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Design and Development of 20 channels shaping amplifiers and discriminators using Eagle.

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Abstract

A study on 20 channels consisting of shaping amplifiers and discriminators has been described in this paper. This module has been designed, fabricated and tested using CAD tool EAGLE .A comprehensive study of the module like basic constituent, operating principle, mathematical derivation and testing results have been presented. The board has been designed with SMD components with 1μs shaping time *Corresponding Author
constant and an integral discriminator of few mV to supply span (5V). Therefore, the simplest concept for pulse shaping is proposed that was used of a CR high-pass filter followed by an RC low-pass filter. Thereafter, 100% finished 2-layer board has been created by Autorouter with desired track size and layer. Finally, adding the ground and mounting holes manufacturing data have been created by using CAM processor and sent to board house for fabrication. After fabrication, the board has been assembled and tested successfully

Keywords: Shaping Amplifier, Discriminator, Time Constant, Threshold, SMD, ERC, DRC, CAM.

Introduction

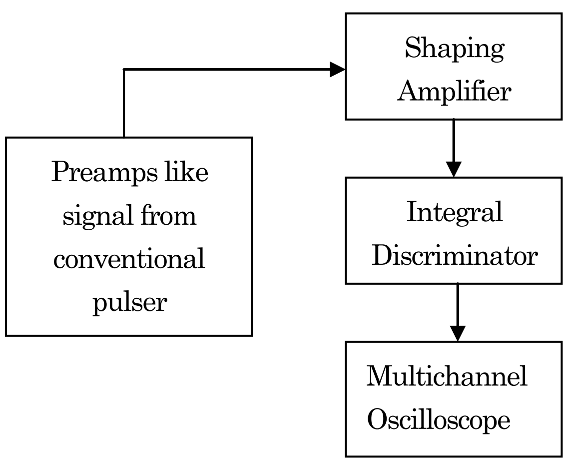

Fig.1: Block Diagram shows the experimental setup for the proposed module.

In dealing with signal pulses from radiation detectors, it is often desirable to change the shape of the pulse in predetermined fashion [1]. By far the most common application is in processing a train of pulses produced by a preamplifier. In order to assure that complete charge collection occurs, preamplifiers are normally adjusted to provide a decay time for the pulse which is quite long typically 50 μs . Pulse shaping affects both the total noise and peak signal amplitude at the output of the shaping Amplifier [2].The preamplifier output is too small to directly measure its amplitude. Therefore amplification is necessary. In order to increase the signal to noise ratio the preamplifier output is filtered in other words it is shaped using special shaping circuits. Shaping serves an additional purpose: it diminishes the duration of the preamplifier pulses in order to reduce the pile-up effect. It can be shown that disregarding the flicker noise an optimum shaping exists.This shaping is the so-called cusp pulse. Unfortunately the cusp pulse has an infinite length, so such a system can never be realised in practice [3]. Actually, shaping performs two key functions as such it optimizes the energy resolution and minimizes the risk of overlap between successive pulses. After designing the schematic Electrical Rule Check (ERC) has been performed for electrical errors and consistency check between schematic and board. Likewise, Digital Rule Check (DRC) has been operated for reporting any errors in the Board like clearance errors under set of design rules [4, 5].

2. Materials and Method

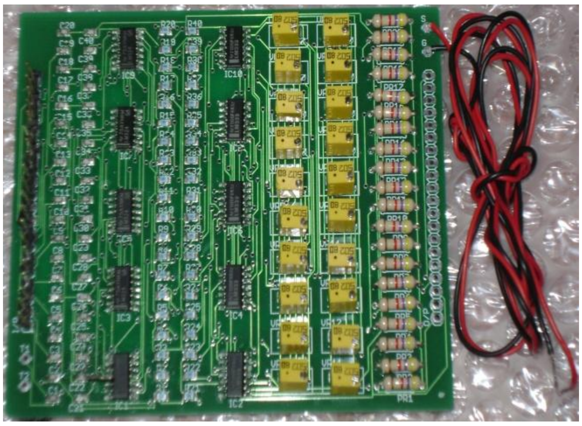

Fig.2: The Designed and Fabricated Board of the Proposed Module created by EAGLE.

2.1: Principle of Operation

The preamplifier signal first passes through the CR filter. It attenuates the low frequencies, which contain a lot of noise and very little signal. The decay time is shortened by this filter, diminishing the probability of pile-up [6]. Just before the pulse reaches the output of the amplifier it passes through an RC low pass filter. This improves the signal to noise ratio by attenuating high frequencies. The CR and RC filters have the same time constant: τ (1 μs). The step response of the CR-RC filter reaches its maximum at t= τ and the maximum value is 0..37. The noise contribution can be minimized by choosing an appropriate shaping time constant. At short time constants the series noise, thermal noise in the channel of the input FET, is dominant. At long shaping time constants the parallel noise viz. leakage currents, resistor thermal noise component dominates and removes DC offsets and baseline fluctuation. In order to determine whether this will be a problem for any application, there is a equation valid for small base line shifts:

$$\frac{S}{H} = R * \tau * 2.5 \times 10^{-6} \qquad (2.1)$$

Where S is the negative baseline shift, H is the pulse height; R is the count rate (counts/sec) τ is the shaping time of the shaping amplifier in μs [7]. The discriminator circuit selects the minimum pulse height. When the input pulse exceeds the discriminator preset level, the discriminator generates an output pulse. The discriminator input is normally an amplified and shaped detector signal. This signal an analog signal because the amplitude is proportional to the energy of the incident particle [8].

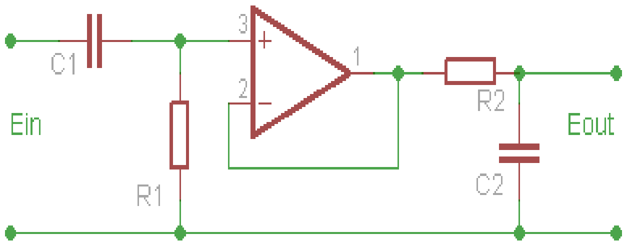

Fig.2.2.1: A shaping network consisting of sequential differentiating and integrating stages sometimes denoted a CR-RC network.

2.2.2: Discriminator Circuit

In order to count the pulses properly, the shaped linear pulses must be converted into logic pulses. The Integral discriminator is the simplest unit that can be used for this conversion and consists of a device that produces a logic pulse only if the linear input pulse amplitude exceeds a set discrimination level. If the input pulse amplitude is below the discrimination level, no output appears. This selection process is illustrated in fig.2.2.2 unless specifically designed otherwise, the logic pulse is normally produced shortly after the leading edge of the linear pulse crosses the discrimination level.

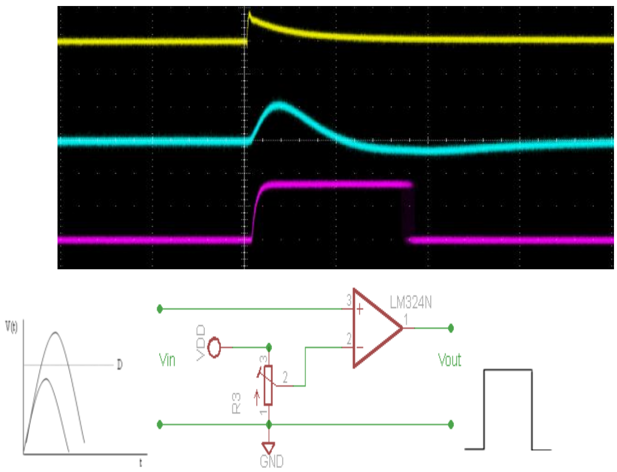

Fig.2.2.2:The function of an Integral Discriminator. The two input pulses shown, only the larger one crosses the discrimination level and produces a logic pulse output.

3. Results and Analysis

The tail pulse output of the preamplifier typically has amplitude of a few tens or hundreds of millivolts and is too small to be counted directly. Furthermore, the pileup of these long pulses at high rates could cause stability problems. Therefore, the next step is normally to process the pulses through a linear amplifier.Table1 and Table2 shows the characteristics data for the 20 channel shaping amplifier with 1 µs shaping time constant. From these tables, first of all, it has been observed that for a step pulse input from a commercial pulser of amplitude 74.00 mV has output ranging from 67.0 mV, worst case, to 70.60 mV. Over all out put amplitude for all channels is quite appreciable. Then the step pulse input has very fast rise time, 192 ns, the corresponding values for the shaping amplifier output are more than 10 µs. Thereafter, the fall time for the input signal is 15.82 µs, that of output pulse is decreasing tendency to some hundreds ns. It is seen from the table that input signal has very small rise time and large fall time on the contrary output signal has opposite nature. The pulse width of the shaping amplifier output is double ,6.32 µs, almost all cases that of input signal 3.36 µs .The positive and negative overshoot for both the cases has been recorded as 0.0%. Finally, the gain for the shaping amplifier has been observed as 90% except the worse cases. Table 3 and 4 shows the functionality testing data for 20 channel discriminator fabricated with 20 channel shaping amplifier into a single board. It has been observed that discriminator output pulse amplitudes for all

Fig.3.1: Shows the Waveform of the Shaping Amplifier and Discriminator.

channel approach to supply voltage. While the supply voltage was 5.0V, the output logic pulse amplitude has been observed as 4.36V and 4.72V for that of 5.0V. The discriminator outputs have large pulse width as seen from 9.66 µs to 18.07 µs. There were no positive or negative overshoot. At the end, Threshold or noise level can be selected from some µV to supply as the board has been designed with multi-turn potentiometers. In the present case, the threshold levels were from 50.71 mV to 57.64 mV. The selected operational amplifier LM324 is low-cost, short circuited protected outputs, single supply operation and four amplifiers per package [13]. The LM339 consists of four independent precision voltage comparators, with an offset voltage specification as low as 20mV max for each comparator, which were designed specifically to operate from a single supply over a wide range of voltages [14].

4. Conclusion

The board has been tested with a low signal amplitude and very fast signal (192 ns). All the channels are functioning properly with this signal. Therefore, the board can be used with a multi-anode detector applications successfully. This project is also helpful for understanding radiation measurement instruments like Radiation Survey Meter, Area Radiation Monitor, Radiation Spectroscopy and Nuclear Counting System.

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