# Manual for GRANDproto35 operation

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## 1. Introduction

In this document we give details needed to start, run and maintain the
GRANDproto35 array, and (tentatively) fix possible issues.

## 2. The Front-End Unit

Here we give a brief description of the structure of the Front-End Unit
and provide informations needed to make sure it runs in a proper state and
identify possible problems if should be encountered. A scheme of the unit
casing is presented in Fig. 1.

### 2.1. Unit connections

Connections to the Front-End units should be carried out in the following
order:

i) First the $75\Omega$ F-type plug of the cables coming from the antenna should
be connected to the corresponding input *ANT X, ANT Y, ANT Z*. Please
make sure you indeed connect the $75\Omega$ F-type connector end (the thin-
ner one), and not the $50\Omega$ one (thicker). Inversion here would destroy
the plug. Also since the 12V DC power supply to the antenna LNAs is
provided through these cables, it is in principle safer to plug/unplugg
them only when the Front-End Unit power is off.

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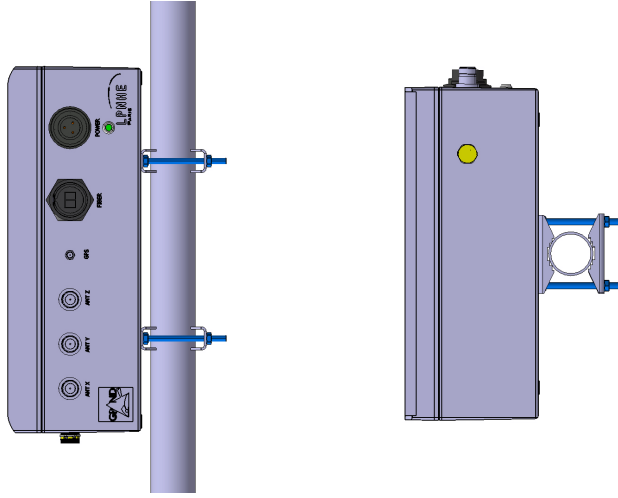*Email address:* `martineau@lpnhe.in2p3.fr` (Olivier Martineau-Huynh)

Figure 1: Front (left) and bottom (right) views of a GRANDproto35 Front-End unit casing once fixed to a pole.

ii) Then connect the GPS antenna. <u>By no means should the GPS antenna be connected when the power is on</u>. This may destroy the GPS unit inside the board (see section 2.2.2) and make it unusable. The GPS antenna should preferably placed above ground. A magnet inside the GPS antenna allows to fix it to a close-by metalic surface.

iii) Then connect the optical fiber (which can however be plugged/unplugged at any time, with no risk of damage).

iv) Finally plug the power cable. Nominal value of the power supply should be 12V, but values between **xx and xx** are still OK. A green LED on the front panel just below the power plug allows to check if the board is powered on.

## 2.2. Front-end board description

A picture of the board is shown in figure 2. It can be divided in 4 functionnal sections: analog, digitial, communication and power supply.

### 2.2.1. Analog part

The description of the analog part of the board is given in details in [1] (in French). Here we just give a brief overview.
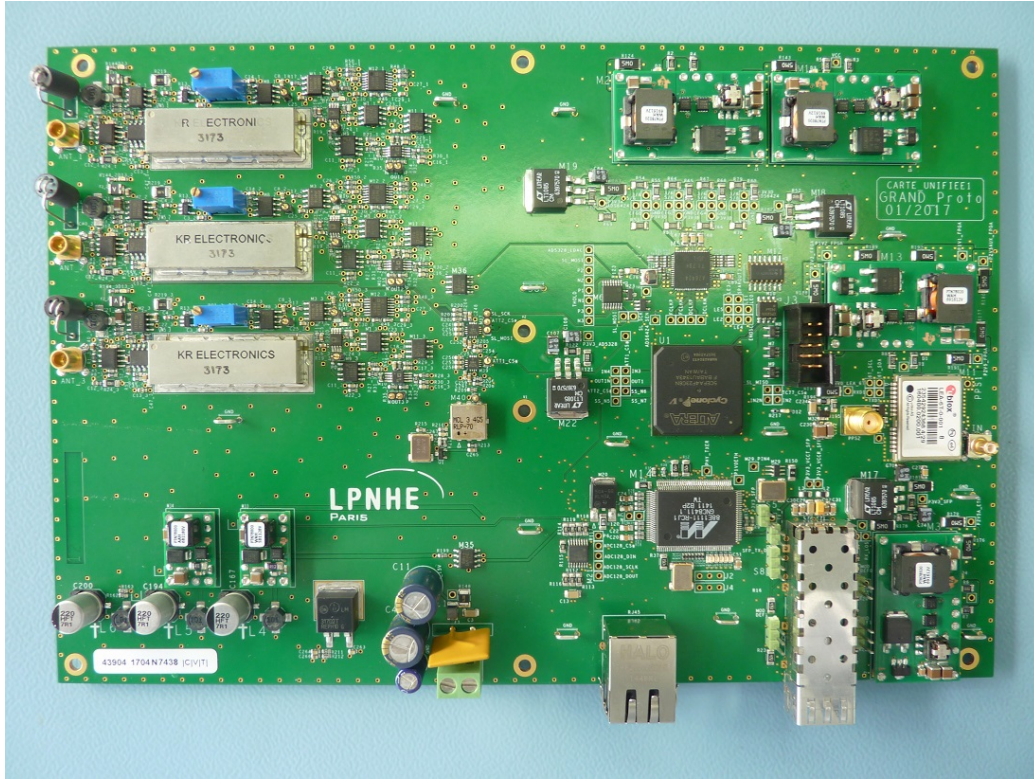The analog part lies in the top-left corner of the board. Signal input to

Figure 2: Picture of the GRANDproto35 Front-End unit board. TO BE UPDATED.

the board is done for each of the three channels through an MMCX 75$\Omega$ jack (connected to the corresponding F-type connector on the casing), with X, Y and Z channels from top to bottom. The signal is adapted to a 50$\Omega$ impedance thanks to a dedicated amplifier set just after the connector. The signal is then fed into the 30-100 MHz filters tagged *KR ELECTRONICS*. Signal is finally processed through a power detector AD8310 [2], which acts as an envelop detector. The power detector runs in differential mode. Its common mode voltage has a default value of 0.9V adjusted thanks to a potentiometer (blue square, just above the filter). It can be measured between ground and the test point shown on Fig. 2.

The analog board also provides the power supply to the LNAs placed inside the antenna nut through a bias-tee system connected to the MMCX plugs. This means that in normal operation, a 12V DC voltage is applied to the

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input plugs, which the user should be aware of when performing tests on a powered board. The LNAs power supply can be switched on and off by the user (see section 3.3.2).

In addition to this, the analog part includes a trigger section, where the signals at the output of the filters are compared to threshold values. A trigger flag is generated and sent to the FPGA (see section 2.2.2) if one channel exceeds it. Note that there are six independant trigger channels, with two polarities for each of the three channels. The user can activate/inhibit independantly each of these trigger channels (see section 3.3.3).

Finaly an internal calibration system is also included in this analog part: its core is a 66.666 MHz quartz oscillator (placed at the center of the board), which generates a sine wave. Its amplitude can be moderated thanks to two attenuators, with attenuation values adjustable by the user (see section 3.3.2). When the user uses the DAQ in calibration mode, the input of the signal treatment chain detailed above is switched from the MMCX connector input to this calibration signal.

### 2.2.2. Digital part

The digital treatment of the signal is is detailed in [3]. It is performed on the right part of the card, starting with a 4-channels ADC [4] running at a nominal frequency of 50 MHz, ajustable up to 100 MHz through the FPGA firmware. The ADC continously digitizes the signal coming from the three channels. The $4^{th}$ ADC channel is used in calibration mode to digitize the signal at the output of the quartz oscillator. The digital signal of each of the 4 channels is buffered in a circular register inside the FPGA. When one trigger is received (see previous section), a subset of length $2 \times OFFSET$ (where $OFFSET$ is a parameter set by the user at run start) is saved for each of the four channels to form one event. A GPS time-tag is also requested to the GPS unit and embeded in the event header and sent to the board output (see section 2.2.3).

### 2.2.3. Communication

Communication with the DAQ computer is done through a Marvell interface chip, using the GEDEC Communication Engine. Messages are exchanged using UDP protocol. Either a standard ethernet plug can be used, or optical transfer through an SFP connector. A jumper placed just below the Marvell chip allows to switch from one to the other (left: ethernet plug, right: optical). The latter is the standard communication system in

GRANDproto35 operation, with a bi-modal SFP ($\lambda_1 = 1310\,\text{nm}$ & $\lambda_2 = 1550\,\text{nm}$) allowing down (data) and upstream (commands) communication on a single fiber.

The Front-End unit is identified through a unique MAC adress given by a specific chip (Dallas DS2502) while its default IP adress is 192.168.1.18 for all units. At DAQ start-up, the Mac adress ID is mapped to an IP adress of format 192.168.1.1xx where xx is the Front-End unit ID, ranging between 1 and 25. This IP adress is then used for communication with the DAQ PC, whose IP is set to 192.168.1.1 within a local network.

### 2.2.4. Power supply

The nominal power supply of the Front-End Unit is 12V DC, and standard power consumption is $\sim$10W in normal run conditions. In standard operation at Ulastai, this DC voltage is provided by the external AC/DC converter installed at the pod level. There is also an internal AC/DC converter fixed on the internal side of the Front-End unit casing, but it is not used.

A re-armable fuse is installed at the input of the board power supply (yellow thing on Fig. 2). It will disrupt power supply in case a current surge is detected (**level ?**). It is re-armed after power cycling.

DC voltages of +3V and -4V are generated by DC-DC converters located on small mezanines placed at 3 corners of the board.

### 2.2.5. Board control

There are several tools to check that the board is in a proper state, and likewise, identify possibel issues.

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## 3. Data acquisition & communication with board

### 3.1. General structure

The DAQ has a multi-layer structure. At the core of it is a very basic system of formated words exchanges between the front-end units and the PC. These are briefly described in section 3.3, and in more details in [3].

One of the central element of the DAQ system is a C program, called `TREND_server`, which runs on the DAQ PC and collects data sent by the Front-End units on a given port of the PC (by defaut 1235 for slow-control data, and 1236

for antenna data). This is the "ear" of the DAQ. It is complemented by its "mouth", a program called `send_message` which issues commands to the Front-End units on another port (by default 1234). Note here that `TREND_server` and `send_message` do not communicate with each other. This is a direct consequence from the fact that the DAQ is based on socket communication in UDP protocol. It is therefore a built-in feature of the DAQ system.

However a third layer of code, which consists of shell scripts, is in charge of properly starting relevent processes, and sending appropriate commands in a timely manier so that all runs smoothly. This third layeris also supposed to send notifications to the user in case things go wrong. The user in principle only accesses this layer.

**TO BE COMPLETED/CORRECTED ONCE WE HAVE CONVERGED TO A STABLE DAQ SYSTEM.**

*3.2. Acquisition modes*

The different types of acquisition are the following:

*3.2.1. Pattern mode*

Here we request that the ADC generates a specific 12-bits pattern which can be:

i) **zeros**, aseries of 8 null bits.
ii) **ones**, corresponding to a numeric value equal to 4096.
iii) **toggle**, corresponding to an alternance between sequences '010101010101' and '101010101010', equal to numeric values of 1365 and 2730 respectively.
iv) **deskew**, corresponding to a sequence '110011001100', equal to a numeric value of 819.
v) **sync**, corresponding to a sequence '111111000000', equal to a numeric value of 4032.

Soft trigger is used to record data. This mode allows to check that the digital section of the unit works properly.

*3.2.2. Calibration mode*

Here the signal processed by the Front-End unit is the sine wave from the calibrator (see section 2.2.1). Soft trigger is used to record data. This

mode allows to test that the analog part of the board works properly, and moreover to calibrate the response of the DAQ chain, as the amplitude of the input signal is known here.

### 3.2.3. Physics mode

This is the standard acquisition mode for cosmic-ray detection. Here the input of the Front-End unit is the antenna signals, and the acquisition is triggered by them, with ajustable threshold values (see section 3.3.3).

### 3.2.4. Minimal bias mode

This mode differs from the previous only by the fact that acquisition is triggered by a soft trigger. This allows to record a baseline signal at a given instant, and is used for monitoring purposes.

### 3.2.5. Slow control

This mode allows to record the slow control information of the Front-End (namely: voltage of the 3 LNAs, voltage at the unit input, absolute value of the +3V and -4V DC levels, temeprature, trigger rates of the six channels).

### 3.3. Configuration files

The parameters defining an acquistion are written in configuration files (.cfg extension). These files are readable -and in principle modifiable- through a standard text editor. They are also read and passed to the DAQ by the `send_message` program. We detail below these parameters and configuration files for the various type of runs.

### 3.3.1. TRENDADC message

Each parameter of a *TRENDADC* message corresponds to the configuration of the ADC (see details in [4]). Only the word with adress 0xa (corresponding to the register 2 of the ADC) differs for the pattern mode, where its value depends on the type of pattern chosen (see section 3.2.1), while it is 0 otherwise.

### 3.3.2. TRENDDAQ message

The main parameters of the DAQ are defined in the *TRENDDAQ* word. They are:

- **DAQon**, a boolean which switches acquisition on or off.

- **AntOn**, a 3-bit-pattern switching on or off the output of channels X,Y and Z. It is set to 0 in calibration or pattern mode, and 7 (all channels on) in standard operation for the other modes.
- **EnOSC**, a boolean switching on or off the calibration oscillator. It is 1 in calibration mode, 0 otherwise.
- **Offst**, a scalar corresponding to half the trace length, in sample units. Default value is 90, corresponding to a $3.6\,\mu$s trace for a $50\,$MHz sampling rate.
- **EnablePD**, a 3-bit-pattern switching on or off the power detectors of channels X,Y and Z. Its default value is 7.
- **DisLNA**, a 3-bit-pattern switching off or on the LNAs of channels X,Y and Z. The default value for this parameter is 7 (all LNAs off). It is also set to this value in calibration or pattern mode, and 0 in standard operation for the other modes.
- **Attr1** and **Attr2** are the values for the 2 attenuators of the calibrator. Their value range between 0 (full attenuation) and 127 (no attenuation). These values do not matter for modes others than calibration.

*3.3.3. TRENDTRIG message*

In the *TRENDTRIG* message, we find the parameters relative to the trigger. Most important for the user are:

- **ST**, a boolean sending a soft trigger order to the Front-End unit.
- **TrgEn**, a 3-bit-pattern enabling the different channels. The order of the channels in the pattern is Z-, Y-, X-, Z+, Y+, X+, where the sign stands for the polarity of the trigger signal.
- **ThXs** (where X=1,2,3 is the channel, and s=+,- the polarity) is the threshold (in mV) of the 6 trigger channels. Obviously these values are relevant only if the corresponding bits in the TrgEn pattern are set to 1.

## 4. Operation

Here we describe how to start and run the GRANDproto35 setup.

*4.1. Start up*
- Once the Front-End Unit has been connected to the appropriate cables (see section 2.1) and powered on, the script `setIP.sh` should be launched on the DAQ PC. It will attribute a dedicated IP adress 192.168.1.1.xx to

each board of ID number xx. Successat this stage can be checked through a ping command to the unit IP adress. Note that the `setIP.sh` script also informs the units about the DAQ PC ID (IP adress and MAC adress). If these 2 parameters do not correspond to the actual values of the PC, then DAQ communication will not be possible. (see troubleshootig section)

- Then the status of the unit can be requested, through the command `SLCreq.sh`. A slow-control event file should appear in the `$DATADIR` folder. Edit it and check that all voltage values are correct (Voltage1=14V, Voltage2=3V, Voltage3=4V, Voltage4 to 6= 12V) and that temeprature is also reasonable (between 10 and 50°C). If all is OK at this stage, this means that DAQ communication with teh board works fine and that the Unit is properly powered.

- Then launch `pattern.sh` with parameters "`$BOARDID` 3" where `$BOARDID` is the board number ID. This executes a *pattern* run in toggle mode (see section 3.2.1) and allows to check that the logical section of the board is running properly.

- Then launch `calib.sh` with parameters "`$BOARDID` 60 60". This execute a calibration run with a total attenuation of **xx** dB. Open the run file with python script with `anaData.py` and check that the average value of the signal is around a value of **xx** Volts, with a standard deviation not above **xx** Volts. This allows to check that analog section of the board is running properly.

- Then launch `minBias.sh` with parameter "`$BOARDID`". Open the run file with python script with `anaData.py` and check that the average value of the signal is around a value of **xx** Volts, with a standard deviation not above **xx** Volts. This allows to check the status of the antenna and of its electromagnetic environment.Check also in the event header that the GPS info is present.

- Finaly launch `phys.sh` with parameter "`$BOARDID` 60 60 60 60 1000 10000". This will start a physics run, with triggers on the X and Y channels. Monitor the trigger rate by launching `loopSLC.sh`, which will request slow control data every 10 seconds. Display the trigger rate with the `anaSLC.py` script.

## 5. Troubleshooting

Below are summarized the most frequent problems encounter on the GRANDproto35 setup, and how they may be solved.

- **no ping:** check network settings on the PC (should be local network, with IP: 192.168.1.1). Check cable and fiber connection. Cycle power on the Front-End unit (may need to be done several times). If this does not work, go on field, and connect directly to unit from local fiber. If this works, then the problem comes from the fiber. If this does not work, then open the casing lid and check the Marvell leds (see section 2.2.5): first two should be blinking, two following should be on. If not, check that jumper is set on the right slot and that SFP is properly set in its slot. If nothing works, switch juper to left slot (with power off) and test connection on field with Ethernet cable. If this works, then problems comes from the SFP module. If this does not work then the communication module has a problem and the unit should be brought back to lab for further test.

- **no DAQ communication (ie no response to `SLCreq.sh`):** Ping Front-End unit. Issue the command `echo $DATADIR` in a terminal window of the DAQ PC, and check that the variable is indeed set to the folder where you want data to be written. Check that IP and MAC adress of the PC actually correspond to those given in `setIP.sh`. Relaunch `setIP.sh`. Launch the `Wireshark` program. When a `SLCreq.sh` command is issued, a response from the Unit should appear in the packet traffic, with appropriate IP and MAC adresses from both sides.

## 6. References

[1] J. David, Carte analogique GRANDproto35, 2017.
URL `http://xxx`

[2] A. Devices, AD8310 technical note, 2017.
URL `http://xxx`

[3] P. Nayman, DAQ for TREND, 2016.
URL `http://xxx`

[4] T. Instrument, ADS6426 technical note, 2013.
    URL `http://xxx`