Cabinet Monitor and Control Points

SKA LFAA

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1 Document Change log

Issue	Date	Change
1.0	15/11/2018	Initial Revision

2 Definitions, Acronyms and Abbreviations

FPGA	Field Programmable Gate Array
I2C	Inter Integrated Circuit
LFAA	Low Frequency Aperture Array
MCU	Micro Controller Unit
PCB	Printed Circuit Board
PLL	Phase-Locked Loop
PPS	Pulse Per Second
SKA	Square Kilometre Array
TPM	Tile Processing Module

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4 Scope

This document describes the cabinet management resources, focusing on the functions and to the possible allocation of them to the hardware and the software. It is a contribution to the Low Frequency Aperture Array (LFAA) Design Description Document.

5 Cabinet Management System Overview

The TPM LFAA cabinet management system is a three-level system, corresponding to the related functions and hardware:

- Cabinet
- Sub-rack
- TPM.

Each level shall manage the related hardware, provide the safety functions and generate an upper level status report.

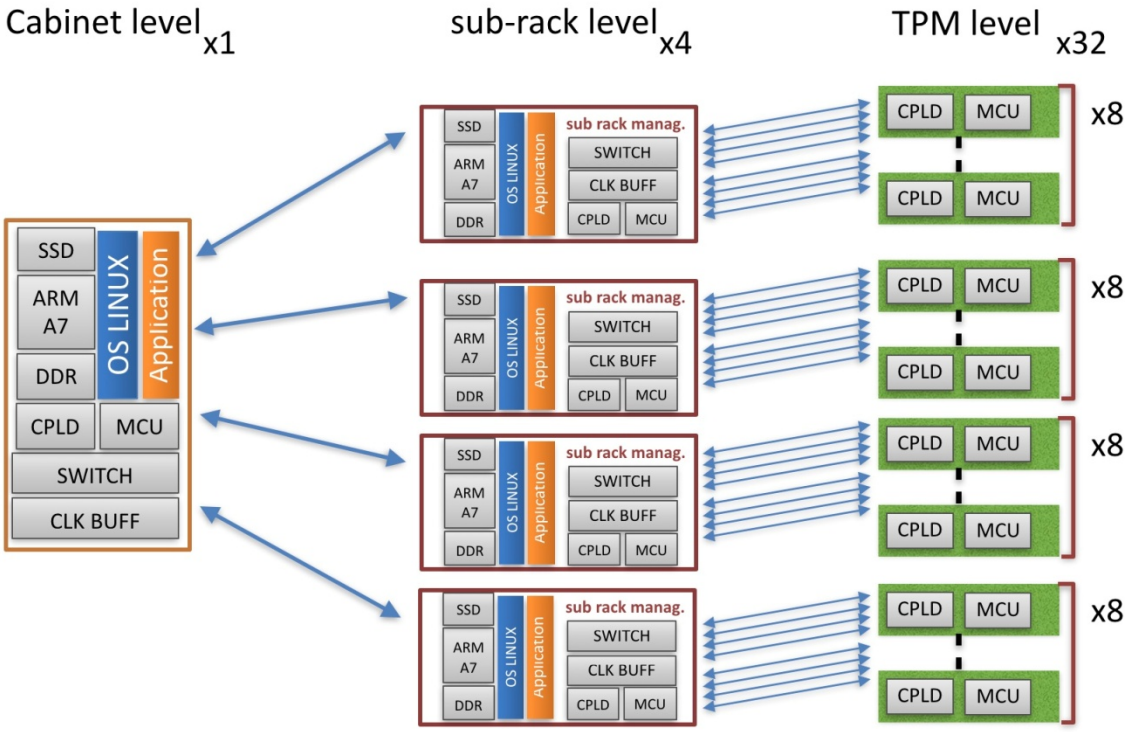


Figure 1: Three-level cabinet management system

All these elements are connected by a gigabit connection link to communicate by direct UDP access or secure TCP protocol at Cabinet and Sub-rack levels.
Each TPM board provides an instant-on CPLD and MCU to execute the management safety operations and to implement the start-up procedures.

5.1 TPM Management

Each TPM provides a Micro-Controller Unit (MCU) and a CPLD that perform the following operations:

- communicate by a SKA UDP protocol over a gigabit network
- execute the power on sequence, power off sequence and low power mode (stand by)
- monitor all the internal voltages
- measure the pre-adu current absorption
- check the input power quality
- load the board configurations (FPGA, PLL, ADC)
- monitor the FPGA status and execute the memory scrubbing
- monitor the status of the 40G Ethernet interface.

Each TPM shall act as slave on the Ethernet bus in order to execute the sequence of operations to be powered, configured, let the acquisition start, and monitored for temperature and some voltages.
The MCU will execute the board safety operations, monitoring the expected temperatures and voltages and executing pre-defined power down sequences.
Each TPM is physically associated to its backplane position and a single wire interface is connected through the backplane to the sub-rack management board, to manage the address assignment and generic error flagging.

5.2 Sub-rack Management

The sub-rack management, integrated with the backplane, shall allow for several complex operations:

- manage the power distribution and current monitoring
- monitor the voltages

- monitor temperatures
- manage the AC-DC power modules
- initialize and configure the TPM on the network
- load the TPM configuration and execute the start up sequence
- execute the TPM stand-by/shut-off sequence
- manage cooling
- distribute the synchronization signals.

The sub-rack measurement points and control points are shown in the figures in the following paragraphs.

The current measurements can be done at four levels:

- Supply output, embedded in commercial modules
- Management Input, associated with a safety programmable switch
- TPM input, associated with a safety programmable switch
- TPM pre-ADU input

5.2.1 Temperature and Current Measurements

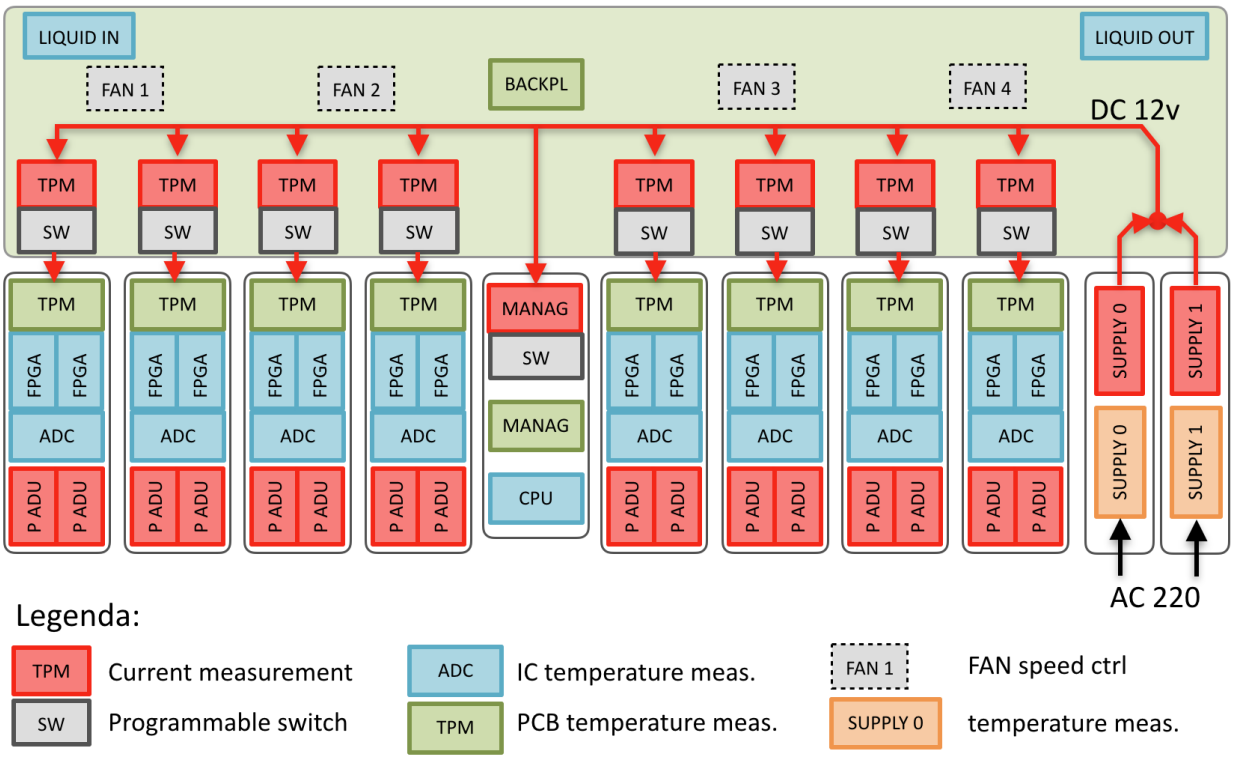


Figure 2: Temperature and current measurements

The programmable switches can be configured in order to execute an automatic shut down if the current threshold has been reached.
The following temperatures shall be collected at sub-rack level in order to check system stability and provide information to the cooling system:

- TPM PCB base temperature (component free area)
- TPM FPGA core temperature
- TPM ADC center temperature (place in the worst case PCB point)
- backplane PCB base temperature (component free area)
- management PCB base temperature (component free area)
- management CPU temperature
- liquid IN and liquid OUT temperature
- power supply input temperature.

The sub-rack fan speed can be controlled separately to provide differentiated air speeds to compensate possible temperature differences, related to the liquid cooling circuit or to the different power absorption of the boards.
Input and output cold plate temperatures are measured in order to provide information to the cabinet level cooling system to manage pump speed or to signal possible OUT OF RANGE values.
The normal operative conditions shall be identified for all temperatures and a power/temperature monitor application shall run on the local sub-rack management board, and report the current values, possible warnings and errors to the upper level application. The sub-rack management board shall signal the TPM status on the front panel LEDs, changing color or blinking, to request for manual maintenance.
The input power supply modules can also be remotely monitored and controlled to check input voltage level, output voltage level, internal temperature, internal fan speed and other power quality information.
With respect to the assumption on TPM ADC temperature stability during acquisition, the stability shall be verified before the acquisition of valid data has started, in order to guarantee the expected RF performances.

5.2.2 Voltage Measurements

The sub-rack voltage monitoring scheme follows the main power distribution scheme.

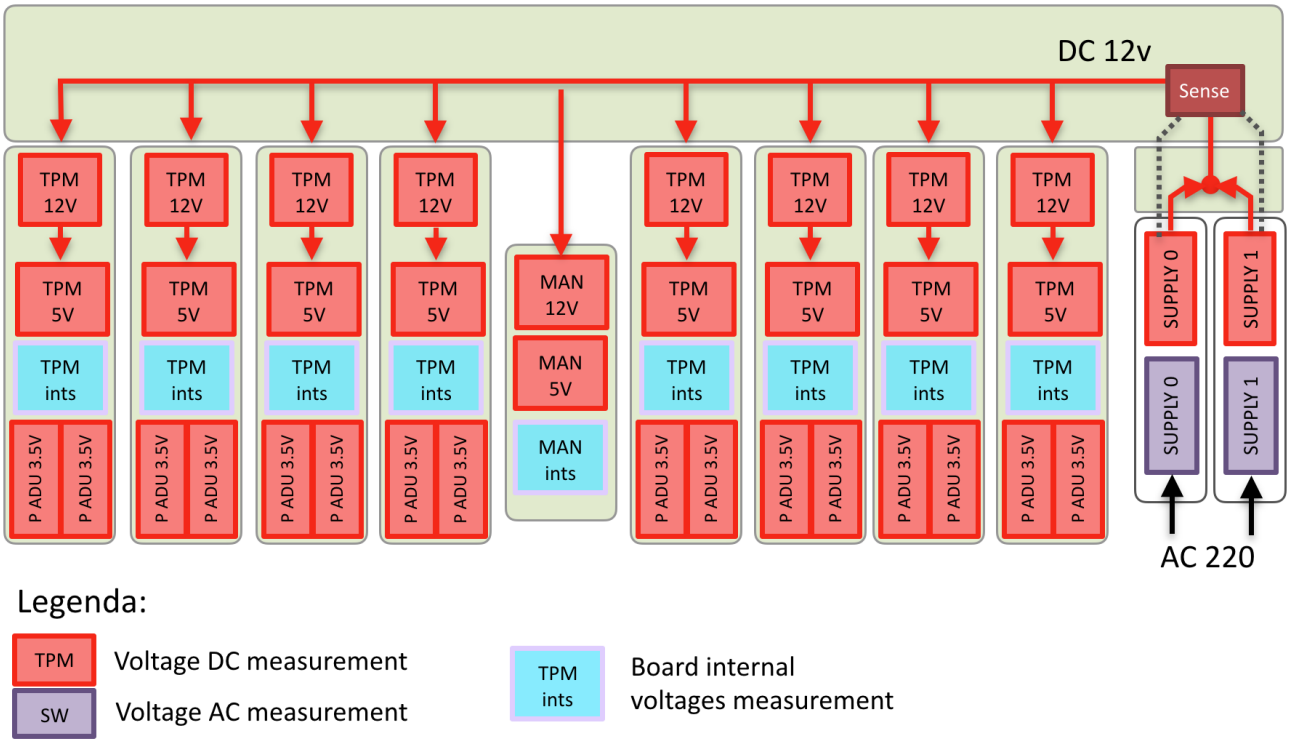


Figure 3: Voltage measurements scheme

The sub-rack management board shall execute the following operations:

- monitor the power supply status in the start-up sequence and in the normal operation
- check for safety power distribution
- check and manage voltage transients.

In the normal operation mode, the sub-rack management board is powered directly by the supply units and starts when the 12V supply is present. Upon a configuration command received by the network, the management will power each TPM, the main supply voltages shall be checked from the sensors present on the TPM itself, and the 12V input and the 5V shall be generated. If these values are as expected, the TPM configuration can proceed and all internal supplies enabled. It is assumed that the TPM supply status is monitored directly by the TPM MCU and only a single flag is monitored by the sub-rack management board. In case of failure,

all values can be requested by the diagnostic application. The voltage of the pre-ADU shall also be verified to diagnose possible unexpected out of range values.

For the safety check, it is assumed that the connectors are the critical points in the power distribution system. Due to large currents involved, if a connector contact resistance becomes high for any reason (e.g. bad insertion, contact oxidation) the related temperature can increase up and possibly cause damages or fire.
To mitigate that, voltage measurement points are present at each current source and after each power connector, to measure possible voltage and power loss.
In the distribution chain the following measurement points have been provided:

- AC input
- Power supply DC output
- Voltage sense on the backplane, one for each power supply modules
- Input voltage on the management board
- Input voltage on each TPM
- Input voltage on each PRE-ADU.

Presence and value of the AC input supply from the cabinet distribution system is measured in the main supply modules.
The supply modules are joined on a dedicated printed circuit board and the generated supply connected to the backplane. Each supply module provides a remote sense voltage detector that measures the effective voltage generated after the connectors. For each supply module, a separate sense line is propagated through the connectors to the backplane. The sense line measures the voltage after the connectors, directly on the power distribution plane that is connected to all the sub-rack elements.
On each element, the input 12V is monitored again and on the TPM, in the end, the supply voltage of the pre-ADU board is measured after the connector.
The sub-rack management board shall monitor all these values and if a voltage drop is measured above a threshold, safety warnings shall be signaled to ask for maintenance.

LFAA power distribution standards admit quite frequent voltage transients and rare severe power interruptions. It is expected that the sub-rack management board manages this situations and identifies system power status in order to determine if normal functions are guaranteed or if some actions are needed. Also the time needed to return to the full operative condition is important and the detected power status can determine what type of operation are needed.

The operation proposed in the [RD1], chapter 7, “Shut down & voltage transient”, shall be executed by the sub-rack management board.

5.2.3 AC-DC Power Modules Management

AC-DC power modules are commercial items that provide several functions accessible by an I^2C interface by the management board, through a backplane connections.
A selection of status registers shall be identified in order to define a status monitoring and warning generation for maintenance purposes. The management board shall continuously check these registers and warn the upper level about possible out of range values.
Managing accidental failures of one supply module and verifying the operating status of the remained one working at double load shall be possible, too.

5.2.4 TPM Power-on and Network Configuration

The sub-rack management board shall perform the following operations:

- detect the presence of a TPM on the backplane (presence wire)
- program the corresponding supply distribution point with a safe power threshold and enable the TPM supply
- check the power on absorption
- assign the TCP address to the board by the one wire interface and register the board physical address (MAC)
- check the network address to the TPM management function (ping, read/write management interface registers)
- check the management supply status.

After these steps have been accomplished, the TPM can be initialized and configured.

5.2.5 TPM Startup Sequence and Configuration

Each TPM can be selectively powered and configured by the sub-rack management board, to implement several types of startup sequence. The following operations shall be executed, either separately or grouped:

- Power-on the ADU digital section
- configure the FPGA
- power-on the ADU analogue section
- configure and start the PLL
- power-on the pre-ADU analogue section

- configure the acquisition parameters and let the acquisition start.

Each step increases the absorbed TPM power and the current threshold shall be pre-configured accordingly by the management application. Overcurrent shall be verified.

5.2.6 TPM Stand-by and Shut-off Sequence

Each TPM can be powered off in reverse order with respect to the above activation sequence by the sub-rack management application. To return to the acquisition state, it is necessary to only reactivate the powered off elements. Different stand-by levels and corresponding power consumptions are possible:

Status	**Functions**	**Absorbed power**
Standy-by	Remote access, some management functions	3W
Digital active	FPGA active, all management functions	53W
Analogue powered, PLL configured	Acquisition configured	88W
Acquisition running	Acquisition running	108W

The time required to return to the acquisition state may vary greatly according to the number and type of operations needed.

5.2.7 Sub-rack Cooling

The sub-rack management board shall monitor all temperatures in order to quickly reach a stable value and maintain it.

Internal temperatures can be controlled by three factors:

- temperature and speed of the liquid in the backplane cold plate
- temperature of the cabinet air
- speed of the air inside the cabinet.

The first two factors are shared at cabinet level by the other sub-racks and controlled at cabinet level.

The sub-rack management application shall control the four internal fans located above the backplane to control the speed of the air inside the TPM. Different speeds can be configured on each fan, when differences in the TPM temperatures are measured.

The temperature working point of the TPM shall be defined and the cooling system shall be implemented to reach quickly the stable condition and maintain it, by acting on the liquid and air speed inside the elements.

5.2.8 Synchronization Distribution

The sub-rack management board receives the synchronization signal and shall distribute to the TPM (see [RD2]). The management shall perform the following operations:

- configure the digital PLL that receives 10MHz & PPS and extract these signals
- monitor the lock status of the PLL to verify the presence of the input signal
- monitor the lock status of the TPM PLL to verify the presence and the quality of the distributed signal
- monitor the PPS register in the TPM to verify the presence of the distributed signal

6 Cabinet Management System Overview

The cabinet management board shall manage the cooling system and communicate with the sub-racks to acquire power and temperature information. The cooling system shall reach quickly and maintain the TPM temperature defined for the acquisition mode.
The cooling process shall execute the following:

- monitor the availability of the cooling interface from the infrastructure (temperature and flow)
- check the pressure and temperature of the internal liquid circuit
- monitor the inlet and outlet liquid temperature in each sub-rack and set the pump speed accordingly
- monitor the cabinet air temperature, the sub-rack air temperature and set the internal air exchanger fan speed accordingly.

When LFAA cabinet is powered, only the auxiliary 24V supply will be active and the cabinet management board powered. The cabinet management board shall execute the following:

- check the AC power quality
- startup the network interface to the LFAA network
- power-on the cooling and execute a cooling status check, general check
- power-up the stations and the related Ethernet switch, upon LFAA request
- manage the input AC supply transients and safe power OFF.

6.1 Cabinet Synchronization

The following operations shall be executed:

- check the presence of the input 10MHz and PPS, input DPLL lock status
- measure the phase of PPS and execute a phase adjustment if needed
- inject the re-phased PPS in the 10MHz and distribute this signal to the sub-racks
- check the DPLL status on the sub-racks
- check the PLL status on a TPMs
- in TEST mode, propagate the synchronization signal towards the sub-rack and the re-phased PPS to a test point interface.

6.2 Cabinet Cooling

The cabinet management board shall manage the cooling system and communicate with the sub-racks to acquire power and temperature information. The cooling system shall reach quickly and maintain the TPM temperature defined for the acquisition mode.
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6.3 Cabinet Diagnostic

The cabinet management board shall interface with the upper level management system for operative status and diagnostic information. The direct information and the status collected from the sub-racks shall be safety collected to be provided to the LFAA diagnostic process.
The following operations shall be executed:

- Supply diagnostic, AC input voltages, auxiliary supply voltages, distribution switch status, cabinet element input supply status, where available
- cooling diagnostic, including all sensor values, pumps and fan speed, out of range check
- network warnings/errors, including the switch port status, corrupted or bad packet counting and out of range check
- synchronization warning/errors, including presence of input signals, input signal quality, sub-rack PLL status
- collection of the detailed diagnostic information from the sub-components
- safe storage of diagnostic information in case of severe supply lack.

7 Cabinet Line Replacement Units

All the cabinet elements present in the 19" rack column can be replaced with a pre-defined sequence and with an expected limited effort. The other elements, the power distribution and the cooling circuit require inspection and repair by an operator.
The diagnostic scheme shall observe the functional dependencies of the management architecture of the cabinet, as shown in the following picture.

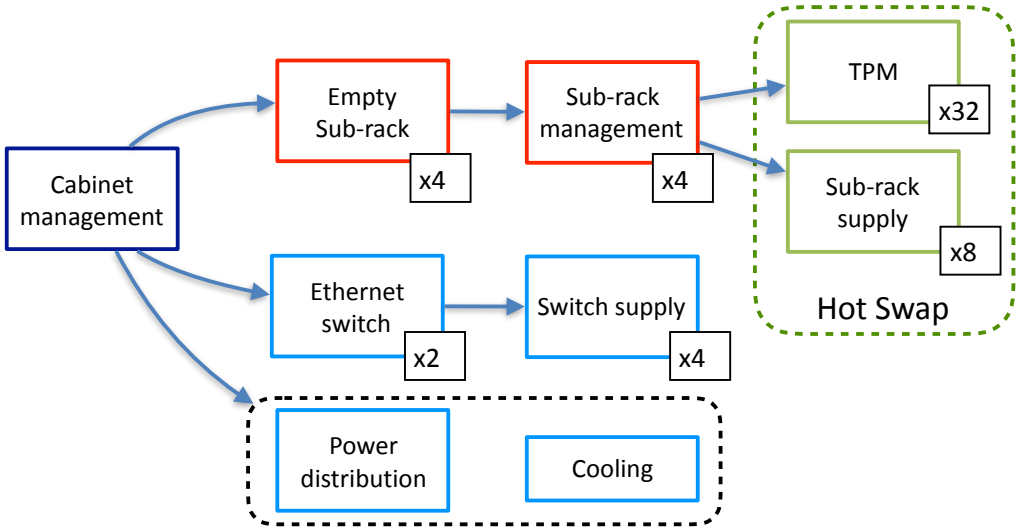


Figure 4: LFAA cabinet diagnostic tree

Each item shall implement a management application that shall provide the following functions:

- monitor all the temperature, voltages, current and health status
- check the previous data with reference for warning and alarm functions
- signal to the upper level warnings and alarms
- if possible, automatically power-down the element upon alarm
- record diagnostic information on a non-volatile memory for further analysis

The cabinet management board shall monitor directly the power distribution and the cooling status and collects the information coming from the lower levels. Based on the warnings and the error flag in the tree, the management application shall identify the element that shall be replaced.
In case of malfunction of the cabinet management board or of the auxiliary supply, the status LEDs in the front panel shall warn for manual inspection.

The possible line replacement units are the following:

1. TPM
2. Sub-rack power supply module
3. Sub-rack management board
4. Empty Sub-rack
5. Network switch supply module
6. Network switch
7. Cabinet management board

The replacement shall be done with different operation modes and managed by a maintenance application.
At sub-rack level, the TPM and the sub-rack supply module can be replaced without un-power all the sub-rack thanks to the hot-swap capabilities.
To replace the sub-rack management module the sub-rack shall be un-powered by the cabinet management application.
At cabinet level, to replace the sub-rack or the Ethernet switch, the cabinet management application shall halt and un-power the corresponding item.
In case of failure of power distribution element or cooling element a cabinet level maintenance operation is needed with manual inspection guided by the diagnostic application.
In case of failure of the cabinet management board the cabinet shall be halted and un-powered to replace the board itself.

8 Reference documents

[RD1]	“Cabinet Performance”, issue 1.0, November 2018
[RD2]	“Clock Distribution Analysis”, issue 1.0, November 2018

9 Applicable documents

[AD1]	