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Setting up High Gain Detector Electronics for TCSPC

Applications that Require High Gain

There are some special photon counting applications that require high gain preamplifiers between the detector and the discriminator input:

- MCP PMTs sometimes have insufficient gain so that the single photon pulses cannot be used to trigger the CFD directly
- MCP PMTs used at count rates above 1 MHz have a limited lifetime due to degradation of the microchannels. The degradation proceeds linearly with the overall charge delivered by the tube. Therefore, to achieve an acceptable lifetime the tube is operated at reduced gain and a high gain preamplifier is used.
- Systems using MCPs with the HRT-41 and HRT-81 TCSPC Routers have an extremely high overall gain. Not only that a preamplifier must often be used in front of the router, the router itself has a gain of about 5. Furthermore, the charge amplifiers in the router have a gain that reaches up to 1000 for frequencies below 10 MHz. The overall gain of such systems is extremely high.

For all high gain systems it is essential to avoid any noise pickup from radio transmitters, computers or laser power supplies. Some recommendations for high gain systems are given below.

Avoiding Ground Loops

High speed electronics normally uses low-impedance signal connections. These connections are relatively immune against capacitive noise pickup. Therefore, inductive coupling is the dominating effect that can introduce noise into the system.

The most important way of inductive noise coupling are ‘ground loops’. Ground loops are formed if there are several ground connections between different parts of the system. If HF radiation from external noise sources penetrates the setup currents are generated in the loop and transformed into the signal lines. Furthermore, power supply currents can flow in the ground system. These currents often contain HF components which partially appear in the signal lines.

If ground loops are the reason for noise pickup simple screening of the system often has little effect. The ground loops must be found and disrupted or at least minimised. Some examples are shown below.

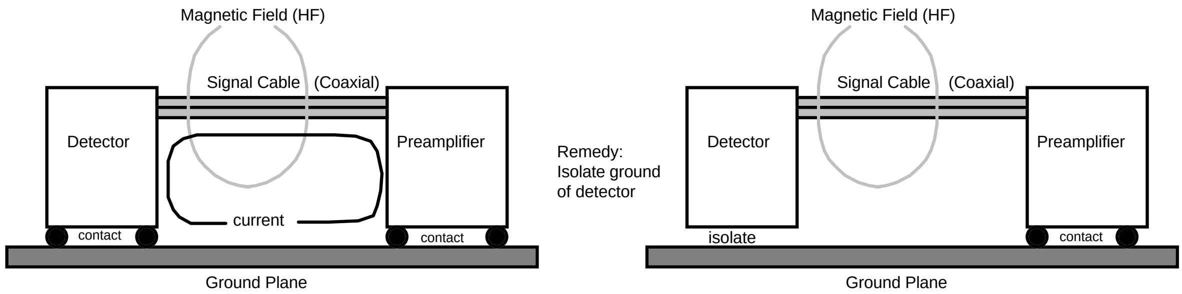

Fig. 1: Disrupting the ground loop by isolating the detector

The HF field penetrates the area between the ground plane and the signal cable. It therefore induces a current flowing through the detector shielding, the ground plane, the preamplifier shielding and the shield of the signal cable. A part of this current is transformed into the detector signal.

One remedy is to disrupt the ground loop by isolating the detector (fig. 1). If there is no closed loop there is also no HF current flowing through the cable and no noise pickup. This is the ideal solution even for very long signal cables.

Unfortunately the detector cannot always be isolated by from the system ground. Several signal lines can be present, and if the detector cannot be operated from a battery there is at least one additional connection to the power supply.

If it is not possible to disrupt all ground loops, the noise pickup can be reduced by reducing the area enclosed by the ground loop. This is shown in figure 2.

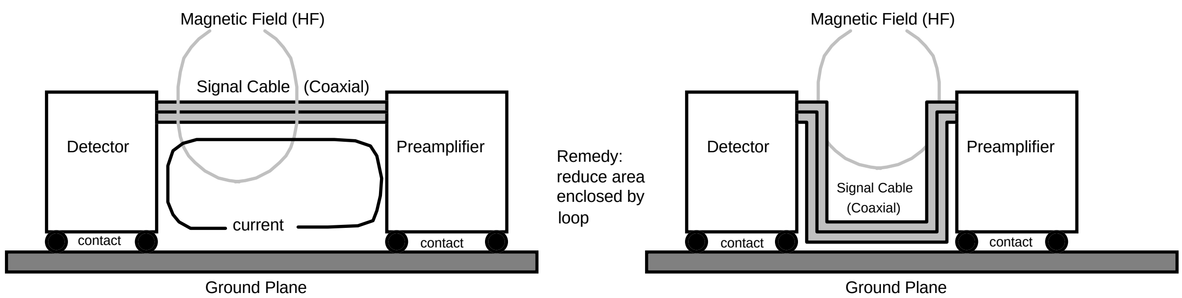

Fig. 2: If the ground loop cannot be avoided, minimise the enclosed area

Please pay attention also to the power supply cables. If there is no metallic ground plane for the complete measurement setup (the ground in the figure above) the system ground is formed by the network of power cables between the different devices (fig. 3, left). These cables can create extremely large loops. The loops often conduct extremely large HF currents which are induced not only by the local HF field but also by the noise currents in the power system of the building. Therefore make sure that all power plugs of the system components are connected to one common distribution board which is powered from only one power plug (fig. 3, right).

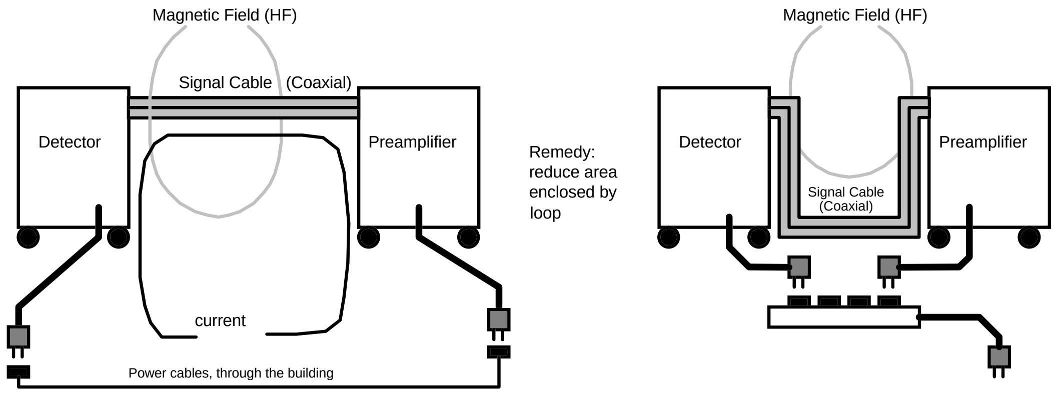

Fig. 3: Ground loop formed by power supply cables

Many experimental setups are a combination of fig. 2 and fig.3., i.e. there is a ground plane (the optical table) and a network of power cables. If all system components are built up on and grounded at the table the noise current from the power cables is shunted by the table (fig. 4). The problem with this setup is that often not all components can be placed on the table or have their grounds not available to be connected to the table. If one of the devices is not connected to the table the result can be worse than fig. 3. Nevertheless, connecting the cases of all system components to the table is a good solution which is worth to be tried out.

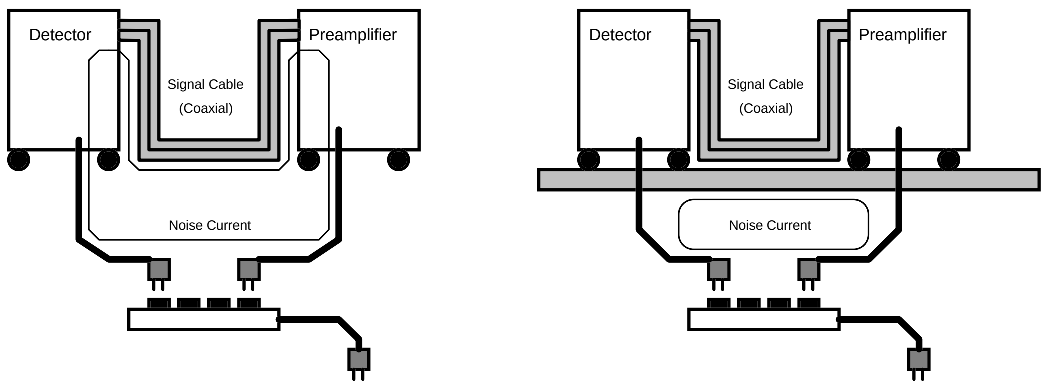

Fig. 4: Shorting power supply ground loop by the ground plane of the experiment

Fig. 4 with **all** device cases grounded might look contradictory to fig. 2 which suggests **not** to ground the detector case at the laboratory table. The reason is the different way the ground loop current is induced. In fig. 2 the noise current flows through the shield of the signal cable and through the table. Therefore, isolating the detector from the table interrupts the loop of the noise current. In fig. 4 the situation is different. Here the current is flowing through the power supply cables. The table shorts this current so that it doesn't flow through the signal connections. In practice, you must develop a feeling which loop most likely causes the problem and find the best countermeasure.

When searching ground loops, please don't forget to check network cables connected to the system computer. From the HF point, the network cables are by far not isolated from the computer. Therefore, network cables often form building-wide ground loops (fig. 5). We therefore suggest to disconnect network cables when using high gain detector configurations.

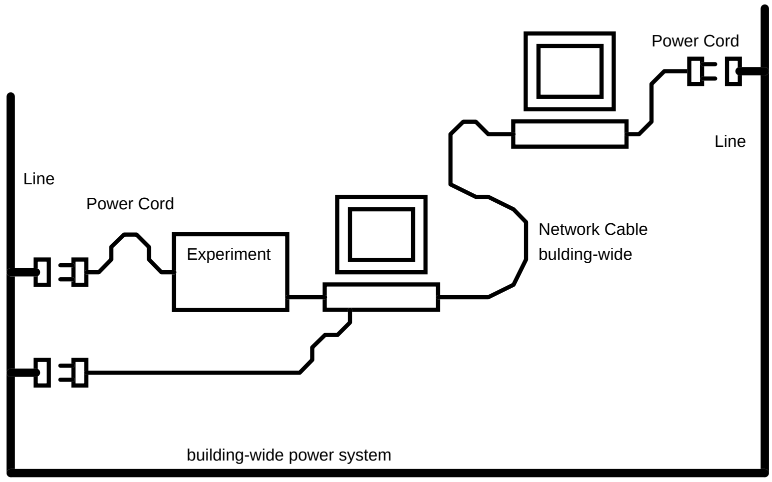

Fig. 5: Network cables often form building-wide ground loops

Loops in the signal ground path

The most unfortunate solutions are ground loops directly in the signal path. An example is shown in fig. 6.

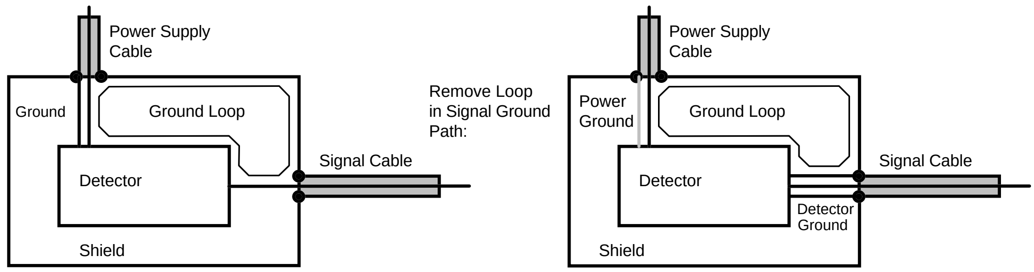

Fig. 6: Ground loop in the signal path

In figure 5 (left) any noise current induced in the loop enclosed by signal cable shield - detector shield - detector ground line - detector appears directly in the signal path. Furthermore, the signal path shares a the detector ground line with the power supply. Any HF component in the power supply current causes induces an HF voltage on the detector ground line which, in turn, appears at the output signal of the detector.

In figure 5 (right) there is a direct connection between the detector and the signal cable shield. Although this does not remove the ground loop, any current induced in the loop now does not appear directly on the output signal. To minimise the remaining noise pickup the detector ground line (formed the shield of the coaxial cable inside the case) should be as short as possible. If the lengths of this connection can be reduces to zero the signal connection is not longer part of a ground loop (fig. 7, right).

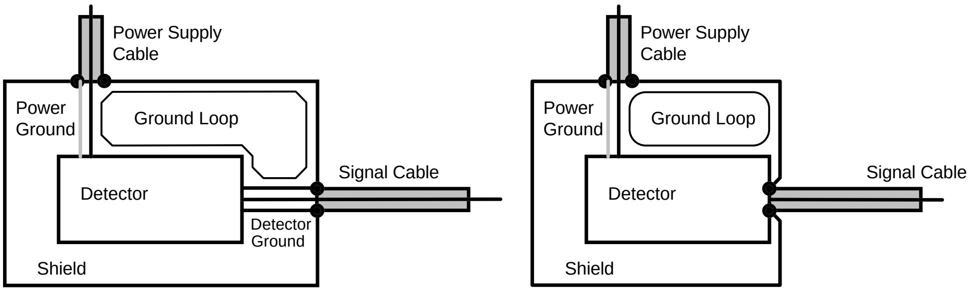

Fig. 7: Avoid that signal lines are part of a ground loop

Shielding

Proper shielding can considerably improve the noise immunity of your setup. However, simply putting a metal box over your setup usually has little effect. The box must be grounded at the right points and cables must be fed through in the right way. Improper shielding actually can help less than nothing.

Fig. 8 shows gives an example. In the setup shown left ground loop currents flowing in the power supply and signal cables are fed into the shielding box. The noise current even flows through the signal cable that connects the detector and the amplifier. Therefore, the box has little effect on the noise immunity of the system.

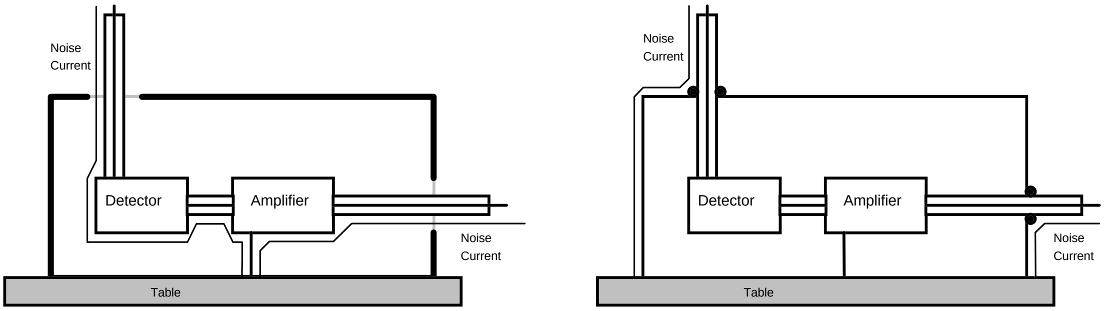

Fig. 8: Prevent ground loop currents from flowing into the shielding case

In Fig. 8 (right) the outer connectors of the cables are connected to the screening box. Noise currents are now shunted by the box and do not reach the detector and the amplifier. It is true that connecting the cables to the box creates some new ground loops, but these are inside the box where the HF noise field is much weaker than outside.

For cable feedthrough we recommend to use appropriate connectors, e.g. Radiall R125 720 001 with female SMA connectors at both sides or R125 303 or R125 308 with a female connector at one side and a cable to be attached at the other.