6 ELECTRONIC COMPONENTS

6.1 The NIM Crate

Marco Arosio

It was intended that miniature versions of the amplifier and discriminator units (in one package) as well as a small high voltage power supply, would be used instead of the bulky electronics in the NIM crate. The idea was that they would be small and light enough to fit into the body of the final detector. The parts were ordered and tested using the MINOS scintillators on the test stand, however there proved to be a problem of excessive noise counts. It was discovered that all of the channels on the discriminator unit, which was small enough to fit onto the end of the PMT, produced counts when one of the channels received a signal. A large amount of time was spent working on the test stand to eliminate the noise but these efforts were unsuccessful and due to time limitations it was conceded that the NIM crate would have to be used for the final presentation.

The signal from the photomultiplier tube entering the NIM crate is amplified, transformed to a logic pulse and finally converted to a TTL signal which can be read by the FPGA board. Figure 69, below, is a schematic of the units contained in the NIM crate which, in link with the FPGA board, runs the detector:

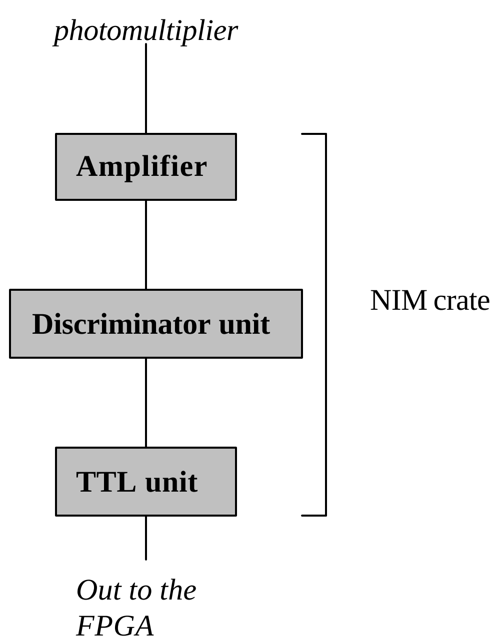


Fig. 69: Schematic of the signal through the NIM crate

Unit	Quantity
Caen N126 High Voltage Power Supply	1
PS 779 32 channel amplifier	1
LeCroy 620D discrimnator	1
LeCroy 623 discriminator	1
TTL logic unit	3

Fig. 70: Table of NIM crate components

Testing of the output signals of the different units had been necessary in order to make sure that correct operations are made by their channels. It was especially important to check that output signals of channels on the same unit were consistent with each other.

In the NIM crate the use of impedance-matched transmission lines is required in order to successfully transmit pulses without degrading the pulse shape. In this case the type of line used was a 50O coaxial cable with Lemo 00 coaxial connectors. In order to prevent pulse distortion through reflection back into the cable, the input of the unit to which the cable is connected must have an internal impedance of 50O . Reflections are reduced if the outputs of the units are also internally matched to 50 O. This is important when a signal needs to be tested on an oscilloscope. Similarly, the inputs of the device must have a 50O termination. It is impossible to get a significant signal on the scope if this operation is not done.

Testing of the units was done by means of a digital oscilloscope on which output signals were displayed and compared. All 36 channels on the amplifier unit were found to work correctly and have output signals consistent with each other. The aim was to find 16 working because of the number of inputs from the photomultiplier unit, but in the end the whole unit turned out to be working correctly. The same luck was not repeated when testing the discriminator units. Only one, out of the many gathered from the department, turned out to function correctly. An additional unit was borrowed from Imperial College but only 6 of the 8 channels present on the unit were found to work as expected In total 14 working discriminator channels were found. The lack of two additional channels means the detector will have to be run without contributions of the signals from two plates.

The discriminator unit converts the input signal from the amplifier into a logic square signal of the form shown in figure 71a (overleaf). It selects signals which are above a certain threshold and converts them to logic pulses of a specific width. The width and threshold of a discriminator unit can be varied by means of adjustment screws positioned on the front panel. The pulse produced by the discriminator is expected to be a square of depth 2 Volts. The shape of signal was osberved to be of the form shown in figure 71b, with the depth of the well lying between -1.5 and -2.0 Volts. All channels were set to the same width (approximately 20ns) and also to the same threshold value, a minimum of -0.3V.

If the threshold setting was increased (adjustment screw turned in the clockwise direction) the signal line on the screen started to fade corresponding to a decrease in frequency of the output signal. This implied that less of the input signal from the amplifier was making it through the discriminator unit.

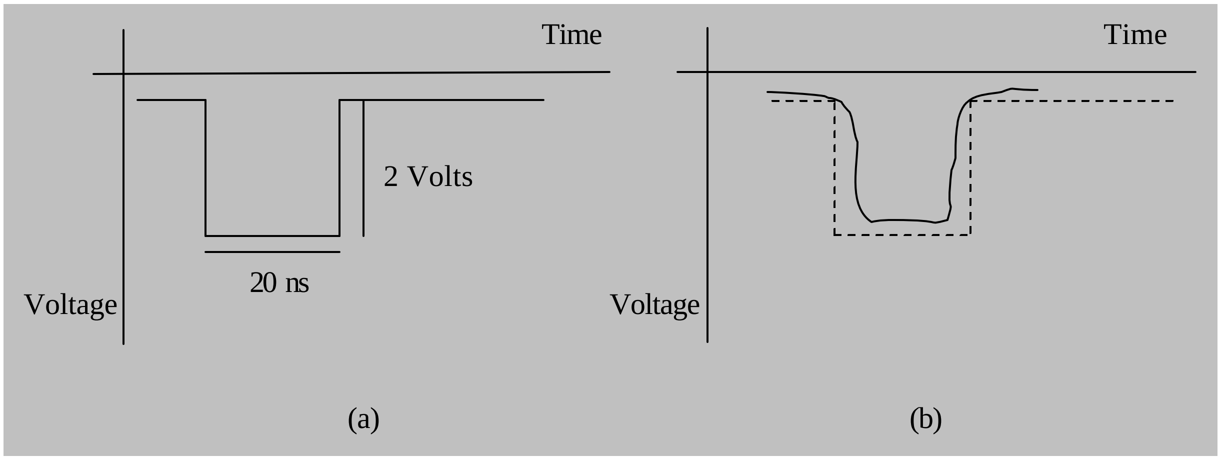
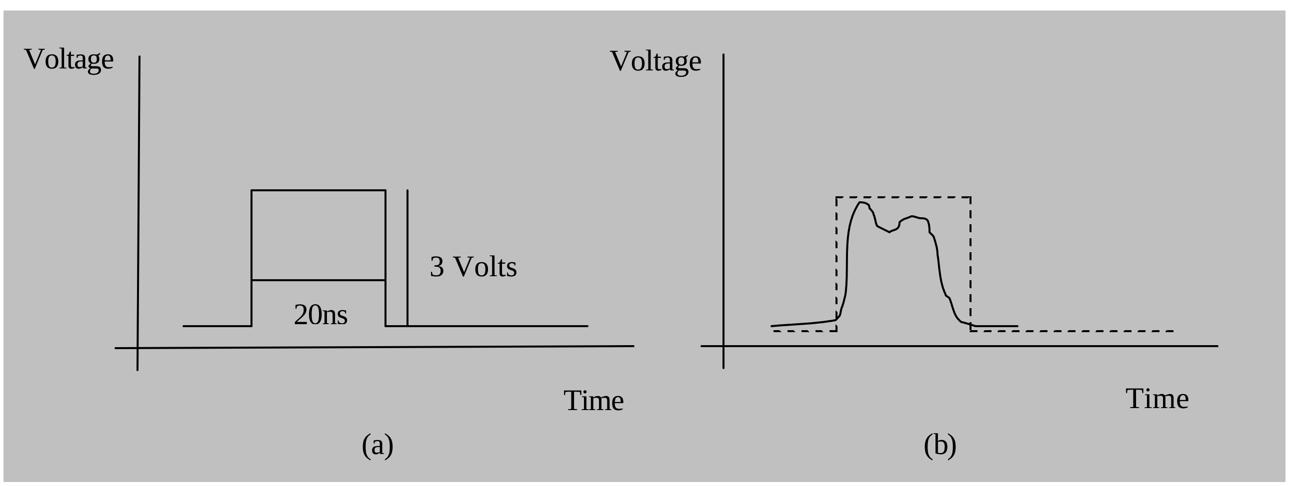


Figure 71: expected (a) and observed (b) discriminator unit output signal.

The TTL units convert the imput signal from the discriminator into a TTL pulse which can be read by the FPGA board.
The TTL signal characteristics are the following:

- a positive square of height between 2 and 3 Volts corresponding to logic 1.
- a positive square of height between 0 and 1 Volts corresponding to logic 0.

The region between 1 and 2 Volts is undefined, in order to avoid the signal being



misinterpreted.

Figure 72: expected and observed TTL unit output signal

The output signal of the TTL unit channels frequently displayed behaviour of the type shown in Figure 72b, above.

The FPGA board picks a signal if above a certain threshold and stretches it to a width of about 50ns. The output signal of TTL gets therefore reshaped by the FPGA. The two-peak characteristic of the TTL unit signal was therefore thought not to represent a problem, e.g. possibility of being interpreted as two different signals by the FPGA. The width of the TTL unit output signal, which has the same value of the input signal from the discriminator unit, was set to 20 ns. Once the FPGA receives the first peaks, no other signal is read for 50ns.

6.2 Field Programmable Gate Array (FPGA) Simon Bevan

The FPGA board is an integrated circuit board which takes 96 inputs, passes these inputs through a logic chip that can be appropriately programmed by the user and then passes the signal to the output pins. In building a cosmic ray detector the inputs are the signals upon which coincidence logic has to be performed. The appropriate LEDs are then turned on and a counter is incremented.

What makes the chip so special, however, is the ability for the user to programme the logic onto the chip. This has the major advantage that the logic can be altered many times without having keep rebuilding circuits. The programme can even be tested before it is downloaded onto the chip by compiling the code and using a testbench to test it. This saves time in trying to test bad code, which means very complicated logic can be applied if necessary.

A very important criteria for this experiment was that the detector be portable. The FPGA reduces the amount of logic components needed and is a very portable device, with dimensions of only 18cm x 10cm. The FPGA requires a 9V supply which was provided by an AC mains adaptor.

6.3 LED Drivers Manuel Kurdian

The LEDs were driven by a 74F540 inverting buffer in the manner shown in figure 73, below. An inverting buffer is a single input device which converts the input signal into one of the opposite state e.g. if the input is true, then the output will be false and vice versa.

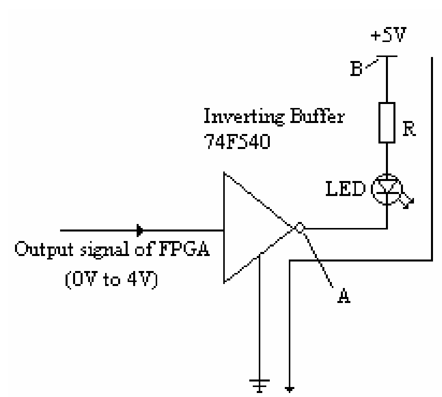


Figure 73: The circuit diagram to drive a single LED.

The input to the buffer was the output from the FPGA (0V - 4V) signaling the ONor OFF states of the LEDs. If the input from the FPGA is 4V, the state of the LED would be ON, since the voltage difference between points A, and B in figure 73 would be 5V. Similarly, with an input of 0V from the FPGA, the voltage drop between points A, and B would be 1V which is not enough to drive the LED (hence OFF)

The 74F540 chip has eight input and output pins thus requiring the use of four such devices (see figure 74). To power the LED drivers, a bench top power supply was used.

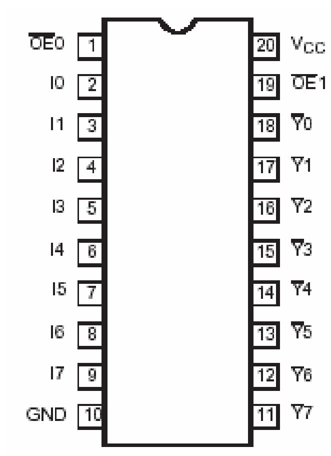


Figure 74: The pin layout of the 74F540 inverting buffer. Pins labelled I are signal inputs corresponding to the appropriate output, which are labeled Y. V_{cc} is the supply pin (-0.5 to 7.0 V) (Philips)

Determination of the value of resistance R required knowledge of the type of LED, and its current rating. The types of LED that were chosen were of 5mm diameter (RED) and in the form of a bar of four conventional 5mm LEDs (GREEN). The resistance of the bar LED in fig.75 was measured to be 115? and the total resistance of the system was required to be:

$$R_T = \frac{5V}{40\,mA} = 125\Omega \qquad [21]$$

Therefore the value of the resistance R is:

$$R = R_T - 115\Omega = 15\Omega \qquad [22]$$

as the resistors are in series.

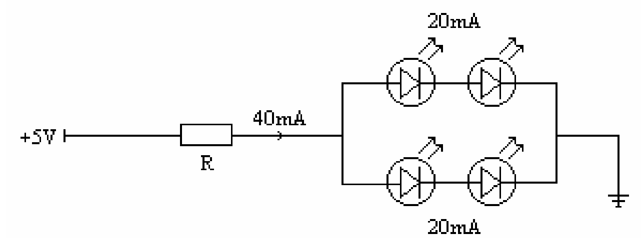


Figure 75: The layout of the bar LED in the circuit

In a similar manner, the resistance was calculated for the single red LED (see fig.76, below) which had a measured resistance of 108? .

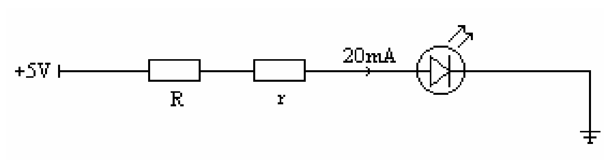


Figure 76: A circuit diagram showing the layout of the single LED.

$$R_T = \frac{5V}{20mA} = 250\Omega \qquad [23]$$

$$r = R_T - 15\Omega - 108\Omega = 127\Omega \qquad [24]$$

Two resistors were required to enable both the bar and conventional LEDs to be driven. The resistor labeled ‘r’ was soldered directly to the LED rather than onto the circuit board, therefore a resistor of resistance 127O was required to provide a current of 20mA to the LED.