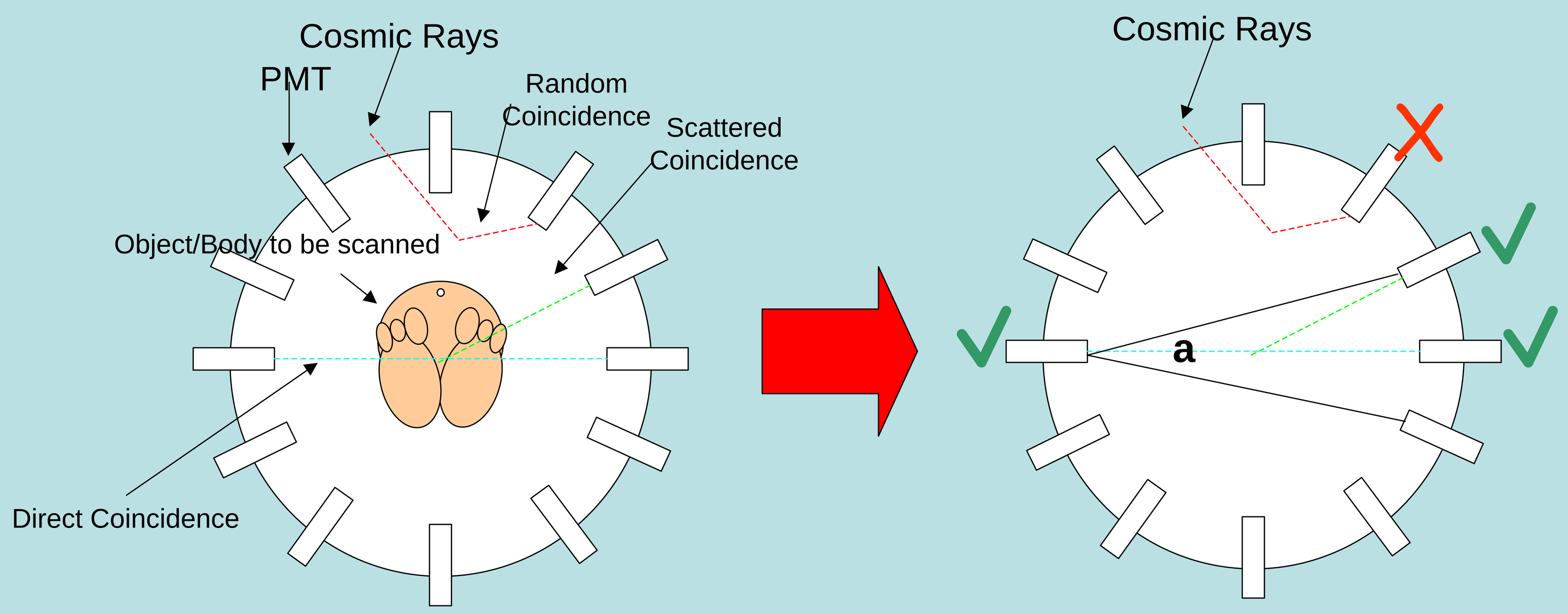
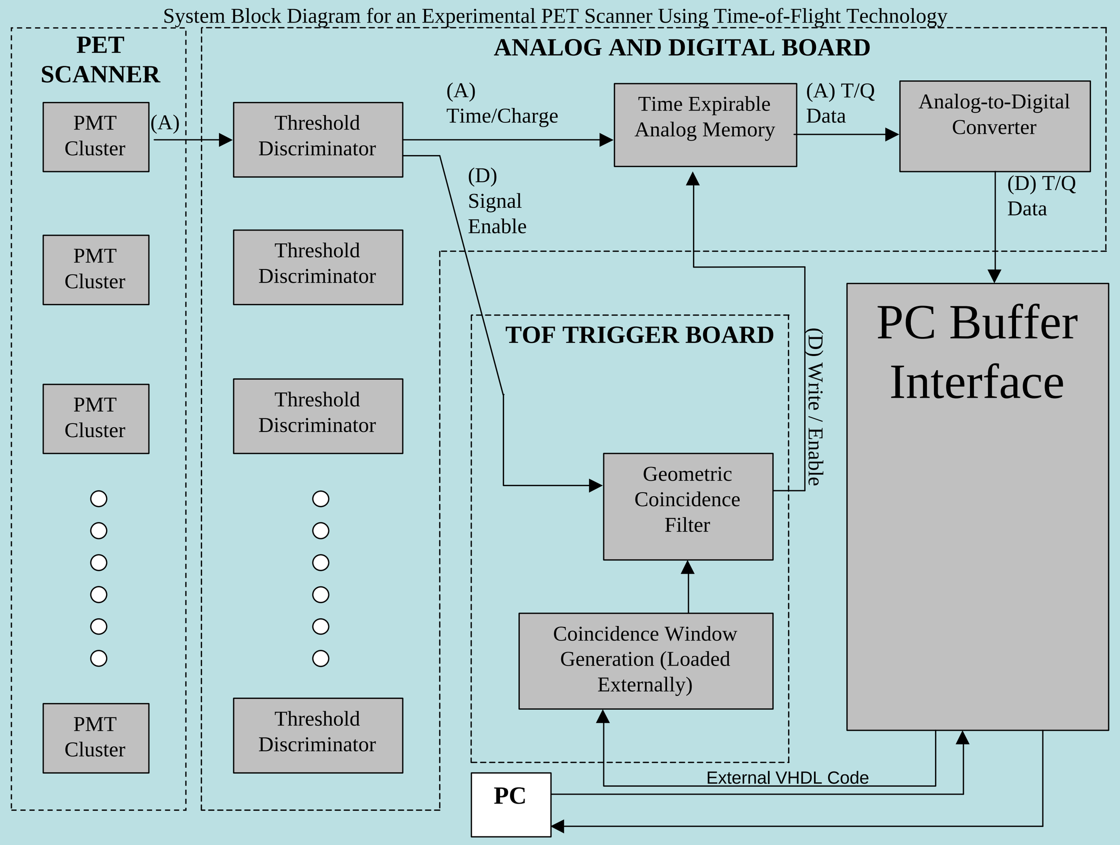
Time of Flight (TOF) Trigger Board for PET

PET OVERVIEW:



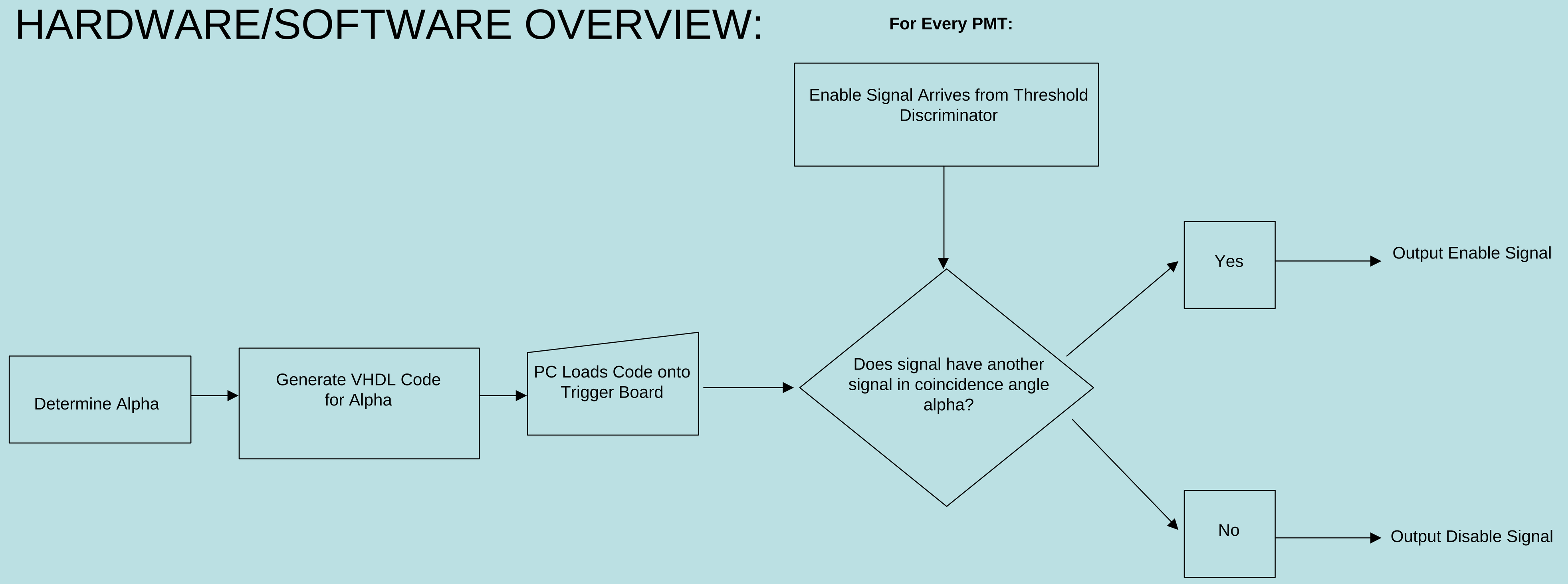
Position Emission Tomography (PET) scanners rely on the release of two excited coincident gamma rays in order to identify the irradiated areas in a patient's body. There are three types of coincidences that occur: Direct, Scattered, and Random. Only the first two are valid, the third type is often caused by cosmic rays which introduces noise. Photomultiplier tubes (PMTs) detect these rays. It is known, however, approximately how much the particles will scatter within the body, this known area is then defined as the coincidence angle alpha (a). Thus, logically, only those pairs which are within the angle alpha are valid. All others must then be invalid and can be disregarded. In this way, unnecessary noise can be eliminated.

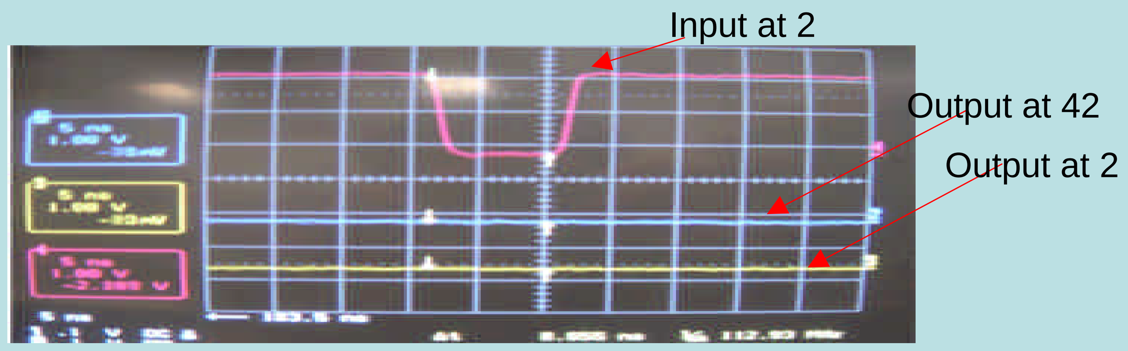
SYSTEM OVERVIEW:



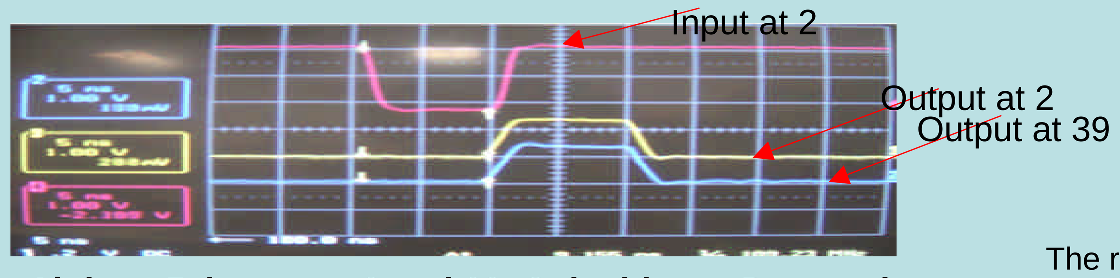
The trigger board receives signals from 72 to 432 Threshold Discriminators, which determine if the energy received by the PMTs are enough to qualify as a coincidence. These signals are then sent to the Geometric Coincidence filter on the board. The angle alpha is changed and then loaded into the trigger board prior to the scan. A Write/Enable signal is sent to the Time Expirable Analog Memory (which stores the actual analog signal from the Threshold Discriminator) if a coincidence at whichever location is determined to have a match within the coincidence angle alpha. The trigger board must finish processing within 50ns in order to satisfy the Time of Flight (ToF) requirements.

HARDWARE/SOFTWARE OVERVIEW:

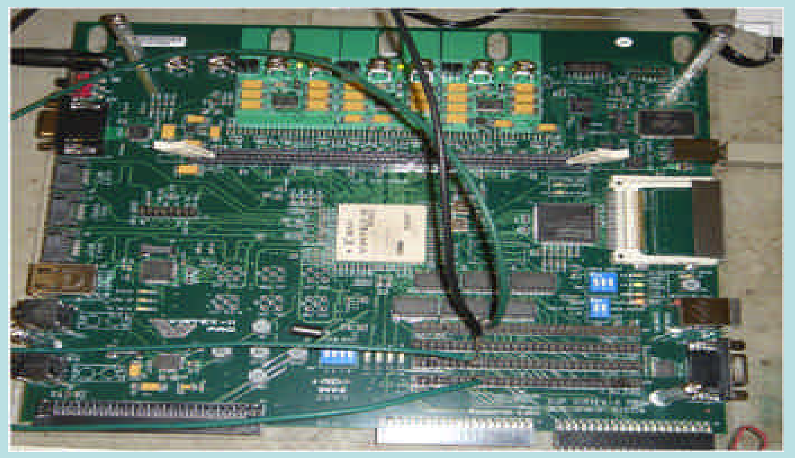




Alpha = 5, inputs at 2 and 42, No coincidence



Alpha = 5, inputs at 2 and 39. Coincidence Detected

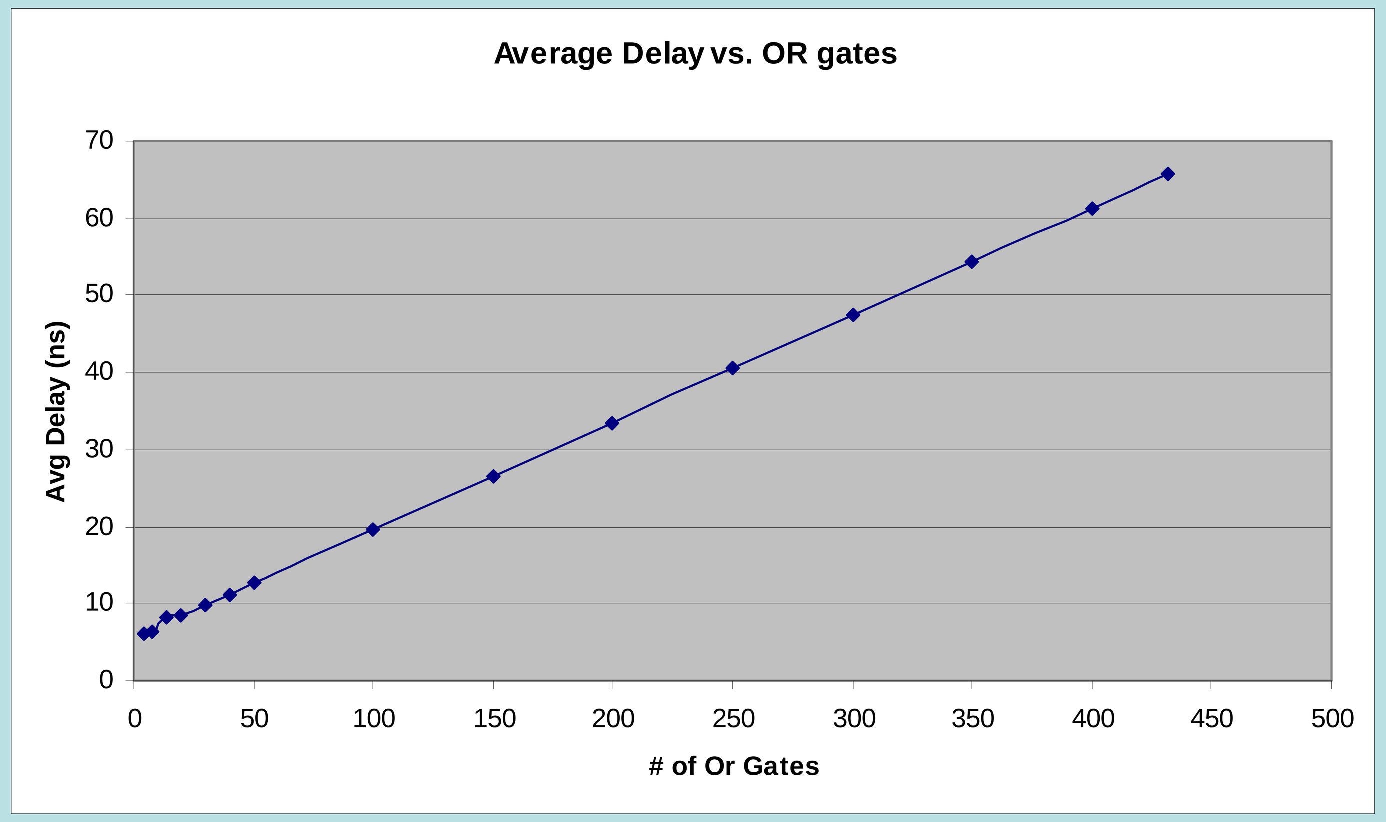


Xilinx Setup for Alpha = 5, with inputs and outputs at PMT 2 and 39

The readouts on the left show the outputs to two PMTs. In the above left, there are inputs to both PMT 2 and 42. However, 42 is outside the angle of 2, so therefore there can be no coincidence.

In the below left, there are inputs detected at both 2 and 39. Since 39 and 2 are both in the same coincidence angle, both outputs (2 and 39) output that positive coincidences have been located.

DELAY RESULTS



The delay graph is constructed using a combination of data from experimental results, data from simulations, and data from extrapolations.

It was found that a linear regression had the highest R-squared value, compared to other types of regression techniques.

From this extrapolation, there should not be any greater than 300 OR gates in operation, otherwise the trigger board would not be able to satisfy time of flight requirements.

The # of OR gates is equal to alpha -1. For a two dimensional pet scanner no alphas can be above 72, so it is well within the limits of the ToF requirements.

Abstract

Recent advancements in processing technology and crystal research have allowed improvements in PET scanner technology. These improvements include the addition of time-of-flight feature. Conventional scanners do not use the physical properties of gamma rays to filter out noise. Consequently, refracted rays that occur due to Compton scattering and rays from cosmic radiation get recorded in the picture and result in blurring. However, with the advent of time-of-flight, these negative effects can be accounted for.

Time-of-flight technology requires the appropriate crystals to meet its timing demands. Current research in Lanthanum Bromide (LaBr3) crystals has made the goal viable. The Medical Physics department has decided to use LaBr-3 because it has high light output, high stopping power, good linearity, and fast decay time. The crystals will be packaged in the anger-logic arrangement.

Along with the suitable crystals, a data processing entity needs to do the filtration process. This is where the time-of-flight trigger board comes in. The trigger board examines the geometrical mapping of the incident gamma rays and filters out the pairs that create noise, thereby logically identifying only those that can be potential coincidences. The filtration is done in real time with a Virtex FPGA Xilinx chip. The signals are filtered out based on a coincidence angle (referred to as "alpha"), where the angle is determined through some physical aspects of the patient being scanned, e.g. height and weight.

The algorithms used in the board are scalable, so that scanners of a larger size can potentially be used. However, the current algorithm was designed for a two dimensional scanner, while delay times for larger scanners were simulated.

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Demonstration Times:

Tuesday, April 18th

11AM, 11:30AM, 1PM, 1:30PM, 2PM, 2:30PM