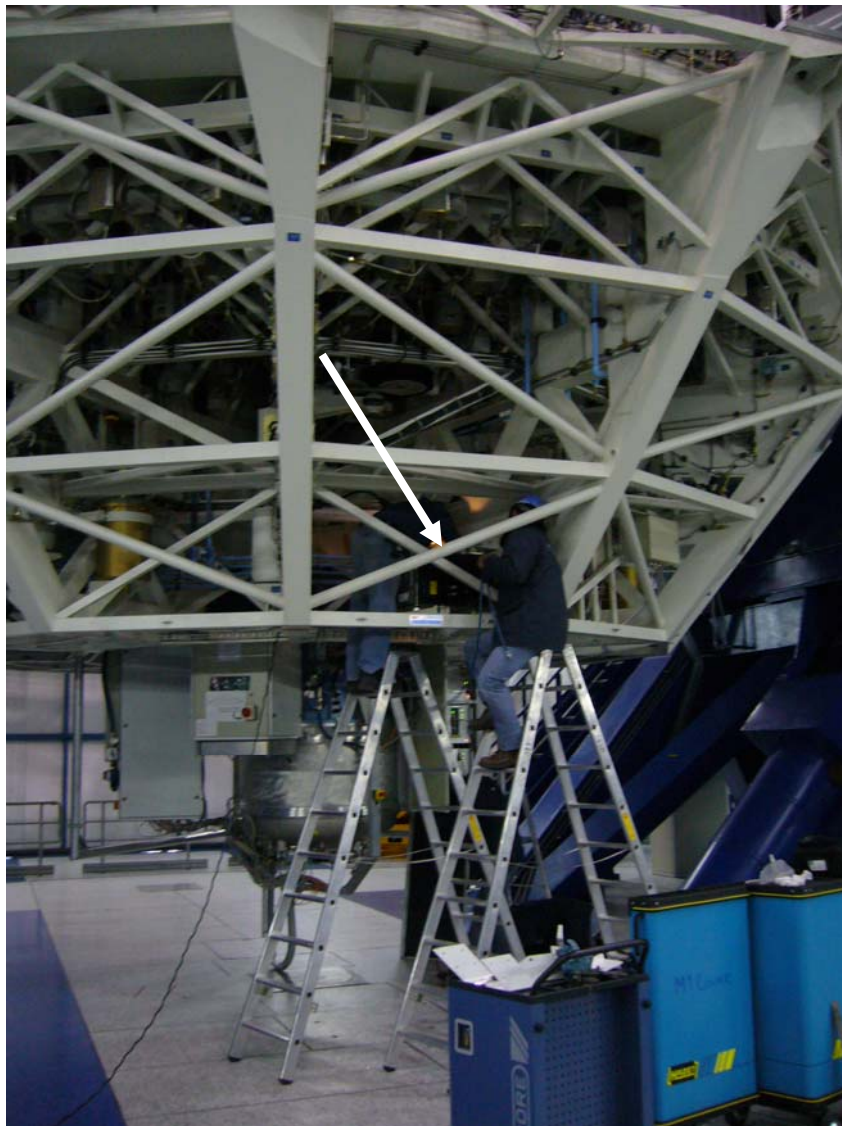

Figure 8.1.1. Integration of the cooling box in the UT4 M1 cell

- Accelerometers mounted on back of M3 cell, electrically not insulated
- The 30 m cable (labelled AO0122 D300 14/06) is connected to Ch1 accelerometer
- The (extended) 10 m cable (labelled AO0122 D100 20/06 on cooling box side) is connected to Ch2 accelerometer
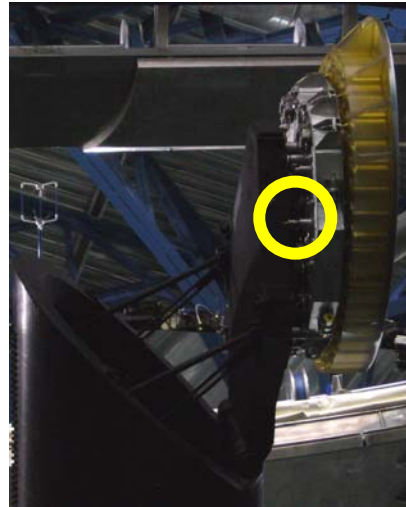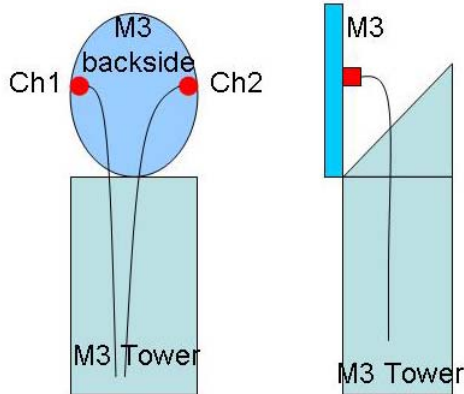
Figure 8.1.2. Location of the accelerometers on UT4 M3 cell

8.2   UT 3

Cooling Box with 2 amplifiers (thus 8 accelerometer capacity) mounted in the M1 cell, Power, cooling liquid, RMN, TIM and network connected.

- Accelerometers mounted on back of M3 cell, electrically not insulated, **Ch1 and Ch2 positions are interchanged with respect to UT4**!
- Both cables are 30 m long, the one connected to Ch1 accelerometer is labeled red on cooling box side
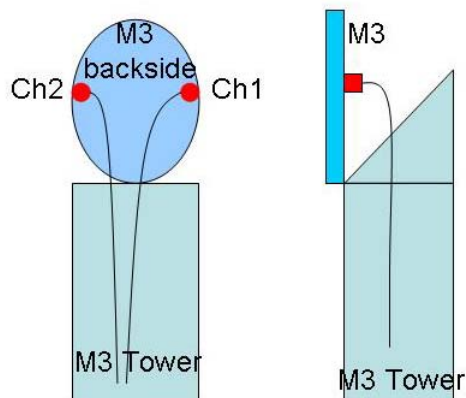

Figure 8.2.1. Location of the accelerometers on UT3 M3 cell

ESO

VLTI - UT Vibration Monitoring System	Doc.	VLT-SPE-ESO-15400-4013
	Issue	1
	Date	09/11/2006
	Page	22 of 27

9 SOFTWARE

The software application makes use of *tac* with its associated flexibility. The application (tac configuration file, custom blocks etc) is being developed in the cmm module *vib*. A support module, *vibBUILD*, is also provided to generate required software and the LCU environment. Each telescope is expected to deliver two doubles on RMN at 2 kHz. These are total displacement (OPL) and total acceleration. Location of these new data on the reflective memory is defined in *rmac* v 1.32 and tac blocks to write and read these data in *taclib* v 1.78.

The basic signal processing to obtain OPL is:
- Acquire accelerometer signals
- If using multiple accelerometers average them (position dependent)
- Cancel any pre-amplifier high pass.
- Add a 3 pole high pass butterworth at 0.1 Hz or as required (2 poles to cancel integrator + AC couple)
- Double integrator to convert to displacement (OPL).
- Cancel anti-aliasing filter.
- Cancel pre-amplifier low pass.
- Add desired low pass to limit feed forward bandwidth.
- Add lead network for time-delay compensation.
- Write result on RMN

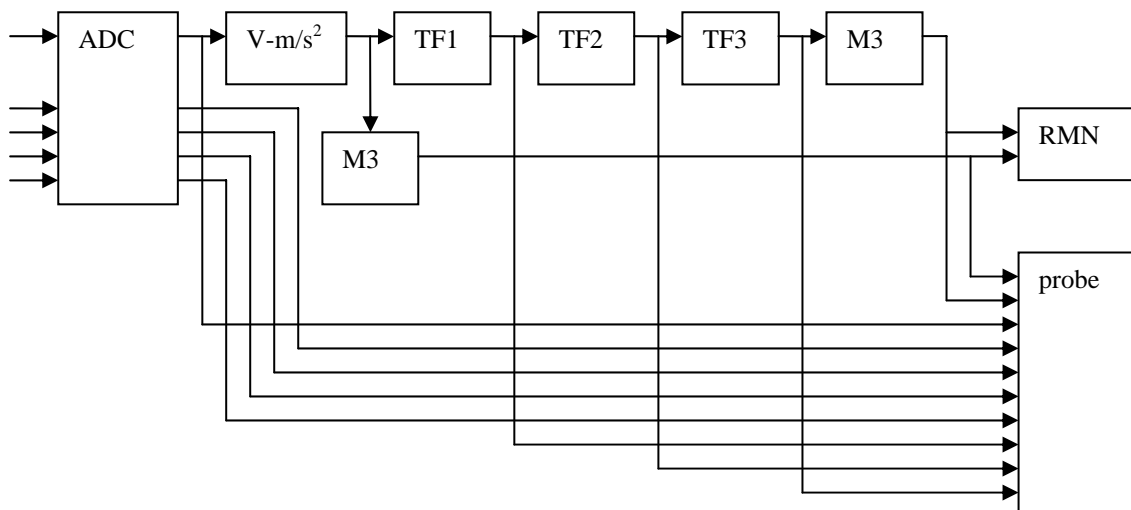The tac configuration file implemented in *vib* v 1.5 is illustrated in Figure 9.1

Figure 9.1. Illustration of algorithm. V-ms^2 must match amplifier setting. M3 is scaling from displacement to OPL, e.g. sqrt(2) in case of M3. TF1, 2 and 3 are cascading filters (see below).

The probe block allows real-time visualization with rtdscope or standard tac sampling into a file. Data columns can be deducted from Figure 9.1.
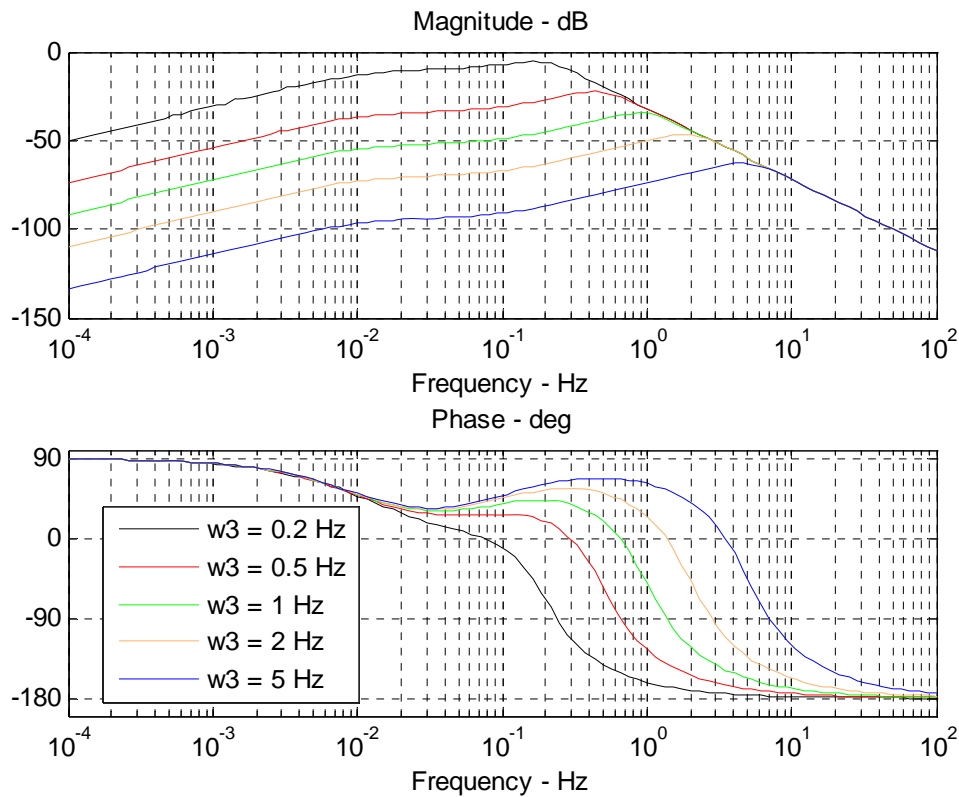
w0 = 0.01 Hz; w1 = 1 Hz; w3 = 0.2 Hz; ts = 0.0005
TAC_BLOCK DigitalTF 1.00014136945,-0.999685890075,-0.999968584567
TAC_BLOCK DigitalTF 6.24803650479e-008,2,1,-1.9993714842,0.999371878861
TAC_BLOCK DigitalTF 0.9996859394,-1,-0.999371878799

w0 = 0.01 Hz; w1 = 1 Hz; w3 = 0.5 Hz; ts = 0.0005
TAC_BLOCK DigitalTF 1.00014136945,-0.999685890075,-0.999968584567
TAC_BLOCK DigitalTF 6.2450912645e-008,2,1,-1.99842797191,0.998430437373
TAC_BLOCK DigitalTF 0.999215218203,-1,-0.998430436406

w0 = 0.01 Hz; w1 = 1 Hz; w3 = 1 Hz; ts = 0.0005
TAC_BLOCK DigitalTF 1.00014136945,-0.999685890075,-0.999968584567
TAC_BLOCK DigitalTF 6.24018254714e-008,2,1,-1.996853488035,0.9968633421364
TAC_BLOCK DigitalTF 0.998431667205,-1,-0.996863334409

w0 = 0.01 Hz; w1 = 1 Hz; w3 = 2 Hz; ts = 0.0005
TAC_BLOCK DigitalTF 1.00014136945,-0.999685890075,-0.999968584567
TAC_BLOCK DigitalTF 6.2303652391e-008,2,1,-1.99369719931,0.993736553707
TAC_BLOCK DigitalTF 0.996868246042,-1,-0.993736492083

w0 = 0.01 Hz; w1 = 1 Hz; w3 = 5 Hz; ts = 0.0005
TAC_BLOCK DigitalTF 1.00014136945,-0.999685890075,-0.999968584567
TAC_BLOCK DigitalTF 6.20091561896e-008,2,1,-1.9841705969,0.984415399237
TAC_BLOCK DigitalTF 0.992207222696,-1,-0.984414445392

Figure 9.2. Selection of possible filters and corresponding tac parameters.
In October w3=2 Hz was used.

LCU boot parameters as stored in non volatile memory are shown below

```
boot device       : dc0
processor number    : 0
host name        : wt3tcs
file name         : /vlt/JAN2006/vw5.4/target/config/mv2604/vxWorks
inet on ethernet (e) : 134.171.218.56:ffffff00
inet on backplane (b):
host inet (h)      : 134.171.218.1
gateway inet (g)    :
user (u)          : vx
ftp password (pw) (blank = use rsh):
flags (f)        : 0x8
target name (tn)    : lt3vib
startup script (s)  : /vltdata/ENVIRONMENTS/lt3vib/bootScript
other (o)          :

boot device       : dc0
processor number    : 0
host name        : wt4tcs
file name         : /vlt/JAN2006/vw5.4/target/config/mv2604/vxWorks
inet on ethernet (e) : 134.171.219.56:ffffff00
inet on backplane (b):
host inet (h)      : 134.171.219.1
gateway inet (g)    :
user (u)          : vx
ftp password (pw) (blank = use rsh):
flags (f)        : 0x8
target name (tn)    : lt4vib
startup script (s)  : /vltdata/ENVIRONMENTS/lt4vib/bootScript
other (o)          :
```

10 MAINTENENACE

10.1 Assembling the Cooling Box

Procedure to mount/dismount Manhattan2 cooling box:
Situation before starting the mounting procedure:

  -cooling box top cover is removed (this can be done in-situ)
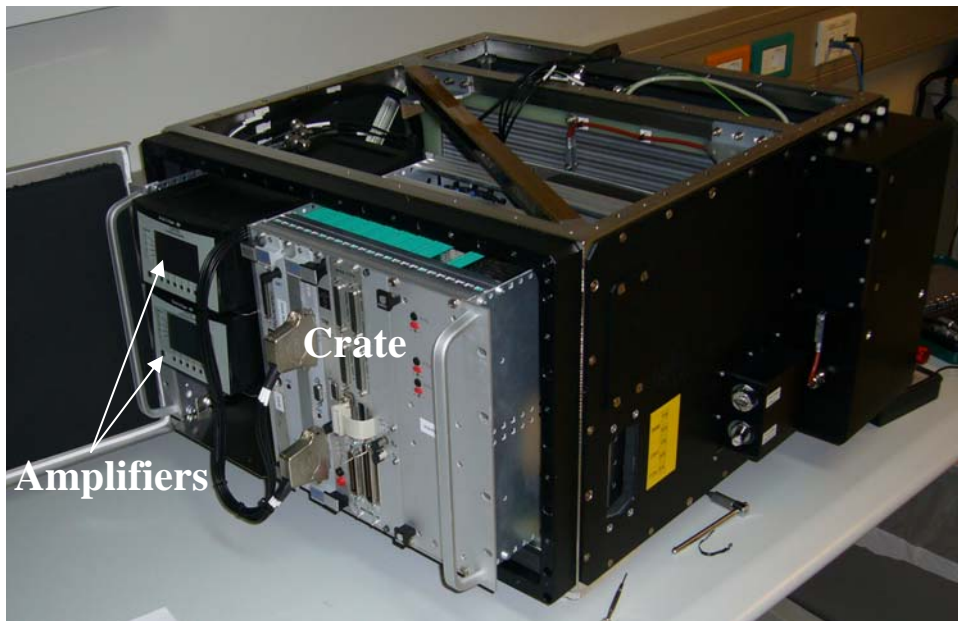 -LCU crate (ltXvib) is completely disconnected and removed from the cooling box

Figure 10.1. Cooling box in semi-assembled state

Figure 10.2. Cooling Box in assembled state

ESO

VLTI - UT Vibration Monitoring System

Doc.   VLT-SPE-ESO-15400-4013
Issue   1
Date   09/11/2006
Page   26 of 27

1. Mount amplifiers into crate
    - mount top amplifier first, then middle, then bottom (amplifiers are fastened from below)
2. Connect amplifier BNC outputs to ADC board
    - Top amplifier output channels 1-4 connected to ADC input channels 1-4
    - Middle amplifier output channels 1-4 connected to ADC input channels 5-8
    (this is the configuration for only two amplifiers; nominal configuration due to cable lengths
    would be: bottom amp. -> ADC channels1-4, middle amp. ->ADC 5-8, top amp.->ADC 9-12)
3. Mount power supplies for amplifiers
    - remove cover plate
    - glue the power supplies to the back plate of the crate using double sided tape
    - put cover plate back
    - connect power supply lemo connectors to amplifier
4. Mount LCU crate into the cooling box
    - make sure the crate main power supply is switched ON
    - slide crate into cooling box
    - connect crate power supply (cable from cooling box)
    - connect the amplifier power supplies (cable from cooling box)
    - connect TNC cables according to channel configuration above
5. Make first functional test
    - power up cooling box, crate should power up automatically
    - power up amplifiers
    - connect accelerometer to all cooling box inputs and check that the correct amplifier channels
    are connected
6. Fasten crate inside cooling box
    - fasten the 8 M8 front screws
    - fasten the 2 'pushers' at the back upper corners of the crate
7. Mount fibre feed through (when dismounting, the fibre patchpanel has to be removed before taking
    the crate out of the cooling box)
    - mount fibre feedthrough to the cooling box
    - connect fibres to the assigned positions
8. Mount cooling box cover
    - mount and fasten cover plate
    - mount interface plates
    - mount vibration insulators
9. Close the remaining amplifier slot to insure efficient air flow
10. Close the front door and fasten with screws (don't loose them!)

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