

# CROCS Electronics

## Introduction

This is an assembly of the relevant documentation and drawings: an explanatory Overview with circuit diagrams is followed by a copy of preceding e-mails.

## Overview

The overall scheme of a central Control Station with up to 4 satellite Detector Stations is shown in [Fig1](#). The plan is to use a multi-core cable both to provide electrical power to the Detector Stations and to carry signals to and from the Control Station. In this scheme the power is derived from a single 24 Volt mains adapter connected to the Control Station.

Just what is needed in each of the Detector Stations is shown in [Fig2](#), namely:

- 1) The Bias Control circuits that allow the Silicon PhotoMultiplier (SiPM) operating conditions to be finely adjusted to have adequate gain with stability.
- 2) The Signal Chain circuits that amplify and condition the tiny pulses from the SiPM and send them along the cable to the Control Station.
- 3) A Communication Path that allows the Control Station both to adjust the SiPM bias (and possibly other features of the electronics) and to monitor what is going on: temperature, voltage, current for example).
- 4) The power circuits that provide the various voltages needed by the Signal Chain and Communication Path electronics.

For preliminary work much of this circuitry is redundant and too elaborate. I suggest that for the early stages, and to keep the project within the scope of a school environment, the remote control aspects be dropped. [Fig3](#) shows a reduced circuit with a manual SiPM bias control that should meet this need. It is this that a school wishing to investigate the operation of a scintillator and SiPM might build.

Please note I haven't tested any of this, so please shout if you see anything that doesn't make sense.

Maurice Goodrick

## The e-mails

These give some explanation of the system and the thinking behind it that should prove useful. Note that the ideas evolve, and some of the details expounded at the start have been changed: the circuits given above should be taken as the latest recommendation.

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1) %%% MJG to the CROCS Community on 28/01/2011 %%%

*I have been giving some thought to the connection between the Control Station and the Detector Stations of a "CROCS" Cosmic Ray setup. It would make sense for us to adopt the same general scheme, so I will try to give an idea of the sort of thing I'm proposing. (But note that none of this is fixed - and will be modified in response to further thought and experience - including input from you).*

*Each Detector Station holds a scintillator tile and Silicon Photo Multiplier (SiPM). The latter needs a stable, low noise and adjustable bias voltage of up to 35V (luckily of very low current). There is also a pre-amplifier that needs around 10V at around 10mA. There will also have to be some form of driver circuit to allow the signals to be sent back along the path to the Control Station in a clean way: this will need a lower supply voltage, typically 3.3V or 5V. The circuitry to allow the adjustment of the bias voltage and other communication functions will probably also runs from 3.3 or 5V. There may be other functions we would like to do within the Detector Station - e.g. signal conditioning, or various monitoring tasks - and we should choose a connection scheme that leaves some room for future extensions.*

*This all boils down to the following requirements for the interconnection:*

- 1) electrical power delivery*
- 2) getting the signal pulses back to the Control Station*
- 3) control of Detector (primarily the SiPM bias control)*
- 4) getting monitoring data back - I'm planning to make the control path of 3) bi-directional to achieve this.*
- 5) the separation of the units could be >10 metres, and the cabling path will be longer than this.*

*Steve has proposed the use of the ubiquitous RJ45 connectors and CAT5E cabling as a cheap and readily available standard. This has (I believe) 4 twisted pairs of rather thin wire. If we allocate 1 pair to signal return and another to the control communication path, this leaves 4 wires to deliver all the power needs of the detector station. It's worth spending a bit of time planning how this is to be done.*

*If we standardise on delivering a single supply, and generate the other voltages we need from this "Bulk" supply, we will only need 1 pair of wires (assuming they can handle the current): if we have 2 pairs free, we could parallel them up to reduce the resistance.*

*We could derive the other voltages from the bulk supply using "Linear Voltage Regulators" - but there are two problems with this:*

- 1) the bulk supply voltage has to be higher than all of the derived supplies.*
- 2) lots of power will be wasted (discuss)*

*Luckily there are relatively cheap and small devices called DC-DC ("DC-to-DC") converters that can efficiently change power supplied at one voltage to a higher or lower voltage (functionally a sort of DC transformer). (How do these work?) They allow us to greatly improve delivery of the power needed over the long, thin wires. Say the total power needed is 10 Watts, and the resistance of the wires is 3 Ohms. If we deliver that power at 5 Volts, that's a current of 2 Amps. That means we lose 6 V along the wires. So we need to drive 11V from the Control Station to get the 5V at the far end. And in addition to the 10 W delivered to the detector, we are wasting  $2A \times 6V = 12W$  in the wires. None of this is good news.*

*But if we choose to deliver the required power at 20V, the current drops to  $10 W / 20 V = 0.5$  Amps, and the drop along the wires will be  $3 \times 0.5 = 1.5$  Volt; the power lost in the wires is  $0.5 \text{ Amp} \times 1.5 \text{ Volts} = 0.75$  Watts, which is far more reasonable.*

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*So I hope I have convinced you of the sense of this approach. I'm sorry not to have produced the odd diagram, but I hope the argument is clear to those who understand  $V = I \times R$  and  $P = I \times V$ . I should mention that there is a potential problem with these DC-DC converters: they generate electrical noise that might upset our sensitive electronics; but I believe this will not be a problem if we choose good converters and take care with their use.*

*The devil is in the detail: the practicalities are:*

*1) TRACO make a large range of these DC-DC converters, and a selection of them are available from Farnell and RS. We should use PCB-mounting varieties, with an output voltage and wattage to suit the particular supply. Some regulate the output voltage to make it constant as either the load current or the input volts change: these are the ones we should use.*

*2) some accept a wide range of input volts, while others specify a restricted range: we should go for the former as we're not sure just what the drop down the wires will be. I would like to standardise on a delivery voltage of 24V (it keeps wire losses down, is safe, and is relatively standard)*

*3) the output voltages available are limited: 12V, 5V, 3.3V are all available in a range of powers, but 35 Volts (that we need for the SiPM bias) is not.*

*4) My solution to this problem is to use the fact that the outputs are usually floating, so it is possible to "stack" the output of one on top of another. Thus we could use a dual output supply that provides  $\pm 15V$  as a 30V supply, and reference this to the +10V supply used for the pre-amplifier, giving a 40V rail for the SiPM.*

*5) The SiPM bias needs to be adjustable within safe limits. Given the very low current needed, we can do this using a potentiometer to "tap-off" the required fraction of this 40V rail. For your lab investigations, this could be a conventional 20-turn screwdriver-adjustable pot. Add series resistors at top and bottom of this pot to restrict the available voltage to a safe and useful range (such as 25-32V ? Look at the SiPM data sheet). Note the original devices we got ran from 17 or 18V. For remote control, I have yet to decide on a scheme.*

*If you go to this page of the Powersolve website, you will see the ranges of PCB-mount DC-DC converters that I've been looking at:*

[www.powersolve.co.uk/jkcm/default.aspx?pg=128&categoryKey=28&categoryParent=28](http://www.powersolve.co.uk/jkcm/default.aspx?pg=128&categoryKey=28&categoryParent=28)

*The TSM 2415D initially looks hopeful for the +24V i/p,  $\pm 15V$  o/p supply, but is not regulated against input voltage fluctuations, **so not this one.***

*The TMR 2423 looks better: for inputs of 18 – 36V it gives a well defined  $\pm 15V$ . The available current is 65mA, which is far more than we need.*

*From the same range, the TMR 2421 might be a good choice for the Pre-amp supply: it gives  $\pm 5V$  at up to 200mA: this would give the 10V rail we need, and, as a bonus, a 5V rail that could be used for the other features I plan on including in the full system, such as the remote control of the bias voltage I talked about in requirement 3) above.*

*I haven't as yet checked price or availability of either of these.*

*I hope all this is comprehensible, typos and lack of diagrams notwithstanding. I will try to put together some drawings as things develop, and will let you have them.*

*Maurice*

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2) %%% MJG to the CROCS Community on 02/02/2011 %%%

*I've put together a couple of drawings that will help make sense of my last e-mail - see the attached .pdf*

*The first page shows the general arrangement of the central Control Station with the (up to) 4 Detector Stations with the power and control interconnections. Note that it is all powered from the 24V power adapter. This should eliminate electrical safety issues. I have suggested a unit that can be purchased from Farnell.*

*The second page shows the power circuits of the Detector Stations: essentially 2 DC-DC converters and a handful of passive components.*

*What I imagined is that you might make up the power circuits, and use them to drive the SiPM and its amplifier. At this stage you could omit the RJ45 connector, and take the 24V in using a power socket that matches the jack on the power adapter. Or you could include the RJ45 to prepare for the next stage: if so, I have a suggested pin-out:*

Pin	Signal
1	Pulse+
2	Pulse-
3	Control+
4	+24V
5	+24V
6	Control-
7	Power Gnd
8	Power Gnd

**\*\*\* Warning: I have changed this recommendation: see Fig2 \*\*\***

*Note that the Amplified SiPM output ("Pulse") is carried on a twisted pair of wires as a balanced signal, as is the Control signal. This gives good speed and noise rejection. Doubling up on the power wires would reduce the voltage drop along the wires.*

*This scheme is compatible with "Power Over Ethernet", which might pay off in some way.*

**04-Nov-2011: the pinout has been changed again: The 24V power pair and the Control pair have been swapped to minimise any cross-coupling issue. Please check Fig2 to ensure this is not a problem for your application.**

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