Paper to be presented at the
Nuclear Science Symposium
San Francisco, 17-19 October 1979

CERN/EF 79-3
8 October 1979

MODULAR TRIGGER LOGIC TECHNIQUES
AT THE CERN OMEGA SPECTROMETER

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CM-P00061310

Summary

Fast trigger logic for high-energy physics experiments often involves the same basic functions on a large number of bits. A set of general-purpose modules has been designed at the CERN Omega Spectrometer to meet this need. The modules are described and their actual use in physics experiments is presented.

1. Introduction

The Omega Spectrometer^{1,2} is a large acceptance detector which is designed for measuring interactions with many particle final states. The tracks are detected by multiwire proportional chambers (MWPCs), of ~ 37000 wires, inside the magnet volume. Three special MWPCs, two multi-cell Čerenkov counters and three scintillator hodoscopes are used for triggering on particles in the forward direction (Fig. 1). The detector is also equipped with a photon position detector and a lead-glass array, mainly for photon physics.

A radio-frequency separated hadron beam and an electron/photon beam give the spectrometer a high degree of flexibility. Physicists from various European universities and laboratories use the Spectrometer and

typically each experiment stays on the floor for three months.

The main detector chambers are of the read-only type, using the GARAM-P/FDS³ technique for the delay section. The electronics associated with each wire is shown schematically in Fig. 2. The amplifier is a dual in-line 16-pin integrated circuit (I.C.)⁴, two channels per chip, with a $1 \mu\text{A}$ threshold and a 70 ns resolving time. The shift frequency of the delay section may be varied from 30 MHz up to 60 MHz, thus allowing for delays from 1 to 2 μs with a 33 ns resolving time in the worst case. The CAMAC remote read-out of the data stored in the long shift register uses a pulse-width modulation technique⁵.

The Omega is intended to be a multi-user facility. For this reason, in order to facilitate the wiring of a large variety of trigger conditions, the resident electronics team initiated the design of a set of NIM and CAMAC modules covering the basic functions that nowadays appear in most trigger logic for large high-energy physics experiments.

Modules were given the general name of MBNIM (Multi-Bit Nuclear Instruments Modules⁶).

Fig. 1 Layout of the Omega Spectrometer for hadron experiments. The read-only MWPCs record the particle trajectories inside the magnetic field. DC1 and DC2 are four-plane high-accuracy drift chambers measuring $3.2 \text{ m} \times 1.5 \text{ m}$; H1, H2 and H3 are scintillation counter hodoscopes with up to 60 channels each; C1 and C2 are large atmospheric pressure Čerenkov hodoscopes with 32 cells each. H1, H2, H3, C1, C2 and the three trigger MWPCs (732 wires each) are used for fast ($< 500 \text{ ns}$) event selection.

Fig. 2 Schematic of the electronics associated with each wire of the read-only MWPCs. Wire signals are continually recorded in the 64-bit shift register. A trigger stops the fast clock. The wanted data bits are then p-locations from the input (p = trigger delay/25 ns); 64 - p extra fast clock pulses will shift the data towards the output and hence set the long shift register bit associated with this wire.

2. The MBNIM System -- Basic Modules

2.1 General Description

A distinguishing feature of MBNIM is the replacement of conventional miniature coaxial cables by a 40-wire flat-cable bus. This is a single-ended ECL 10K bus terminated at both ends and carrying 16 data lines, a data ready line, an acknowledge line, and a read/write line. The connectors are 40-pin stamp-on socket connectors, which allow fast and convenient custom wiring.

The bus drivers are the ECL 10123 I.C. and the receivers the ECL 10216 I.C. Special care has been taken in the design and the packaging of the MBNIM modules to optimize performance, reliability, cost, and maintenance.

2.1.1 Bus Interface Boards. In order to have a well-defined bus load at each port, two standard interface boards have been designed: the dual-port interface and the single-port interface board, which may also receive 8 miniature coaxial connectors giving access to 4 NIM to ECL 10K level converters and 4 ECL 10K to NIM level converters. Three 100 Ω resistor networks can be inserted to terminate the bus wherever necessary (a front panel light-emitting-diode indicates whether the termination is in or not). At the rear of each interface port, two rows of three dual in-line 16-pin connectors are used to transmit the buffered bus signals to the function board in the user module.

2.1.2 CAMAC Interface. Another standard board is used on the CAMAC dataway side of modules which can be loaded with reference data. This interface decodes and transfers the CAMAC commands given in Table 1 to the function board in the user module. An unusual feature is the check procedure: a comparator on the function board compares the memory contents with the data that is presented on the write lines of the CAMAC dataway; whenever a mismatch is found by the comparator, further Q responses are inhibited and an error flag is set.

The dual-port interface board and the CAMAC interface board may be seen in Fig. 3. All boards are double-sided printed-circuit boards equipped with AUGAT HOLTITE pins for integrated circuits and resistor networks.

Table 1

CAMAC commands implemented in the CAMAC interface for memory modules

Command	Q	X	Comments
F(16) A(0)	Yes	Yes	In write mode: write into memory at S1 increment memory address counter at S2, Q = 0 after the last address has been reached. In check mode: compare data with memory contents at S1, increment address counter at S2, Q = 0 if error condition is encountered.
F(24) A(0) S2	No	Yes	Clear memory address register, set to write mode. Disable front bus operation.
F(24) A(1) S2	No	Yes	Clear memory address register, set to check mode. Disable front bus operation.
F(26) A(0) S2	No	Yes	Enable front bus operation.
F(27) A(0)	Yes	Yes	Check error flag.

Fig. 3 Side view of an MBNIM module (the BIT ASSIGNER) showing the dual port front bus interface board, the function board (middle) and the CAMAC interface board for memory modules (rear). All boards are conventional double-sided printed circuit boards.

2.2 MBNIM Basic Modules

2.2.1 The Strobed Coincidence Register (Fig. 4) is a 16-channel coincidence register in the NIM standard. Unlike conventional coincidence circuits it is edge sensitive: pulses with the leading edge in the time gate of the common strobe (ST), are latched into the 16-bit register driving the MBNIM bus. The clear (CL) resets the register and the pulse width on the bus is defined by the time difference between the trailing edge of the strobe and the leading edge of the clear. The BUSY output may be used to gate off the associated electronics whenever a strobe has occurred. The ACKnowledge output

Fig. 4 Four MBNIM modules used in coincidence matrix applications. From left to right: the edge sensitive Strobed Coincidence Register, the BIT ASSIGNER (to generate an expected bit pattern), the ALU-16 (any bit to bit logical function), the MULTIOLOGIC (OR, AND, NOR or XOR functions together with binary coded multiplicity information on the output pattern).

may be used as clear whenever the system is being operated at low speed. The input resolving time is 7 ns, and 10 ns pulses can easily be handled on the MBNIM bus. The input to output propagation delay is 15 ns.

2.2.2 The BIT ASSIGNER, second left in Fig. 4, is a 16-bit bit-predictor for coincidence matrix applications. To each bit of the input bus, the BIT ASSIGNER assigns logical-1 values to sets of bits on the output bus. When several bits are at logical-1 value in the input bus, the bit to bit OR of the assigned patterns is presented on the output bus. The BIT ASSIGNER may also be used to generate 16 OR functions of 16 variables; it has a 30 ns input to output propagation delay.

Bit assignment is written and checked via the CAMAC dataway as described in Section 2.1.2.

2.2.3 The ALU-16 (Figs. 4-5) is a 16-bit arithmetic and logical unit based largely on the ECL 10181 I.C. The function can either be selected via CAMAC or by means of front panel switches; a row of light-emitting diodes indicates which function is enabled.

If A and B denote the two 16-bit input patterns, and C the output pattern, then $C = A$, B , $A \cdot B$, $A + B$, $A \cdot \bar{B}$, $\bar{A} \cdot B$, A minus B can readily be selected. The module has a 30 ns input to output propagation delay. If the module is the last in the logic chain the DTRD (data ready) output may be fed into the ACKN (acknowledge) input in order to have the slow, but easy, timing of the system via the handshake lines of the MBNIM bus.

2.2.4 The MULTIOLOGIC (Fig. 4) is a fast NIM module that performs the bit to bit AND (OR, NOR or XOR) of two 16-bit input patterns. With its 15 ns propagation delay, it is faster than the ALU-16, but much less flexible. This module also gives in binary form the number of bits set in the output pattern.

2.2.5 The RAHM (Fig. 5) is a $1K \times 16$ bit random access high-speed memory for look-up table applications. It has a 45 ns input to output propagation delay and the table contents are written and checked via CAMAC. A module number (front-panel switches) can be used whenever several modules are necessary to form the look-up table.

2.2.6 The TERMINIM (Fig. 5) is a level converter often used at the end of an MBNIM logic system to convert bus levels into NIM levels, e.g. for checking purposes. It has a 15 ns input to output propagation delay time.

2.3 The System From a User's Point of View

The modules described in the previous section use the standard interface boards. Up to 10 ports can be connected to the same bus without significantly affecting the data transmission (less than 0.3 ns per port). All modules are single-width NIM (double width CAMAC) to give easy access to the front-panel sockets. The power requirement does not exceed that of present CAMAC systems.

The cost of wiring MBNIM logic is five times lower than that of miniature coaxial cable. However, the wiring of complex systems requires some knowledge of the topological problems posed by flat ribbon cables.

The mean commercial cost of the modules is \$900.

Fig. 5 Three MBNIM modules used in look-up table applications. The RAHM, a 1024×16 bit word memory written via CAMAC; the ALU-16 for integer arithmetic operations; the TERMINIM which converts ECL bus levels into NIM levels.

3. Uses of MBNIM at the CERN Omega Spectrometer

Typically, MBNIM is used to provide a forward trigger with the three scintillator hodoscopes and the two Čerenkov hodoscopes. In this case, most experiments use a four-level coincidence matrix system based on 16 BIT ASSIGNERS and 10 MULTIOLOGICs, wired according to the specific experiment needs.

The basic 16×16 matrix arrangement is shown in Fig. 6, the complete set up being typically $4 \times (32 \times 32)$ matrices. If $H_i(H_j)$ denotes the H_i pattern predicted from the actual H_j pattern and $H1, H2, H3, C1$, and $C2$ denote the scintillation and Čerenkov hodoscopes described in the Introduction (see also Fig. 1), then the trigger pattern T used by the experiments is

$$T = H2 \cdot H2(H1) \cdot H2(H3) \cdot H2(C1) \cdot H2(C2) .$$

This trigger system was used by the CERN WA56 experiment⁷ (Search for baryonium states in $\bar{p}p$ at 2.02 and 2.20 GeV) and the WA60 experiment⁷ (Study of strangeonium and baryonium). It is currently in use by the WA57 experiment⁷ (High-mass vector-meson study). The

arrangement of the modules differs from experiment to experiment and the modularity has proved to be extremely useful.

A trigger on the sagitta of two forward particles was also used by the above-mentioned WA56 experiment. This trigger involves two (or three) trigger chambers with fast parallel read-out. Leftmost and rightmost wires in each chamber are binary coded and presented onto a MBNIM bus. Using RAHMs and ALU-16s modules, it is then possible to make a momentum selection and scan all the possible combinations of two hits in two (or three) planes. A subset of this trigger is shown in Fig. 7.

The system may also be used for the recognition of event patterns either by straightforward look-up table techniques or by more sophisticated logic schemes, such as the hash-addressing technique⁸ used in the WA55 experiment⁷ (K^*p elastic scattering at 12 GeV/c around 90° c.m.).

It is fair to say that the system has proved versatile and cheap and that the users have expressed full satisfaction with its performance.

Fig. 6 Schematic of a 16×16 coincidence matrix in the MBNIM standard. A $(n \times 16) \times (n \times 16)$ coincidence matrix would use $2 \times n$ Strobed Coincidence Registers, n^2 BIT ASSIGNERS and n AND modules (ALU-16 or MULTIOLOGIC). The decision time is 60 ns irrespective of the matrix size.

Fig. 7 Schematic of momentum calculation in the MBNIM standard. The 3 RAHMs are used as look-up tables to perform the two multiplications and the momentum calculation. The decision time is of the order of 120 ns per set of 3 coordinates.

Acknowledgements

The author wishes to acknowledge the participation of Messrs. A. Beer, A. Corre, G. Critin, J.-P. Marcelin, R. Pegaitaz, H. Pflumm, G. Schuler in the design of the modules. He would also like to thank Drs. T. Armstrong and C. Bizeau for useful discussions and Drs. W. Beusch, O. Gildemeister and P. Sonderegger for their confidence and support.

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