Digital Trigger Crate – Camera Power Interface Control Document

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Summary	Interface control document for the electrical interface between the NectarCAM camera power system and the digital trigger crate.
Annexes	

Document Change Record				
Edition	**Revision**	**Date**	**Modified Pages**	**Observations**
0	1	2017-05-02	–	Very preliminary draft version
0	2	2017-05-30	4-9	Updated power consumption and DT crate connection scheme
0	3	2017-08-07	4-8	Revised with to reflect that aux power cannot come from PSBs

Distribution	***CTA Internal***

Contents

1 Introduction

This document is intended to define the electrical interface between the NectarCAM camera power subsystems (which are common components with the LST camera) and the digital trigger crate, which will also supply +24V power to the front-end boards (FEBs). The digital trigger crate is also responsible for sequencing power to the FEBs, which will be used to manage the inrush current to the FEBs.

A diagram of the digital trigger topology is shown in Figure 1. For the remainder of this document, we define "main power" to be power from the eight PULS QT40.241 power supplies, which are housed in two power supply boxes (PSBs) at the rear of the camera. We define "auxiliary power" to mean power to the digital trigger crate itself, which contains an FPGA and other elements. The digital trigger crate provides power to the L2 controller board (L2CB) and 18 clock and trigger distribution boards (CTDBs). Each CTDB provides power and clock signals to up to 15 modules (1 module = 7 PMTs + FEB + digital trigger backplane (DTB)).

It is important to note that there are no electrical signals exchanged between the digital trigger crate and the camera power subsystem. Control of the power system will be managed by the embedded camera controller (ECC) via an Ethernet interface. There is no communication between the ECC and the digital trigger crate.

1.1 Scope of the document

This document describes the power interface to the digital trigger crate. It only applies when the NectarCAM digital trigger is used (rather than the analog trigger). This document mainly discusses power requirements and the physical connection of the digital trigger crate to the camera power system. It also discusses the power sequencing requirements for the digital trigger crate. Power monitoring and FEB turn-on sequencing are not discussed in this document.

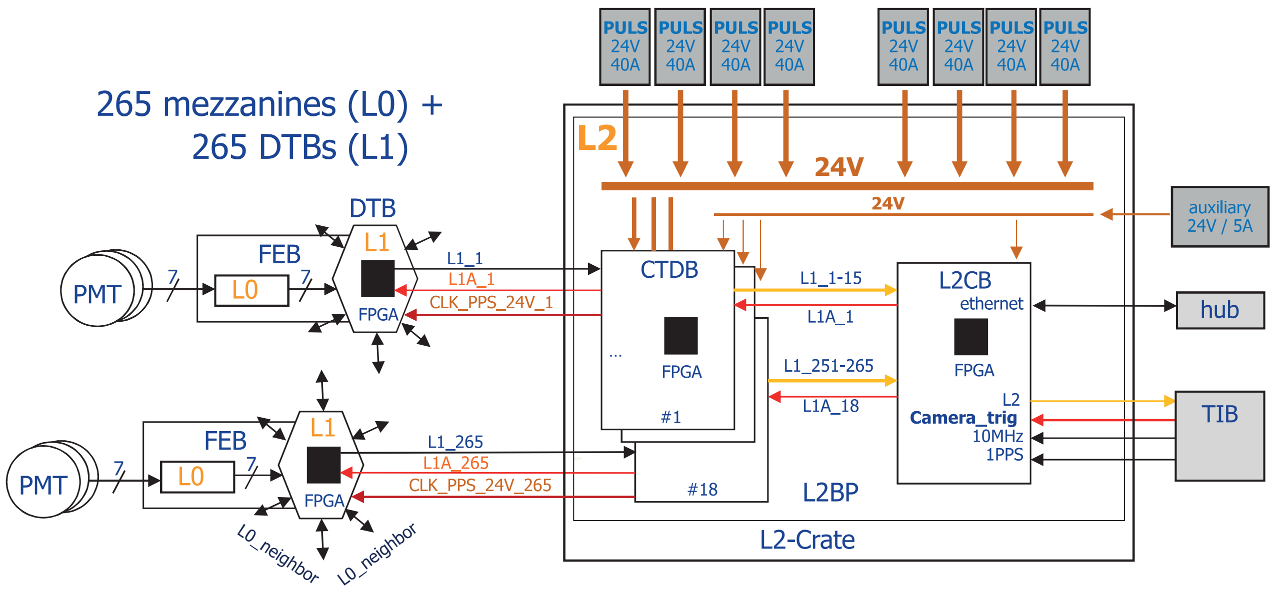

Figure 1: Diagram of the digital trigger topology.

1.2 Applicable Documents (AD)

Applicable Documents (AD)			
AD	**Title**	**Reference**	**Version**
1	Power Distribution in LST & Nectar Cameras	LMST-CAM-TN-0070	1.3
2	Embedded Camera Controller – Power Supply Boxes Interface Control Document	LMST-CAM-ICD-0178-IFAE	2.1
3			

1.3 Reference Documents (RD)

Reference Documents (RD)			
RD	**Title**	**Reference**	**Version**
1			
2			
3			

1.4 List of abbreviations

List of Abbreviations			
CTA	Cherenkov Telescope Array	MST	Medium-Sized Telescope
ECC	Embedded Camera Controller	EMI	Electromagnetic Interference
PSB	Power Supply Box	FEB	Front-End Board
DTB	Digital Trigger Backplane	L2TB	Level 2 Trigger Backplane
CTDB	Clock & Trigger Distribution Board	L2CB	L2 Controller Board

2 Power Consumption

2.1 Auxiliary Power

The measured power consumption of the digital trigger crate itself (i.e., the auxiliary power consumption) is approximately 60 W. The maximum current consumption shall be no more than 5 A, which corresponds to a maximum power consumption of 120 W.

The auxiliary power inrush current has been measured using a single L2 controller board (L2CB) with both a single CTDB and a trio of CTDBs. Each CTDB has two inrush peaks, each less than 1.4 A and spaced approximately 20 ms apart. Each CTDB contains a DC-DC converter, and each will fire at a slightly different time. As a result, the inrush peaks should be temporally separated and should not pile up (no pile-up was observed for three CTDBs).

2.2 Main Power

The steady-state consumption for each NectarCAM 7-PMT module – one module consisting of a front-end board, focal plane module, and a digital trigger backplane – is 19.6 W (0.82 A), with an estimated maximum (inrush) current of 20.5 W (0.85 A). At no time should the current from one module exceed 1 A (24 W). Since NectarCAM contains 265 modules, the total steady-state power consumption will be 5194 W.

3 Power Sequencing

Power to the digital trigger crate must be supplied before the modules are powered up. This sequencing requirement is due to the CTDB's FPGA configuration time, which is 64 ms (we round up to 100 ms to be conservative). By default, the CTDBs apply power to the FEBs. Therefore, if the main power is applied during this configuration time, all of the FEBs will receive power until the CTDB FPGA is configured. Therefore, properly sequencing the power will be critical for the completed camera in order to avoid initializing all of the FEBs at once.
The power-on sequence for the digital trigger crate will be as follows:

1. Auxiliary power on
2. Wait 100 ms or more
3. Main power on

The power-off sequence is simply the inverse of the power-on sequence:

1. Main power off
2. Wait 100 ms or more
3. Auxiliary power off

Sequencing power to the digital trigger crate requires being able to control the main power and auxilliary power independently. This creates some difficulty because the main power, when on, has a current of > 200 A. There are two hardware options for implementing the power sequencing:

1. Use relays to switch the auxiliary and main power. This requires using four relays rated for at least 80 A (preferably ≥ 150 A to meet RAMS requirements) attached to each of the PSB outputs, as well as a smaller (5 A or more) relay for the auxiliary power.

2. Use a small ($\sim$100 W) 24 V power supply to provide auxiliary power. Control of the auxiliary power would be via a remote shutdown of this power supply, or an a small relay.

Option 2 is currently preferred. Presently, the possibility of placing a small power supply inside the digital trigger crate is being studied.

The entity responsible for this power sequencing is TBD.

4 Main Power Connectors and Cables

4.1 Overview

In this section, we will discuss the main power applied to the digital trigger crate. This power should be applied according to the sequencing discussed in section 3.

The digital trigger crate will be connected to both PSBs, which together can supply a maximum steady-state current of 320 A (160 A each). The +24V power will be carried by a pair of large (50

Figure 2: Amphenol SurLok Plus receptacle (left) and plug (right).

mm^2) finely-stranded copper wires, each of which can carry up to 160 A at 24 V (normally they will carry no more than 80 A). The return is also via a pair of 50 mm^2 wires. There are therefore 4 cables (two +24V, two return) out of each PSB, for a total of eight connections to the digital trigger crate.

Because the DTBs are connected to the camera frame, the GND return could be via the frame (with short cables near to the PSBs and digital trigger crate connecting them to the frame). It may be preferable (from an EMI point of view) to keep the camera frame as a protective earth and avoid using it as a return (especially for large currents). Therefore, the baseline design is to conduct the return current from the digital trigger crate to the PSBs via the 50 mm^2 wires.

4.2 Power Supply Box Connectors

The main +24V power in the camera is provided by eight PULS QT40.241 switch-mode power supplies. Pairs of these power supplies are attached to PULS YR80.241 redundancy modules, which isolate the QT40's in the event of failure (e.g., short circuit). Four QT40 power supplies and two YR80 redundancy modules are housed in each power supply box (PSB), which are located at the rear of the camera. There are four connectors on the PSB for output power: two for +24V, and two for ground (return).

The connectors on the PSB are Amphenol SurLok Plus, and are color-coded (red for +24V and black for ground) and keyed to prevent accidental incorrect connection. These connectors have push-button locking and are rated for 200 A at up to 1000 VDC. The part numbers for the connectors on the PSBs are listed in Table 1. Manufacturer's images for the SurLok Plus receptacle and plug are shown in Figure 2.

Part No.	Purpose	Color	Keyway
SLP IR B 50 C P S R 1	+24V Out Receptacle	Red	180°
SLP IR B 50 C P S B 0	Ground Out Receptacle	Black	90°
SLP IP B 50 B S R 1	+24V Plug	Red	180°
SLP IP B 50 B S B 0	Ground Plug	Black	90°

Table 1: List of Amphenol SurLok Plus connectors used in the PSBs.

Figure 3: Example of a tubular terminal.

4.3 Digital Trigger Crate Connectors

The preliminary design for the connection of the 50 mm^2 copper wires is to use an adapting copper sheet fixed by several M4 screws to the digital trigger crate's internal bus bar. The dimensions of the bus bars are not yet fixed. We will call this copper sheet the "adapter plate."

One possibility for connecting the 50 mm^2 wires to the adapter plate is to use tubular terminals such as those shown in Figure 3. The 50 mm^2 wires would be crimped inside the tubular terminal and attached via some large screws through ∼10 mm holes in the adapter plate. This is the preferred solution by DESY.

Alternatively, Amphenol SurLok Plus connectors with screw terminals could be used.

4.4 Cable Specification

The connection between the PSBs and digital trigger crate will be via 50 mm^2 output wires. The current reference for this wire is General Cable Carolprene 90°C Welding Wire (manufacturer part number: 01774.35T.01). This finely-stranded wire has a continuous duty suggested ampacity of 190 A at 600 V for an ambient temperature of 40°. It is jacketed in EPDM rubber and has a nominal outer diameter of 14.22 mm.

5 Auxiliary Power Connectors and Cables

5.1 Overview

In this section, we will discuss the auxiliary power applied to the digital trigger crate. This power should be applied according to the sequencing discussed in section 3.

This section is TBD until the auxiliary power source is selected.

6 Responsibilities

6.1 Design

The design of the PSB interface and cabling is the responsibility of IFAE, which has overall responsibility for the camera power system (note that this is a common component with the LST). The detailed design of how the cables from the PSB are connected to the digital trigger crate is the responsibility of DESY, as is the selection of the digital trigger crate-side termination of the wires between the PSBs and digital trigger crate. The auxiliary power supply and connections may be the responsibility of DESY (TBD).

The grounding scheme for the digital trigger crate should be agreed upon between IFAE and DESY, but shall ultimately be decided by IFAE as the responsible entity for power within the camera and confirmed by the NectarCAM EMI and systems engineering teams.

6.2 Procurement, Manufacturing, and Shipment

Each institution is responsible for the procurement, manufacturing, and shipment of the parts described in this ICD as follows. The cabling (wire plus connectors) shall be the responsibility of IFAE. Parts appurtenant to the PSB shall also be the responsibility of IFAE. Parts appurtenant to the digital trigger crate shall be the responsibility of DESY. This may include an auxiliary power supply (TBD).

6.3 Verification and Quality Control

Verification and quality control plans TBD. This will likely be done at IRFU (Saclay).

6.4 Assembly, Integration, and Maintenance

IFAE will be responsible for the assembly of the cabling and the integration of the digital trigger crate with the rest of the camera power system. DESY is responsible for any assembly and integration specifically related to the digital trigger crate. Likewise, IFAE will be responsible for maintenance related to the PSBs and cabling, while DESY will be responsible for the digital trigger crate and is connection to the cabling.

We note that neither the power system nor the digital trigger crate are likely to be able to self-diagnose any problems during operation. Power-related problems shall be diagnosed and reported by the ECC. Details of this process are outside the scope of this document.