18 ATLAS policy on grounding and power distribution

18.1 Introduction

As is well known from previous experiments, careful attention must be paid to the grounding and power distribution of each of the detector systems if they are to operate successfully at the low signal levels required. While this has been an important issue in previous experiments, it is an especially important issue for ATLAS given the large expense and time required to redo any system, and given the very large power in most systems. In this Chapter, we outline the present ATLAS policy on grounding and power distribution. The primary content of this Chapter is a set of proposed guidelines that have been arrived at, via reasonably extensive consultation with each of the sub-systems. The intent is that these guidelines must be followed unless specific approval for a deviation is granted by the Executive Board. Some discussion is also presented as to how the guidelines can be accomplished. It is expected that recommended implementations will become increasingly detailed after further discussion and thought and as experience in test beams and system tests provides additional information.

18.2 Summary of ATLAS policy

The primary guidelines are the following. First a summary list is presented and then comments are presented on each item.

- All detector systems will be electrically insulated.
  No connection to ground other than 'Safety Network'.
  No electrical connection between different detector systems.
- Low voltage power supplies floating.
  Power return either fully insulated from ground or connected by a device which has high impedance for normal operation but low impedance during failure (e.g. saturable inductors or diodes).
- High voltage power supplies floating.
  HV return likely to be insulated from detector by resistor.
- Data transmission, clock and control distribution.
  Optical or shielded twisted pair.
- Detector located in Faraday cage.
- Monitor and control signals.
  Optical, shielded twisted pair, or similar insulation.

18.3 Comments on individual guidelines

18.3.1 All detector systems will be electrically insulated

The electrical insulation really has two different aspects: insulation from 'ground' and insulation of one detector system from each of the others. The first aspect is concerned primarily with the desire to eliminate, or at least minimize, ground loops. Each system will have to be connected to earth at some location for safety reasons, but the location and manner of this connection must be chosen carefully. In the last section of this document, the location and nature of the proposed safety connections to earth are summarized for each of the major sub-systems. By designing the system so that it can in principle be 'completely' insulated from earth (safety considerations aside), one has maximum control over how the connection to earth is finally made, and the best assurance that unintended connections are avoided.

Inadvertent or unintended connections between detector systems could well foil the intended noise immunity of a particular system and would certainly make debugging noise problems much more difficult. In the final installation, it could prove advantageous to connect some detector systems together, but any such connections should be carefully designed and implemented only optionally and with the agreement of all sub-systems.

While parasitic AC 'connections', either to ground or between detector systems, can never be completely avoided, an effort should be made to identify those that are likely to be problematic and to minimize them.

18.3.2 Low-voltage power supplies floating

The focus here is on treatment of the power supply return, whether it is connected to earth and if so in what fashion. It is our present understanding of CERN safety policy that if the voltage is less than 50 V it is acceptable to have the power returns completely insulated from earth at the power supply. For larger voltages, a 'safety' connection of the power supply return may be required. In the event that a 'safety ground' is required, for those sub-systems that do not intend to make their 'primary' earth connection at the power supplies, it will be requested that this connection be made via circuit elements which provide a 'high' impedance to earth during normal operating conditions but a very low impedance in the event of failure. Examples of such elements are 'saturable insulation inductors' and diodes; a schematic of the power supply configurations, for voltages less than 50 V and for larger voltages, is presented in Figure 18-1.

18.3.3 High-voltage power supplies floating

Again the focus is on treatment of the power supply return. Where truly high voltages are utilized (e.g. > 1000 V), and distribution is via coaxial cables, it is likely that the shield of the cable must be connected to earth. In this case it is customary to break potential ground loops by connecting the high-voltage (HV) shield to the detector via a resistor, typically of order 1 kΩ. (In some cases a resistor may also be inserted in the HV supply conductor, to provide a more balanced system). In the initial plans, most sub-systems in ATLAS plan on this traditional approach. It may also be considered whether safety connections that provide high impedance during normal operation, such as those discussed for low-voltage power supplies, will be allowed. An alternative approach could also be to distribute the HV power and HV power return via two conductor cables with an outer shield. In this case, grounding the outer shield should be sufficient for safety purposes (this could also reduce noise conducted into the detector).

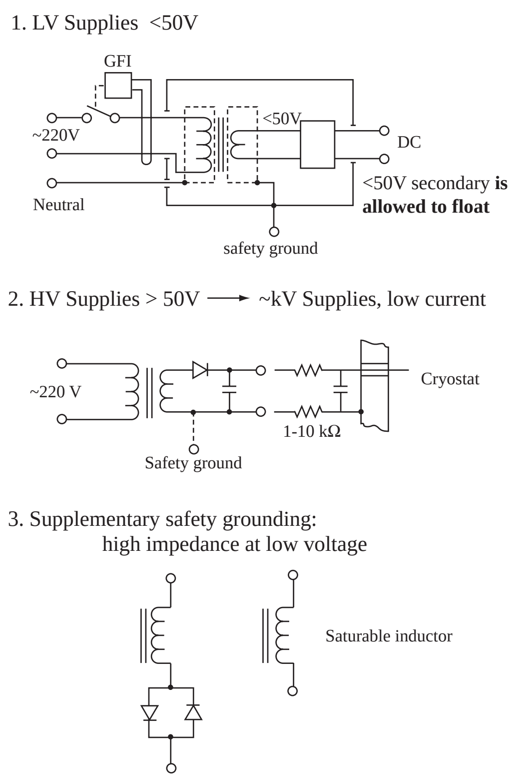

Figure 18-1 Examples of safety grounds for power supplies of low and high voltages.

18.3.4 Data transmission, clock and control distribution

Transmission of the data and clock and control is expected to be either via optical fibre or shielded twisted pair using low-level differential signals. If the latter is utilized, it is expected that the shield of the cable will be connected directly to the local detector ground at the detector and via a capacitor to the local ground at the other end. This provides for maximum shielding and noise immunity at high frequencies while at least breaking any ground loops created at low frequencies. An example (certainly not unique) of a system which uses shielded twisted pair in this fashion and obtains very good noise immunity is NA48; a diagram of their signal and ground connections is presented in Figures 18-2 and 18-3.

18.3.5 Detector located in Faraday cage

The maximum protection against EMF noise is produced by locating the detector(s) in a carefully designed Faraday cage. Currently this is planned for the liquid-argon calorimeter, tile calorimeter, TRT and muon systems. The SCT and pixel systems are less susceptible to pick-up than some of the others, but some form of overall shielding may be necessary.

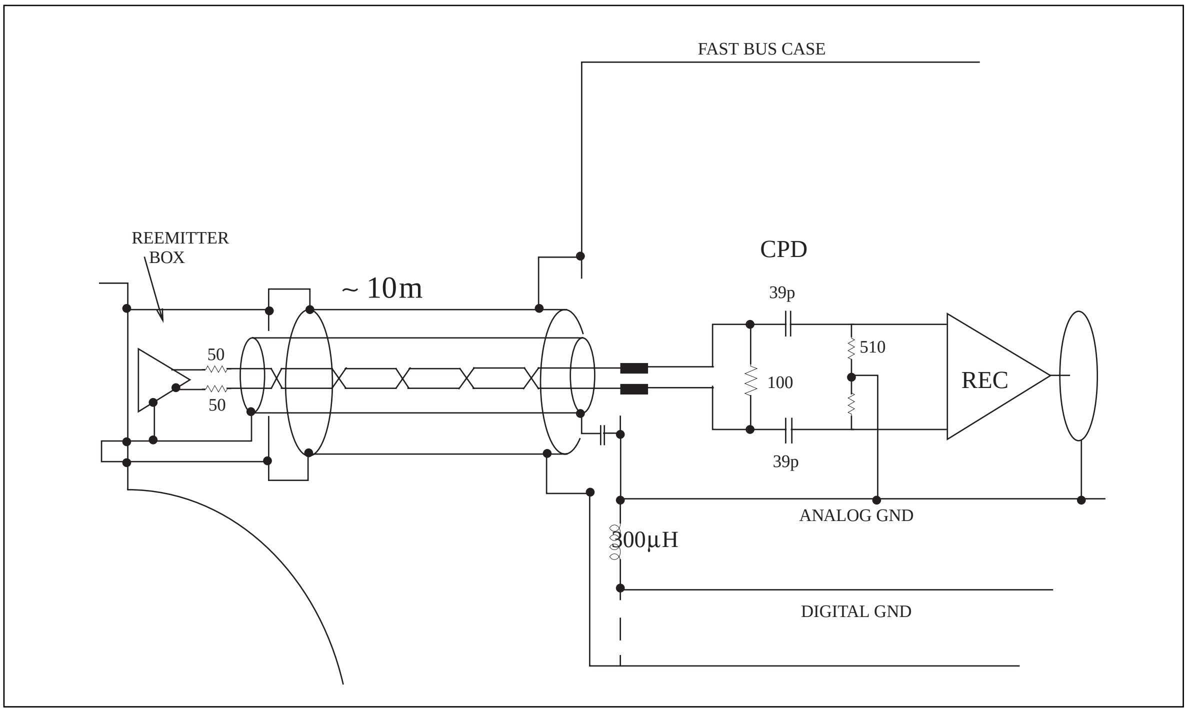

Figure 18-2 Example of grounding connections between detector and receiving electronics (NA48).

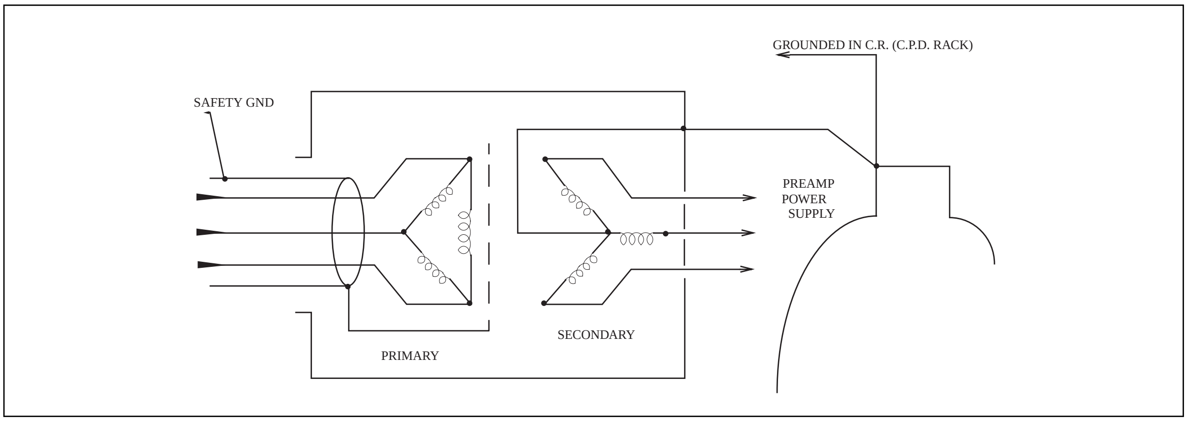

Figure 18-3 Example of grounding connections between power supply and detector (NA48).

18.4 Plans for implementation in each sub-system

Each sub-system is required to provide a description of how it intends to achieve the guidelines stated above. Key features of this description include:

- Summary list of how electrical insulation is maintained for ALL mechanical and electrical interfaces to the sub-system.
- Schematic diagram(s) indicating where, and in what manner, all connections to earth or safety grounds are made.
- Summary of primary outstanding issues, if any.
- Identification of an individual to serve as primary contact for information and meetings concerning grounding and power distribution.

Initial plans have been received for almost all of the sub-systems, and also for the magnet systems. Most of these are available on the web via the front-end electronics link from the ATLAS page. An example summary of the techniques used to achieve insulation is shown in Figure 18-4 for the liquid-argon calorimetry system. Additional details of the plans for implementation will be provided during autumn 1998.

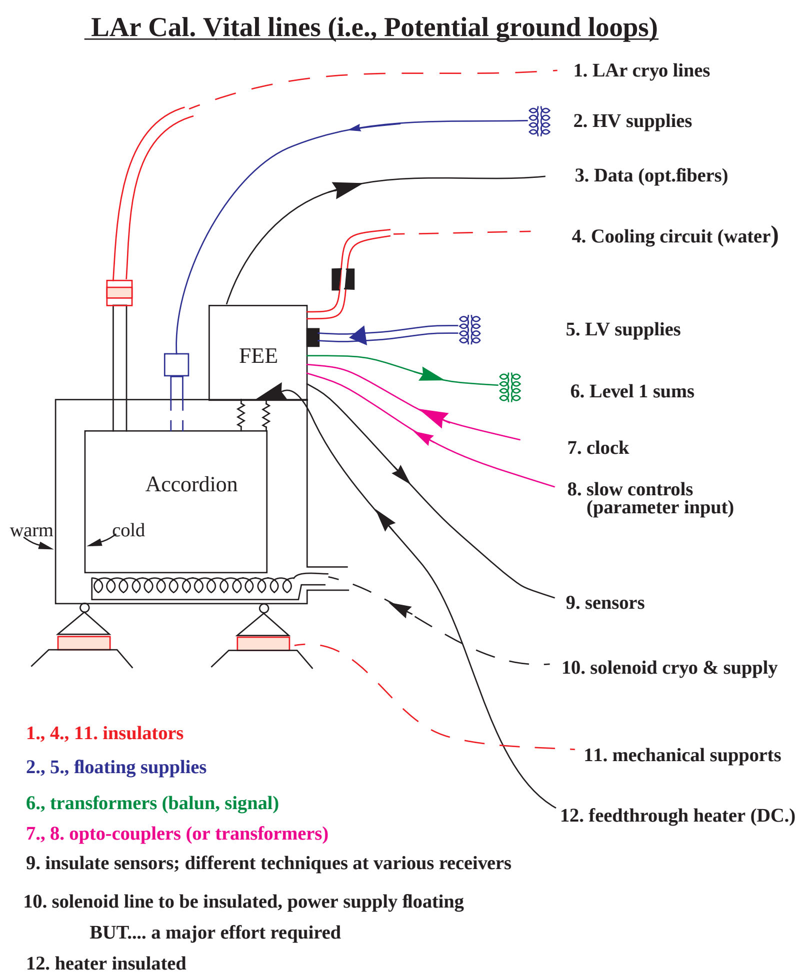

Figure 18-4 Example of techniques used to eliminate ground loops (liquid-argon calorimeter).

18.5 Planned connections to earth - safety grounds

For reasons of safety, all conducting objects of any size in a sub-system must be connected to earth. We note here that connections to earth will in practice be made via a small number of cables which travel from the cavern or USA15 or other halls to the surface building. Because of the poor conductivity of the rock surrounding the cavern, there is no 'local' earth connection. As noted above, to eliminate ground loops there should be a 'single point connection' for each piece of a sub-system that is electrically insulated from other sub-systems and from other pieces of the same sub-system. (A 'single point connection' could consist of a number of connections or conductors as long as the routing of the conductors and the location of the conductors does not allow significant loops.) Considerable discussion has been held amongst the sub-system communities to determine where this connection would be best made. The TRT, liquid-argon calorimeter, tile calorimeter, and muon systems currently endorse the following plan:

- The safety connection to earth will be made in USA15.
- The connection should be made via a well-defined number of connections or cables, such that the quality of the connection and the current flowing can be easily monitored.
- There will be NO connection of the detectors to earth, including large metallic objects such as the cryostat, in the cavern.
- A safety procedure should be established such that the safety connection in USA15 cannot be removed unless an alternative safety connection has been made.

We note that this approach is nearly identical to that of the NA48 experiment. Diagrams specifying the location and nature of connections to ground for the NA48 experiment have already been presented in Figures 18-2 and 18-3. In this case the primary connection to safety ground is made at the CPD crates which receive signals sent from the calorimeter. There are no additional connections to ground either at the cryostat or at the power-supply return leads at the preamplifier supplies.

Common aspects of the TRT, liquid-argon calorimeter, tile calorimeter, and muon systems that argue for the above approach are the following.

- It is expected that the power supplies will be located in the cavern in a number of different locations.
- Signals are expected to be transmitted over twisted pairs to USA15 (except for the muon system which intends to use optical fibre).

Thus, making safety grounds at the power supplies would create ground loops (unless high-impedance safety connections were used). There is also a strong argument to reduce any potential difference between the 'local grounds' of the receiving electronics and the 'local detector ground' at the electronics on the detector. Making the earth connection for the sub-systems at USA15 accomplishes this since little or no d.c. current should be flowing in the ground connection between the detectors and USA15.

For the SCT and pixel systems a different approach is anticipated.

- It is planned to locate all power supplies either in USA15 or US15.
- All transmission to USA15 is optical.
- The SCT and pixel detector systems are highly modular, encompassing 4088 and 2600 insulated modules, respectively. Each of these modules has an independent power supply. Thus it is planned that the safety connection will be made at the power supply for each module.

18.6 Requirements and location of power supplies

Each sub-detector requires low-voltage power supplies for the front-end electronics situated on the detector. Some of them require also HV power supplies for the detector. The location of the power supplies is an important issue because the size of the cables necessary to bring the power inside the detector strongly depends on their length for a given acceptable voltage drop and because the amount of power allowed to be dissipated into the experimental area is limited.

Having the power supplies located in the cavern (UX15) would be very attractive, but the level of radiation and magnetic field at that location is significant as shown in Table 18-1.

Table 18-1 Magnetic field and radiation levels at the location of power supplies in the cavern

B field	200 - 1000 Gauss
Ionizing radiation for 10 years	10 Gy
Neutron flux for 10 years	$5 \times 10^{11}/\mathrm{cm}^2$

A decision has been taken to locate the HV power supplies in the underground counting rooms (USA15 and US15) at a place where there is neither magnetic field nor radiation. The impact on the cable cost is quite small as only very low current is carried by the cables.

The low-voltage power supply requirements are summarized in Table 18-2.

Table 18-2 Summary of the power-supply requirements for ATLAS front-end electronics (on detector)

System	Units	Nominal voltages and currents	Comments
Pixels	2600	1.54V/0.8A, 3V/1.6A, 10V/0.02mA, 4V/75mA, 600V/2mA	
SCT	4088	1V/6mA, 3.5V/1A, 4V/250 mA, 7V/6 mA, 10V/0.01mA, 300V/4 mA	
TRT	1350	3.3V/6A, -3.3V/3 A, 5V/1A	
EM	64	+ 10V/7 A, +7 V/104A, +5V/277A, +3V/21A, -3V/114A, -5V/5A	
HEC	320	-3V/100 mA, 4V/500 mA, 8V/1A	
Tile	256	5V/500 mA, 15V/500 mA, - 15V/500 mA	HV Distribut.
Tile	128	5V/20A, -5V/10A, 9V/400 mA	Barrel
Tile	128	5V/14 A, -5V/7A, 9V/300 mA	Extend. Barrel

Both the SCT and pixel sub-systems have decided to locate their power supplies in USA15 and US15. The other sub-systems are studying the possibility to locate them either in the experimental cavern (outside the muon detector) or inside the detector. This last option could be selected for liquid-argon calorimeter electronics; it is envisaged to have d.c./d.c. converters located close to the front-end electronics. These d.c./d.c. converters would be fed with low-current 400 V supplies, thus saving a lot of cabling space.

A common effort, in collaboration with the EP-ESS group, has been launched in ATLAS to study the behaviour of power supplies in magnetic and radiation fields. Initial results from these studies are very encouraging.