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Model P7887, PCI-based
4 GHz Multistop TDC, Multiscaler, TOF

FEATURES

- Fully digital design, no software corrections required
- 180 ps time-resolution FWHM, typical, line width @ 10 us, taking data for 60 min.,
  350 ps FWHM @ 1 ms taking data for 60 min.,
  300 ps FWHM @ 100 ms, with optional oven controlled oscillator taking data for 24 hours
- 4 GHz max. count rate (burst) - 250 ps pulse pair resolution
- Start- and Stop-Input via built-in 4 GHz, +/-1V falling-edge discriminators, sensitivity: <10 mV
- 38 bit dynamic range (32ns to 68.7s programmable range with 250 ps resolution)
- No dead time between time bins, No missed events, No double counting
- On-board FIFO for ultra fast data transfers at approx. >12,200,000 stop events/sec. to the PC for data storage in list-mode or on-line histogramming
- Simultaneous acquisition and data transfer to PC
- Sweep summing at rates up to wrap around speed
- Five operating modes: Continuous (wrap around), stop after sweep, sequential and Time Interval, Autocorrelation (optional)
- Two versatile, software configurable Sync-outputs for triggering of external devices
- Ultra high sweep repetition rates up to wrap around speed
- Optional Tag inputs (8) with 16 ns time resolution (i.e. for sequential data acquisition, multi-detector configurations, coincidence studies, etc.
- Presettable 32 bit sweep counter; programmable acquisition delay and trigger hold-off after sweep



- Up to four P7887 can be operated in one PC
- User configurable "GO"-line for experiment synchronisation (compatible with other FAST ComTec devices
- 8-bit digital I/O port

Applications

Typical applications are:

- TOF Time-of-Flight Spectrometry
  with exceptional dynamic-range and time resolution of 180 ps FWHM @ 10 us and 350 ps @ 1 ms, data taken for 60 minutes
- Static TOF SIMS secondary electron Mass-spectrometry - used for example in plant pathology, analyzing molecules from biological samples
- Quantum Cryptography research
- Laser-induced fluorescence spectroscopy in biological samples
- Laser-induced photo-electron spectrometry to analyze the electronic state of gas and solid state samples
- Single molecule counting
- Single photon counting
- LIDAR (4 cm spatial resolution)

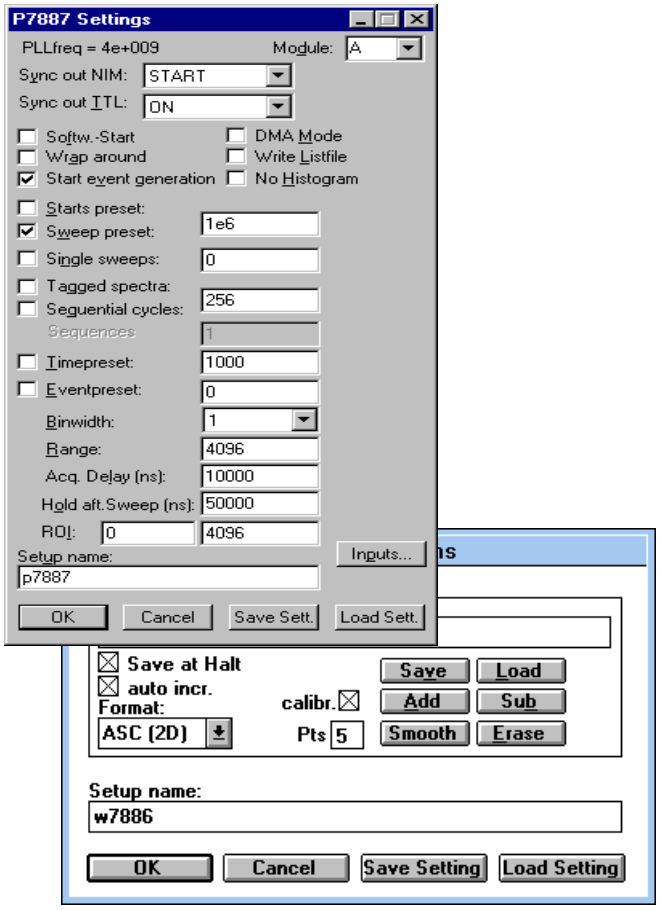
DESCRIPTION

The Model P7887 is a 250 ps time bin, 4 GHz multiple-event time digitizer (TDC). It can be used in ultra-fast Multiscaler/TOF systems, in Time-of-Flight mass-spectrometry and time-resolved single ion- or photon counting.

In operation the sweep is started by a user-supplied start (trigger) pulse. Then subsequent events detected at the stop input are recorded, each in a specific time bin corresponding to the time of arrival relative to the start pulse. Compared to non-multihit devices, the P7887 can accept a new stop event as soon as 250 ps after a prior event - limited by the max. count rate of 4 GHz only. The P7887 is designed with fully digital circuitry capable of accepting peak (burst) count rates of up to a full 4 GHz.

The P7887 has been optimized for the best possible pulse-pair resolving while providing state-of-the-art time resolution available in digital designs. Two built-in 4 GHz discriminators can be adjusted for a wide range of signal

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levels.

The large single sweep time range enables the user to take data of up to 1s, with an offset of up to 68 seconds with a time resolution of 250 ps. A PLL oscillator assures a resolution of typically <180ps FWHM at a full scale time range of 1us (measured in the last time bin of 4.000 time bins, for 30 min.).

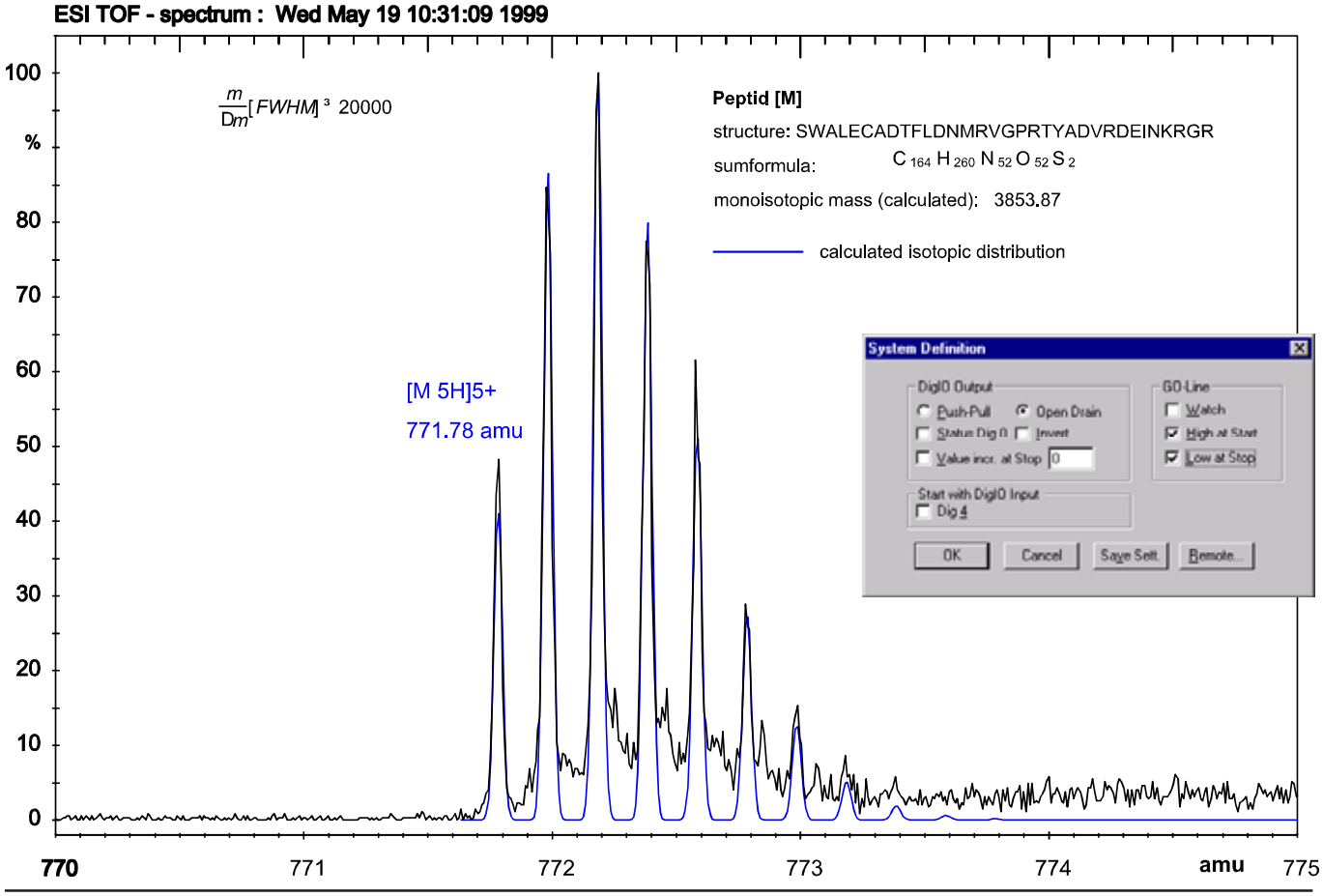
The FIFO memory buffers all stop events at full speed (4 GHz) for at least 2 microseconds while a second 16k FIFO buffers the PCI transfer. Thus, the P7887 histograms or stores data at rates of approx. >12.200.000 events/ second.

For experiments requiring repetitive sweeps the spectral data obtained from each sweep can be summed in the PC enabling very high sweep repetition rates up to wrap around speed.

The P7887 is designed with "state-of-the-art" components which offer excellent performance and reliability.

The high-performance hardware is matched by a sophisticated software delivered with each P7887.

MCDWIN - the MS-WINDOWS-98/NT and WIN2000 based operating software - provides a powerful graphical user interface for setup, datatransfer and spectral data display.



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PERFORMANCE

Number of Time Bins: 128 to 2^{38} selectable in steps of 64. Transfer of recorded data in List-Mode to RAM or Hard-Disk.

Time range per shot: Total 2^{88} 250 ps = 68.7s in steps of 2^{32} x 250ps = 1.07s, 2^{24} with TAG-word

Memory: 127 word high speed 4 GHz multi-event FIFO plus 16k PCI-interface FIFO - capable of recording at 4 GHz burst counting rate for approx. 2 us (2.032 us).

Time Resolution: 180 ps FWHM, typical mass line resolution after Gauss-fit measured at a distance of 10 us, 350 ps @ 1ms after the start (4.000.000 time bins) over 60min. With optional oven controlled oscillator: 300 ps FWHM typical @100 ms, 24 hours

Pulse Pair Resolving Time: 250 ps

Bin-width: 250 ps, independent of selected range.

Deadtime: No deadtime between time bins.

Count Rate: The burst count rate is 4 GHz to the FIFO, the average data throughput is >12,200,000 stops/sec. to the computer memory (using a computer with a AMD or Intel 2000+ processor).

No Double Counting ! No loss of counts ! prevented by the proprietory input logic used.

Linearity: Differential linearity <<+/-1%

Data Reduction: by recording stop-events only within a selected time window (no "0" events as recorded by transient digitizers) significantly increases the sweep repetition data rate capabilities.

Operating Modes: Continuous (wrap-around), end after sweep, sequential (by software) and time interval

Sweep Counter: hardware sweep counter (32 bit) with programmable preset. Optional Start-of-Sweep marker insertion in the list mode data stream

Dead Time:
Continuous mode: wrap around time (no dead time at the end of a sweep).
Triggered sweep: approx. <320ns dead time per cycle (sweep)

SPECIFICATIONS

CONNECTORS (mounting bracket)
Start Input: SMA-connector >3 GHz bandwidth (-3db), +/-1V, falling edge sensitive, progr. threshold in steps of 1mV, Z_{in} = 50 Ohm, sensitivity <10 mV.

Stop Input: SMA-connector, >3 GHz bandwidth (-3db), +/-1V, falling edge sensitive, programmable threshold in steps of 1mV, Z_{in} = 50 Ohm, sensitivity > 10 mV.

Two General Purpose Analog Outputs: Lemo-connectors, 12 bit, resolution +/-10V, user definable to control external devices (HV supplies etc.)

Sync output 1: SMA-connector outputs FAST-NIM pulses, Z = 50 Ohm, user selectable signals

Start, Stop inputs, Sync out 1 and DAC 1 & 2 are located on the board mounting bracket.

I/O port connector: 16 pin header cable connected to 15-pin D-SUB (female, bracket mounted), TTL compatible, 8-bit user configurable digital I/O port, GO-line, Sync output 2, +5V power

TAG Inputs: 8-bit TTL inputs, default impedance 100 Ohms. 16 ns time resolution.

GO-line connector: 2-pin header on the PCB, open drain (wired-AND), 100k Ohm pull-up

Operating Temperature Range: 0°C to +50°C

Power Requirements: +5V, 2.2.A, +12V, 0.2A, -12V, 0.25A, supplied by the PC via the PCI connector and an auxilliary power cable.

PC: 32 bit PCI slot, 32 bit Windows XP /Vista/7, no Dell PC.

Physical: full size PCI board

Shipping weight: 1.8 kg (net 0.75 kg)

Options:

Ovenized crystal oscillator Frequency stability 0.03 ppm @ 0 ... 50 °C,

LW800, 800 MHz discriminator with fiber optical isolation

DLL/VI's for LabVIEW, C and Visual Basic

- MS-Windows based customer-specific user interfaces can be easily made using supplied documentation, libraries and examples
- Example program in Visual Basic
- Example LabVIEW application and library containing basic LabVIEW VI's
- Automatic execution through MACRO commands
- Local Area TCP/IP Network support for remote control via optional MCDLAN software

The 32 bit MCDWIN software for the P788x family consists of a hardware-dependent server program with DLL and a general graphics program that controls the hardware via the DLL. Any other Windows application can also control the hardware via the DLL. To support the programming of such customer-specific user interfaces, we optionally deliver documentation such as sourcecode and example

programs for Visual Basic and LabVIEW, laboratory automation environment with example programs for LabVIEW, Visual Basic and "C" - see separate datasheet

LINUX Drivers

- LINUX Driver to control up to four P7887 boards.
- Library and Sample program with Source code are included.
- Clearly structured software interface defined in one header file, seperated parameter structures for Board Properties, General Settings, Preset Parameters, Digital I/O and DAC Settings, and Acquisition Status.
- Function library with source code allows to set and get all acquisition parameters, start, halt, erase, get status, sweep.
- Sequential mode with fast switching of acquisition segments implemented.
- Control of the Digital Input / Output and the DACs for the threshold of the input discriminators.
- RAM for spectra accumulation can be allocated from the library or the user program.
- Sample console-program with source code contains command interpreter, can be easily expanded by the user to implement customer-specific features.
- The driver is for the actual LINUX Kernel versions 2.4.4 and 2.4.19 on the x86 platform.
- Free updates will be provided for future kernel versions.
- DMA and Multithreading is implemented. Performance measurements with a P7887 on an Athlon and Intel computer showed a throughput of 12.2 * 10^6 events per sec.

LINUX is now established as a very stable operating system especially for the x86 PC hardware and is winning over enthusiastic adherents in many application areas. Especially customers developing their own applications like LINUX for its performance and stability and free compile- and debugging tools.

We therefore support now with this new LINUX software interface especially those customers who want to use our boards of the MCD-2 and P788x family on the x86 LINUX platform and adapt it to their own customer-specific appli-cations.

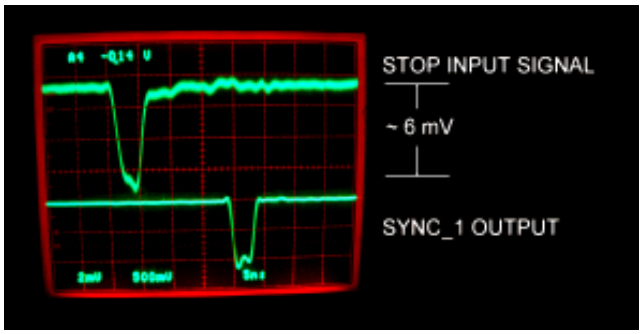
The kernel device driver module supports up to four boards in one computer. A ready-to-use library module with source code provides direct access to the hardware and all board capabilities. The software interface is clearly structured and defined in one header file. A short console sample program with source code shows how to use the library. It contains a simple command interpreter, can be immediately used for actual

General

Setting of the START and STOP input thresholds was never that easy...

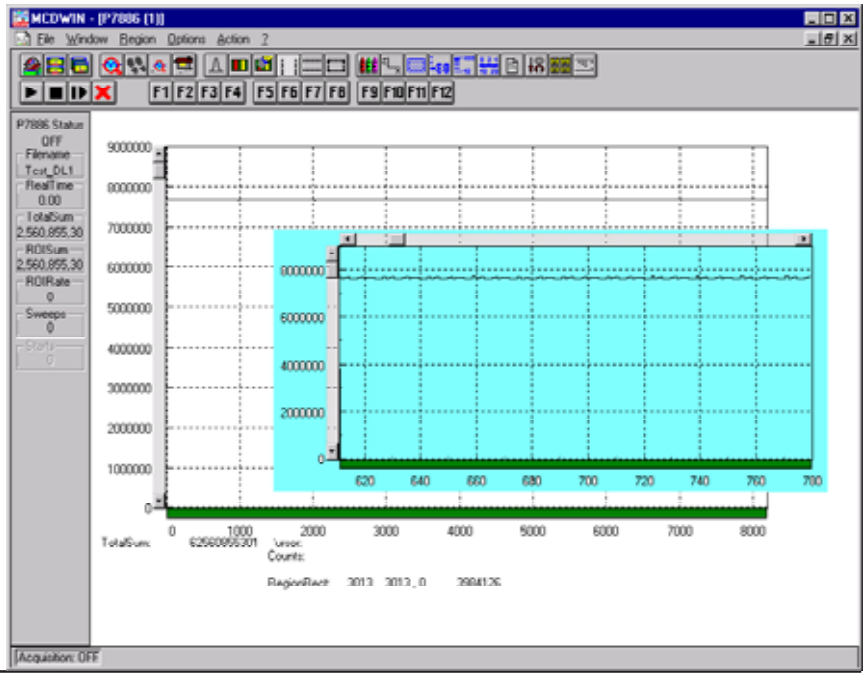
The P7887 START and STOP input threshold can be precisely set using an oscilloscope and observing the actual input signal and the SYNC_1 output.

The example below shows a stop input signal of about 6 mV that is still triggering the P7887.



Differential Linearity

The P7887 further improves the excellent differential linearity specifications of the P7886-series instruments. At <<1% linearity error the P7887 has far better specifications and is much faster than any other analog TAC or digital TDC presently available.

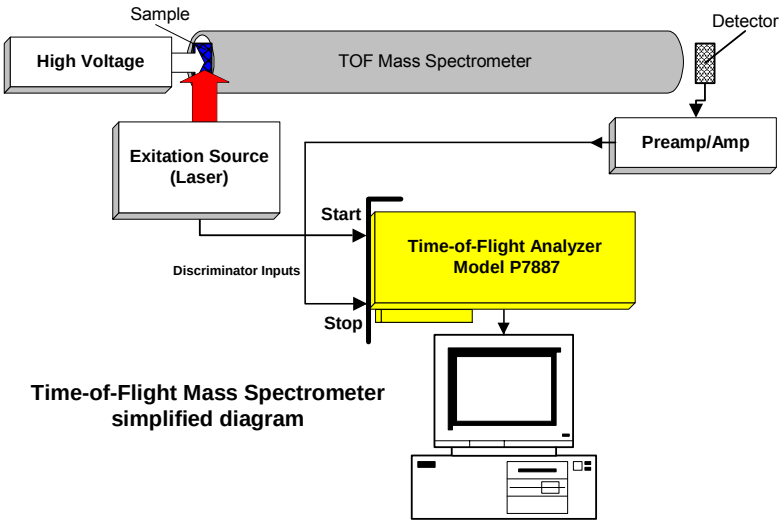


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Typical Applications

Time-of-Flight Spectrometry

This application is specifically suited to the capabilities of the P7887. Because the P7887 has been optimized for the best pulse-pair resolving time while providing excellent time resolution one can easily record mass lines that are very closely spaced. Because of the multistop capability of the P7887 stop events in all mass lines can be recorded during a single shot - something practically impossible with analog-type instrumentation.



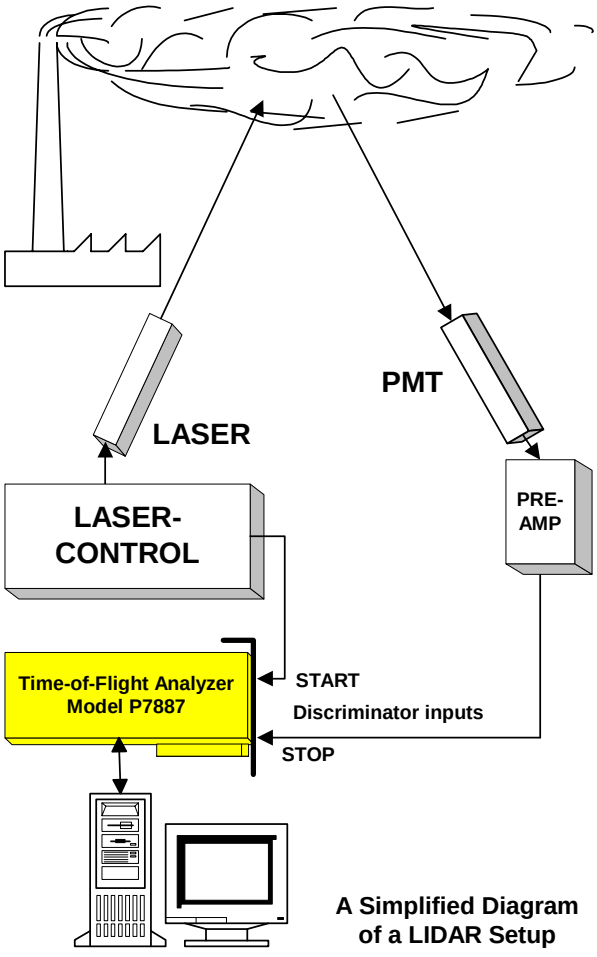
Time-of-Flight Mass Spectrometer simplified diagram

LIDAR

The beam of a pulsed LASER is aimed at an object from as close as a plume of a smoke stack to as far as a cloud or the exhaust vapor of a Jet engine flying at high altitudes. The reflected beam is detected, for example with a PMT and the photons are counted as stop pulses by the P7887.

Responses from repeated shots from the LASER are summed to improve the statistical precision.

The time range of the P7887 from 32 ns to 68 s can be used to measure objects from close range up to distances far exceeding the useful range of a LIDAR System. The spatial resolution is 4 cm - uniformly over the entire selected range.



A Simplified Diagram of a LIDAR Setup

Very important in LIDAR applications is the multistop capability of the P7887 which will produce a full spectrum with relatively few shots. Therefore the P7887 is ideally suited to analyze transient phenomena such as exhaust plumes of fast moving objects at very high altitudes.

Time-resolved fluorescence- and luminescence analysis

Lifetime measurements

Time resolved Single-Molecule detection: the P7887 can record decay schemes with multiple decay time constants. Due to the zero deadtime between recording of events at up to 4 GHz count rates the fast components will not be distorted - i.e. no correction of the accumulated (raw) data is required.

General Information

Principle of operation

For every stop signal the P7887 generates a 32 bit word which contains the time information (number of 250 ps pulses generated by the internal 4 GHz oscillator) elapsed since the last valid start signal (using TAG bits: 24 bit time

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information and 8 bit TAG information)

Stop Rates and Memory Range

The number of available time bins in histogram mode is limited by the memory capacity of the host PC only. Utilizing new PCI technology the P7887 can transfer stop events at rates up to 12.200.000 stops/s continuously to the memory in the host PC while burst rates can be as high as 4.000.000.000 stops/s.

Example: A burst with a maximum counting rate of 4 GHz will fill the FIFO buffer in 2 µs, thereafter the counting rate will drop to an average of 12.200.000/s.

Depending on the shot repetition rate, the actual burst rate and the No. of time bins selected the throughput can be significantly higher than the average rate might indicate. FAST ComTec has decided against on-board memories although they would allow histogramming rates of up to 15 MHz but would severely limit the memory size and certainly are less cost effective.

Up to 4 GB RAM can be made available in the host PC which means that for whatever time range required the PC can be flexibly configured with sufficient RAM.

For list-mode recording the incoming data can be directly recorded on hard disk. Appropriate RAID controllers can handle the full 12.200.000 stops/s transfer rate and offer the recording of a virtually unlimited time range.

TAG-Bits and Multi-Input capabilities

There are 8 digital input lines available which can be used to tag each stop signal. One can either input up to eight discrete TAG signals or use an encoder to expand them up to a maximum of 256 useful TAG inputs.

The time resolution of the TAG signals is 16 ns. This can be used to record stops from different detectors at counting

rates of up to 62.5 MHz which virtually turns the P7887 into a multi-input device yet retaining the full 250 ps resolution for each stop event. External logic is required to OR the stop signals and provide the required TAG signals.

Modes of Operation

The P7887 offers five modes of operation:

Recording multiple stop pulses after a start trigger and histogramming the incoming data and/or storing the listmode information continuously taking data (wrap around) and synchronize the experiment using the programmable sync-output.

Sequential recording is used to record successive time sections - say 1µs in rapid succession. The data is stored in a 2-D histogram and is mostly used to show dynamic changes during the session.

Time-Interval histogramming. In this mode the time difference between each stop pulse and the next is calculated and histogrammed.

Autocorrelation (optional) - a two-dimensional histogram M(i,j) is incremented when within a single sweep the channels i and i + j have an event.

General Operation

A two step FIFO memory concept provides the ultra high event rate capability. Full 4 GHz bursts can be buffered for at least 2 µs. Data reduction is performed by recording interesting, i.e. stop events that arrive inside a preselected time window only.

For experiments requiring repetitive sweeps the spectral data obtained from each**sweep can be summed in the PC at rates of up to 12.200.000 stops/s** enabling extremely high sweep repetition rates. A presettable 32 bit sweep counter enables the user to perform exact normalization calculations.

The **ultra fast discriminator inputs** (±1V input voltage range) accept a large range of amplitude variation of START and STOP input signals.

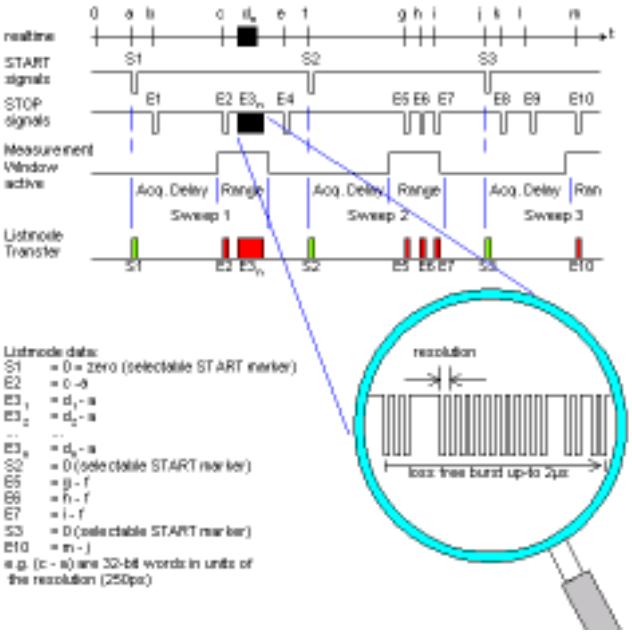
An open-drain **'GO'-line** (compatible to other products of FAST ComTec) allows for overall experiment synchronization.

Two software configurable **SYNC outputs** provide synchronization and triggering of external devices or experiment

monitoring - here are a few examples - two can be selected simultaneously:

- START: Discriminated START input signal
- STOP: Discriminated STOP input signal
- ON: indicates a running sweep when logic '1'
- WINDOW: indicates the active measurement / acquisition time window 125MHz: 125 MHz continuous signal synchronously to the internal timebase
- FIFO1_FULL: the ultra fast 127 deep FIFO is full
- FIFO2_FULL: the large 16k deep FIFO is full
- COUNT[0] (to 26): 16 ns = 2^0 (to 2^{26}) x 16 ns

periodic

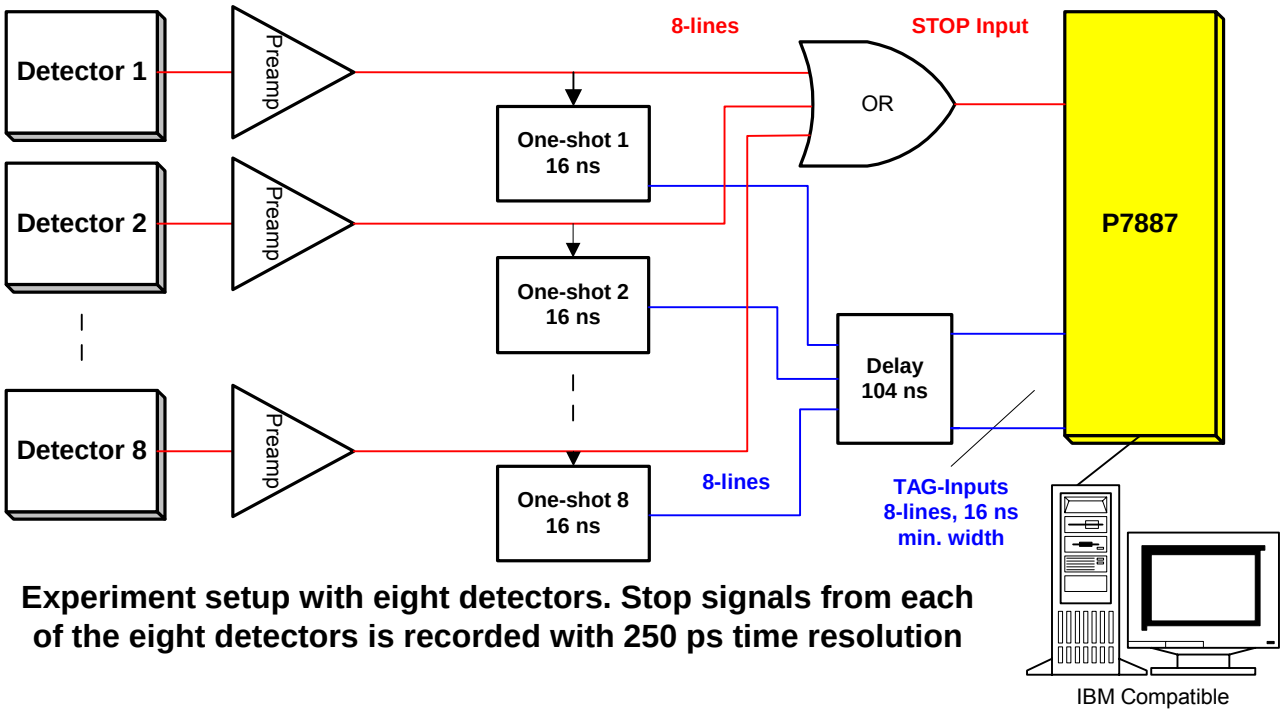


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timer signal, active only while a sweep is running

- SWEEP[0]: bit 0 (LSB) of the sweep counter
- SWEEP[1] (to 30): bit 1 (to 30) of the sweep counter
- SWEEP[31]: bit 31 (MSB) of the sweep counter

A versatile 8 bit digital I/O port may further satisfy your experimental needs.



Experiment setup with eight detectors. Stop signals from each of the eight detectors is recorded with 250 ps time resolution

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