Time Correlated Single Photon Counting Systems

PC Based Systems
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Multi-wavelength detection of fluorescence decay functions

16 wavelength channels recording simultaneously
Spectral range 300-850 nm
High time resolution: 180 ps fwhm IRF width
Useful count rate > 2 MHz
Ultra-high sensitivity
Short acquisition times
Greatly reduced pile-up
Works with any bh TCSPC module

Biomedical fluorescence
Autofluorescence of tissue
Time-resolved laser scanning microscopy
Multi-spectral lifetime imaging
Recording of chlorophyll transients
stopped flow fluorescence experiments

The PML-SPEC uses bh's proprietary multi-dimensional TCSPC technique. The light is split into its spectrum by a polychromator. The spectrum is detected by a 16-channel multi-anode PMT. The single photons detected in the PMT channels are recorded in a bh TCSPC module. The TCSPC module builds up a photon distribution over the time in the fluorescence decay and the wavelength. The technique does not use any time gating, detector channel multiplexing, or wavelength scanning and therefore reaches a near-ideal counting efficiency.

Covered by patent DE 43 39 787
PML-Spec Multi-Wavelength Lifetime Detection

Optical System

<table>
<thead>
<tr>
<th>Type of grating, lines/mm</th>
<th>400</th>
<th>600</th>
<th>1200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recorded interval, nm</td>
<td>320</td>
<td>208</td>
<td>106</td>
</tr>
<tr>
<td>Wavelength channel width, nm</td>
<td>20</td>
<td>13</td>
<td>6.65</td>
</tr>
<tr>
<td>Spectral range of grating, nm</td>
<td>300-600</td>
<td>300-850</td>
<td>300-600</td>
</tr>
<tr>
<td>F number</td>
<td>F / 3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input slit width, mm</td>
<td>0.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input slit height, mm</td>
<td>7.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Optical Input Versions
- Fibre bundle, fibre probe with 1 excitation fibre and 6 detection fibres, or SMA-905 connector

1 any interval within spectral range of grating
2 Detector with bi-alkali cathode
3 Detector with multi-alkali cathode

Detector

- Cathode spectral response: bi-alkali, 300 to 600 nm; multi-alkali, 300 to 850 nm
- Typical dark count rate, s⁻¹: 200; 800
- Number of spectral channels: 16
- Timing output polarity of detector: negative
- Average timing pulse amplitude: 40 mV
- Time resolution (FWHM): 150 to 200 ps
- Time skew between channels: < 40 ps
- Timing output connector: SMA, 50Ω
- Routing signal: 4 bit + Count Disable Signal, TTL/CMOS
- Routing signal connector: 15 pin Sub-D / HD
- Power supply (PML-16): ± 5V from SPC module, -800...-900V / 0.35 mA from external HV power supply
- Power supply (PML-16C): ± 5V, +12V from DCC-100 detector controller. Internal HV generator

4 please see data sheet and manual of PML-16 and PML-16C multichannel PMT heads

Applications

- Multi-Wavelength Fluorescence Decay Measurement
- Multi-Wavelength Picosecond Laser Scanning Microscope

Related Products and Accessories: SPC-134 through SPC-830 TCSPC boards, ps diode lasers, FLIM upgrade kits for scanning microscopes. Please see www.becker-hickl.com or call for individual data sheets.

The TCSPC Microscopy Solution SPC-830

High Resolution Time-Correlated Single Photon Counting Imaging and FCS Module for Laser Scanning Microscopes

- Complete picosecond imaging system on single PC board
- Picosecond resolution
- Ultra-high sensitivity
- Multi detector capability
- High-speed on-board data acquisition
- Works at any scanning speed of microscope
- High resolution picosecond lifetime imaging
- FRET imaging
- High-resolution steady state imaging
- Single-point time-lapse lifetime analysis
- FCS, FIDA, FILDA, BIFL measurement
- Time channel width down to 813 fs
- Image size up to 4096 x 4096 pixels
- Electrical time resolution down to 8 ps fwhm / 4 ps rms
- Reversed start/stop: Laser repetition rates up to 200 MHz
- Useful detector count rate up to 8 MHz - dead time 125 ns
- Active and passive scanning control
- Software versions for windows 95 / 98 / 2000 / NT

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Covered by patents DE 43 39 784 and DE 43 39 787
The TCSPC Microscopy Solution  SPC-830

Photon Channel
Principle
Time Resolution (FWHM / RMS, electr.)  Constant Fraction Discriminator
Opt. Input Voltage Range  7 ps / 4 ps
Min. Input Pulse Width  - 50 mV to - 1 V
Lower Threshold  400 ps
Zero Cross Adjust  - 20 mV to - 500 mV

Synchronisation Channel
Principle
Opt. Input Voltage Range  - 50 mV to - 1 V
Min. Input Pulse Width  400 ps
Threshold  0 to 200 MHz
Frequency Range  1-2-4-8-16
Frequency Divider  -20 mV to -500 mV
Zero Cross Adjust  -100 mV to + 100 mV

Time-to-Amplitude Converter / ADC
Principle
Ramp Generator / Biased Amplifier
TAC Range  50 ns to 2 us
Biased Amplifier Gain  1 to 15
Biased Amplifier Offset  0 to 100% of TAC Range
min. Time / Channel  3.3 ns to 2 us
TAC Window Discriminator  813 fs
ADC Principle  Any Window inside TAC Range
Diff. Nonlinearity (dith width 1/8, 90% of TAC range)  < 0.5% rms, typically <1% peak-peak

Data Acquisition, Histogram Modes
Method
on-board 4-dimensional histogramming process over t, x, y, and detector channel number
Dead Time
Saturated Count Rate / Useable Count Rate 125ns, independent of computer speed
Number of Time Channels / Pixel  8 MHz / 4 MHz
Image Resolution (pixels), 1 Detector Channel
4096 x 4096  2048 x 2048  1024 x 1024  512 x 512  256 x 256  128 x 128  64 x 32
Image Resolution (pixels), 4 Detector Channels
1024 x 1024  512 x 512  256 x 256  128 x 128  64 x 64  32 x 32  16 x 16
Counts / Time Channel 216-1
Count Enable Control none / stop / repeat and acquire
Overflow Control 100 ns to 1000 s
Display Interval Time 10ms to 1000 s
Repeat Time 0.1 ms to 1000 s
Curve Control (Internal Routing / Scan Sync In Mode)
Routing Control / Detector Channels 14 bit TTL / 16384
Count Enable Control 1 bit TTL
Control Signal Latch Delay 0 to 255 ns
Experiment Trigger TTL

Data Acquisition, FIFO/Time-Tag Modes
Method
Time-tagging of individual photons and continuous writing to disk
Macro Time Resolution
ADC Resolution / No. of Time Channels 50 ns / 4096
Dead Time 12 bit / 4096
Output Data Format (ADC / Macrotime / Routing)
FIFO buffer Capacity (photons) 150 ns
12 / 12 / 4 8 million photons

Multi Module Systems
Number of modules operable parallel 4

Operation Environment
Computer System  PC Pentium
Bus Connector  PCI
Power Consumption  approx. 20 W at +5V, 0.7 W at +12V
Dimensions  312 mm x 122 mm x 28 mm

Related Products and Accessories
Detector Heads (MCPs, PMTs), Multichannel Detector Heads, Routing Devices for Multichannel Measurements, Preamplifiers, PIN and Avalanche Photodiode Modules, ps Diode Lasers, Adapter Cables for Scanning Microscopes. SPC-600/630 TCSPC modules for single molecule and correlation spectroscopy, SPC-700/730 and SPC-144 for imaging and SPC-134 for optical tomography. Please download or call for individual data sheets. To control detectors and shutters please see DCC-100 detector controller.

Please visit our web site to download the manual, the device software and application notes.

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Time-Correlated Single Photon Counting Modules

- Complete TCSPC Systems on single PC Boards
- Multi-Detector Capability
- Multiplexing Capability
- Histogram Mode: Recording of Decay Curves
- Dual-Memory Architecture: Unlimited Sequential Curve Recording
- Double-Kinetic Mode: Fast Triggered Accumulation of Sequences
- FIFO / Time-Tag Mode: FCS, FIDA, FILDA, or BIFL Experiments
- Reversed Start/Stop: Repetition Rates up to 200 MHz
- Electrical Time Resolution down to 8 ps FWHM / 5 ps rms
- Channel Resolution down to 813 fs
- Up to 4096 Time Channels / Curve
- Ultra-High Count Rate: Up to 8 MHz (125 ns Dead Time)
- Measurement Times down to 10 µs
- Operating Software for Windows 95 / 98 / 2000 / NT
- Parallel Operation of up to 4 Modules

Decay curves recorded within seconds

Ultra-fast sequential recording

Multi-wavelength detection

Anti-bunching

Fluorescence Correlation

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Covered by patents DE 43 39 784 and DE 43 39 787
**SPC-630**

**Photon Channel**
- **Principle**: Constant Fraction Discriminator
- **Time Resolution (FWHM / RMS, electr.)**: 8 ps / 5 ps
- **Opt. Input Voltage Range**: - 50 mV to - 1 V
- **Threshold**: - 20 mV to - 500 mV
- **Zero Cross Adjust**: - 100 mV to + 100 mV

**Synchronization Channel**
- **Principle**: Constant Fraction Discriminator
- **Opt. Input Voltage Range**: - 50 mV to - 1 V
- **Threshold**: 20 mV to - 500 mV
- **Frequency Range**: 0 to 200 MHz
- **Frequency Divider**: 1-2-4-8-16
- **Zero Cross Adjust**: - 100 mV to + 100 mV

**Time-to-Amplitude Converter / ADC**
- **Principle**: Ramp Generator / Biased Amplifier
- **TAC Range**: 50 ns to 2 us
- **Biased Amplifier Gain**: 1 to 15
- **Biased Amplifier Offset**: 0 to 100% of TAC Range
- **Time Range incl. Biased Amplifier**: 3.3 ns to 2 us
- **TAC Window Discriminator**: 813 fs
- **ADC Principle**: 50 ns Flash ADC with Error Correction
- **Diff. Nonlinearity (dith. width 1/8)**: < 0.5 % rms, typically 0.6 to 1 % peak-peak

**Data Acquisition (Histogram Modes)**
- **Method**: on-board 2-dimensional histogramming process
- **Dead Time**: 125ns, independent of computer speed
- **max. Number of Curves in Memory**: 4096
- **max. Number of Detector Channels**: 128
- **Number of Time Channels / Curve**: 2^16
- **max. Counts / Channel**: 128
- **Overflow Control**: none / stop / repeat and correct
- **Collection Time**: 0.1 us to 1000 s
- **Display Interval Time**: 10 ms to 1000 s
- **Repeat Time**: 0.1 ms to 1000 s
- **Curve Control (internal)**: Programmable Hardware Sequencer
- **Curve Control (external Routing)**: 7 bit TTL
- **Add/Sub (Lock-in) Control**: 1 bit TTL
- **Count Enable Control**: 1 bit TTL
- **Control Signal Latch Delay**: 0 to 255 ns

**Data Acquisition (FIFO / BIFL Mode)**
- **Method**: Time-tagging of individual photons and continuous writing to disk
- **Dead Time**: 150 ns
- **Output Data Format (ADC / Macrotimer / Routing)**: 12 / 24 / 8
- **FIFO buffer Capacity (photons)**: 128 k
- **Macro Timer Resolution**: 50 ms, 24 bit
- **Curve Control (external Routing)**: 8 bit TTL
- **Count Enable Control**: 1 bit TTL
- **Routing Signal Latch Delay**: 0 to 255 ns

**Operation Environment**
- **Computer System**: PC Pentium or 486
- **Bus Connector**: PCI
- **Power Consumption**: approx. 20 W at +5V, 0.7 W at +12V
- **Dimensions**: 312 mm x 122 mm x 28 mm

**Multi Module Systems**
- **Number of modules operable parallel**: 4

**Accessories and Associated Products**
Detectors (MCPs, PMTs), multichannel detector heads, routing devices for multi-detector operation, detector controllers, preamplifiers, PIN and avalanche photodiode modules, ps diode lasers with multiplexing capability. Also available: SPC-134, SPC-144, SPC-730 and SPC-830 time-correlated single photon counting modules, gated photon counters and multiscalers. Please call for individual data sheets and manuals. For TCSPC imaging applications please see SPC-730/830 data sheets, for ultra-high count rate SPC-134 and SPC-144 data sheets.

Please visit our web site for free download of the manual, the device software and application literature.
The TCSPC Imaging Package  
SPC-154

Four-Channel Time-Correlated Single Photon Counting Module

Four fully parallel TCSPC channels
Picosecond resolution
Ultra-high sensitivity
Multi-detector capability in all four channels
High-speed on-board data acquisition
Photon distribution and time-tag modes
Image acquisition by synchronisation with ext. scanner
Unlimited sequential recording of curves or images
Imaging in histogram mode and in time-tag mode
Works at any scan rate of CLSMs or MPLSMs
Time channel width down to 813 fs
Electrical time resolution down to 8 ps fwhm / 4 ps rms
Reversed start/stop: Laser repetition rates up to 150 MHz
Total saturated count rate 40 MHz
Total useful recorded count rate up to 20 MHz
Channel dead time 100 ns

Multi-wavelength FLIM
Double-exponential FLIM
Fast-Acquisition FLIM
Fast Sequential FLIM
Single and double-exponential FRET imaging
FCS, FCCS, FIDA, FILDA, BIFL
FCS Imaging
DOT, static and dynamic brain imaging
Transient fluorescence lifetime effects

Covered by patents DE 43 39 784 and DE 43 39 787
**Photon Channels**
- **Principle**: Constant Fraction Discriminator (CFD)
- **Time Resolution (FWHM / RMS, electr.)**: 8 ps / 5 ps
- **Opt. Input Voltage Range**: - 50 mV to - 1 V
- **Min. Input Pulse Width**: 400 ps
- **Lower Threshold**: - 20 mV to - 500 mV
- **Upper Threshold**: - 100 mV to + 100 mV
- **Zero Cross Adjust**: 1-2-4

**Synchronisation Channels**
- **Principle**: Constant Fraction Discriminator (CFD)
- **Opt. Input Voltage Range**: - 50 mV to - 1 V
- **Min. Input Pulse Width**: 400 ps
- **Threshold**: 0 to 200 MHz
- **Frequency Range**: 0 to 80 MHz
- **Frequency Divider**: 1-2-4
- **Zero Cross Adjust**: -100 mV to + 100 mV

**Time-to-Amplitude Converters / ADCs**
- **Principle**: Ramp Generator / Biased Amplifier
- **TAC Range**: 50 ns to 2 us
- **Biased Amplifier Gain**: 1 to 15
- **Biased Amplifier Offset**: 0 to 100% of TAC Range
- **Time Range incl. Biased Amplifier**: 813 fs
- **ADC Principle**: 50 ns Flash ADC with Error Correction
- **Diff. Nonlinearity**: < 0.5% rms, typ. <1% peak-peak

**Data Acquisition (Histogram Mode)**
- **Method**: on-board multi-dimensional histogramming process
- **100ns, independent of computer speed**: 10 MHz / 40 MHz
- **5 MHz / 20 MHz**: 256 x 256
- **Channels / Curve per TCSPC channel**: 4096
- **max. Scanning Area per TCSPC channel**: 4x4x4
- **Channels / Curve per TCSPC channel**: 128 x 128
- **max. Counts / Time Channel**: 256 x 256
- **Frequency Range**: 40 MHz
- **Overflow Control**: none / stop / repeat and correct
- **Collection Time**: 0.1 us to 1000 s
- **Display Interval Time**: 0.1 us to 1000 s
- **Repeat Time**: 10ns to 1000 s
- **Sequential Recording**: Programmable Hardware Sequencer
- **Synchronisation with Scanning**: Unlimited recording by memory swapping, in curve mode and scan mode
- **Count Enable Control**: 1 bit TTL
- **Experiment Trigger**: TTL

**Data Acquisition (FIFO / Time-Tag Mode)**
- **Method**: Time-tagging of individual photons and continuous writing to disk
- **Dead Time**: 100 ns
- **Output Data Format (ADC / Macrotime / Routing)**: 12 bit ADC / 12 bit macro time / 4 bit routing
- **Output Data Format for Scan Clock Markers (pxl, line, frame)**: 12 bit macro time / pxl, line, frame
- **FIFO Buffer Capacity (photons and clock markers)**: 2 M
- **Macro Timer Resolution, internal clock**: 25 ns, 12 bit
- **Macro Timer Resolution, clock from SYNC input**: 10 ns to 100 ns, 12 bit
- **Curve Control (external Routing)**: 4 bit TTL
- **Count Enable Control**: 1 bit TTL

**Operation Environment**
- **Computer System**: PC Pentium
- **Bus Connectors**: PCI
- **Used PCI Slots**: 4
- **Consumption**: approx. 60 W from +5V, 0.7 W from +12V
- **Dimensions**: 240 mm x 130 mm x 85 mm

**Product Literature**
The TCSPC Imaging Package  SPC-144

Four-Channel Time-Correlated Single Photon Counting FLIM Module for Laser Scanning Microscopes

Four fully parallel TCSPC imaging channels
Picosecond resolution
Ultra-high sensitivity
Multi-detector capability in all four channels
High-speed on-board data acquisition
Works at any scanning speed of CLSMs or MPLSMs
Time channel width down to 813 fs
Lifetime image size up to 1024 x 1024 pixels
Steady-state image size up to 2048 x 2048 pixels
Electrical time resolution down to 8 ps fwhm / 4 ps rms
Reversed start/stop: Laser repetition rates up to 150 MHz
Total useful recorded count rate up to 20 MHz
Dead time 100 ns

Multi-wavelength picosecond lifetime imaging
FRET imaging
FCS, FIDA, FILDA, BIFL
High-resolution steady state imaging
Single-point time-lapse lifetime analysis

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Covered by patents DE 43 39 784 and DE 43 39 787
Photon Channels
Principle
Time Resolution (FWHM / RMS, electr.)
Opt. Input Voltage Range
Min. Input Pulse Width
Lower Threshold
Upper Threshold
Zero Cross Adjust

Synchronisation Channels
Principle
Opt. Input Voltage Range
Min. Input Pulse Width
Threshold
Frequency Range
Frequency Divider
Zero Cross Adjust

Time-to-Amplitude Converters / ADCs
Principle
TAC Range
Biased Amplifier Gain
Biased Amplifier Offset
Time Range incl. Biased Amplifier
min. Time / Channel
ADC Principle
Diff. Nonlinearity

Data Acquisition (Histogram Mode)
Method
Dead Time
Saturated Count Rate, per TCSPC channel / total
Useful count rate, per TCSPC channel / total
Channels / Curve per TCSPC channel
max. Scanning Area per TCSPC channel
max. Counts / Time Channel
Overflow Control
Collection Time
Display Interval Time
Repeat Time
Sequential recording
Synchronisation with scanning
Count Enable Control
Experiment Trigger

Data Acquisition (FIFO / Time-Tag Mode)
Method
Dead Time
Output Data Format (ADC / Macrotime / Routing)
FIFO buffer Capacity (photons)
Macro Timer Resolution, internal clock
Macro Timer Resolution, clock from SYNC input
Curve Control (external Routing)
Count Enable Control

Operation Environment
Computer System
Bus Connectors
Used PCI Slots
Total power Consumption
Dimensions

Related Products and Accessories
Detectors and Detector Modules, Multichannel Detector Heads, Step Motor Controllers, Detector/Shutter Controllers, Preamplifiers, ps Diode Lasers. Also available: SPC-134, SPC-6, -7, -8 time-correlated single photon counting modules, gated photon counters and multiscalers. Please download or call for individual data sheets and manuals.

Please visit our web site to download the manual, the device software and application literature.

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Tel: 0131 664 8122
Fax 0131 664 8144
The TCSPC Power Package

Four Channel Time-Correlated Single Photon Counting Module

- Four Completely Parallel TCSPC Channels
- Ultra-High Data Throughput
- Overall Count Rate 32 MHz
- Channel Count Rate 10 MHz (Dead Time 100ns)
- Dual Memory Architecture: Readout during Measurement
- Reversed Start/Stop: Repetition Rates up to 200 MHz
- Electrical Time Resolution down to 8 ps FWHM / 5 ps rms
- Channel Resolution down to 813 fs
- Up to 4096 Time Channels / Curve
- Measurement Times down to 0.1 ms
- Software Versions for Windows 95 / 98 / NT
- Direct Interfacing to most Detector Types
- Single Decay Curve Mode
- Oscilloscope Mode
- Sequential Recording Mode
- Spectrum Scan Mode with 8 Independent Time Windows
- Continuous Flow Mode

Covered by patents DE 43 39 784 and DE 43 39 787

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### Photon Channels

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle</td>
<td>Constant Fraction Discriminator (CFD)</td>
</tr>
<tr>
<td>Time Resolution (FWHM / RMS, electr.)</td>
<td>8 ps / 5 ps</td>
</tr>
<tr>
<td>Opt. Input Voltage Range</td>
<td>-50 mV to -1 V</td>
</tr>
<tr>
<td>Min. Input Pulse Width</td>
<td>400 ps</td>
</tr>
<tr>
<td>Threshold</td>
<td>-20 mV to -500 mV</td>
</tr>
<tr>
<td>Upper Threshold</td>
<td></td>
</tr>
<tr>
<td>Zero Cross Adjust</td>
<td>-100 mV to +100 mV</td>
</tr>
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### Synchronization Channels

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Principle</td>
<td>Constant Fraction Discriminator (CFD)</td>
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<tr>
<td>Opt. Input Voltage Range</td>
<td>-50 mV to -1 V</td>
</tr>
<tr>
<td>Min. Input Pulse Width</td>
<td>400 ps</td>
</tr>
<tr>
<td>Threshold</td>
<td>-20 mV to -500 mV</td>
</tr>
<tr>
<td>Frequency Range</td>
<td>0 to 200 MHz</td>
</tr>
<tr>
<td>Frequency Divider</td>
<td>1-2.4</td>
</tr>
<tr>
<td>Zero Cross Adjust</td>
<td>-100 mV to +100 mV</td>
</tr>
</tbody>
</table>

### Time-to-Amplitude Converters / ADCs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle</td>
<td>Ramp Generator / Biased Amplifier</td>
</tr>
<tr>
<td>TAC Range</td>
<td>50 ns to 2 us</td>
</tr>
<tr>
<td>Biased Amplifier Gain</td>
<td>1 to 15</td>
</tr>
<tr>
<td>Biased Amplifier Offset</td>
<td>0 to 100% of TAC Range</td>
</tr>
<tr>
<td>Time Range incl. Biased Amplifier</td>
<td>3.3 ns to 2 us</td>
</tr>
<tr>
<td>min. Time / Channel</td>
<td>813 fs</td>
</tr>
<tr>
<td>ADC Principle</td>
<td>40 ns Flash ADC with Error Correction</td>
</tr>
<tr>
<td>Diff. Nonlinearity</td>
<td>&lt; 0.8% rms, typ. &lt;2% peak-peak</td>
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### Data Acquisition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>on-board 2-dimensional histogramming process</td>
</tr>
<tr>
<td>Dead Time</td>
<td>100 ns, independent of computer speed</td>
</tr>
<tr>
<td>Number of Curves in Memory</td>
<td></td>
</tr>
<tr>
<td>Number of Time Channels / Curve</td>
<td>4096 1024 256 64</td>
</tr>
<tr>
<td>max. Counts / Channel</td>
<td></td>
</tr>
<tr>
<td>Overflow Control</td>
<td>none / stop / repeat and correct</td>
</tr>
<tr>
<td>Collection Time</td>
<td>0.1 us to 10000 s</td>
</tr>
<tr>
<td>Display Interval Time</td>
<td></td>
</tr>
<tr>
<td>Repeat Time</td>
<td>0.1 us to 1000 s</td>
</tr>
<tr>
<td>Curve Control (internal)</td>
<td>Programmable Hardware Sequencer</td>
</tr>
<tr>
<td>Count Enable Control</td>
<td>1 bit TTL</td>
</tr>
<tr>
<td>Experiment Trigger</td>
<td>TTL</td>
</tr>
</tbody>
</table>

### Operation Environment

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer System</td>
<td>PC Pentium</td>
</tr>
<tr>
<td>Bus Connectors</td>
<td>PCI</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>approx. 18 W at +5V, 0.7 W at +12V</td>
</tr>
<tr>
<td>Dimensions</td>
<td>225 mm x 125 mm x 85 mm</td>
</tr>
</tbody>
</table>

### Related Products and Accessories

Detectors (MCPs, PMTs), multichannel detector heads, routing devices for multi-detector operation, detector controllers, detector / shutter assemblies, preamplifiers, PIN and avalanche photodiode modules, ps diode lasers with multiplexing capability. Also available: SPC-134, SPC-144, SPC-630, SPC-730 and SPC-830 time-correlated single photon counting modules, gated photon counters and multiscalers. Please call for individual data sheets and manuals. For TCSPC imaging applications please see SPC-730, -830 and -144 data sheets.

Please visit our web site for free download of manuals, device software and application literature.
Simple-Tau 830   Table-Top TCSPC Systems

Ultra-fast time-correlated single photon counting systems in laptop format

- Complete TCSPC system and detector control
- Cooled fast PMT module
- Picosecond resolution
- Unprecedented count rate
- Unprecedented timing stability
- Time channel width down to 813 fs
- Multi-dimensional on-board data acquisition
- Lifetime imaging capability
- Optional multi detector operation
- Optional multi-spectral operation
- Standard fluorescence lifetime applications
- On-line FCS recording
- Fast triggered sequential recording
- Lifetime imaging with scanning microscopes
- Works at any scan rate of microscope
- High-resolution steady-state imaging
- Diffuse optical tomography
- Single molecule spectroscopy
- Works under windows 2000, NT or XP

Covered by patents DE 43 39 784 and DE 43 39 787
Photon Channel

Principle
Time Resolution (FWHM / RMS, electr.)
- 7 ps / 4 ps
- 20 mV to - 1 V
- 100 mV to + 100 mV

Opt. Input Voltage Range
- 50 mV to - 1 V
- 20 mV to - 500 mV
- 0 to 200 MHz

Min. Input Pulse Width
- 1-2-4-8
- 100 mV to + 100 mV

Threshold
- 20 mV to - 500 mV
- 3.3 ns to 2 us

Frequency Range
- 813 ts
- Any window inside TAC range

Frequency Divider
- 50 ns Flash ADC with Error Correction
- < 0.5% rms, typ. <1% peak-peak

Zero Cross Adjust
- 100 mV to + 100 mV

Synchronisation Channel

Principle
Constant Fraction Discriminator (CFD)
Opt. Input Voltage Range
- 50 mV to - 1 V
- 20 mV to - 500 mV
- 0 to 200 MHz
Min. Input Pulse Width
- 1-2-4-8
- 100 mV to + 100 mV
Threshold
- 20 mV to - 500 mV
- 3.3 ns to 2 us
Frequency Range
- 813 ts
- Any window inside TAC range
Frequency Divider
- 50 ns Flash ADC with Error Correction
- < 0.5% rms, typ. <1% peak-peak
Zero Cross Adjust
- 100 mV to + 100 mV

Time-to-Amplitude Converters / ADC

Principle
Ramp Generator / Biased Amplifier
Opt. Input Voltage Range
- 50 mV to 2 us
- 1 to 15
- 0 to 100% of TAC Range
Min. Input Pulse Width
- 3.3 ns to 2 us
- 813 ts
Frequency Range
- 0 to 200 MHz
Frequency Divider
- 1-2-4-8
Zero Cross Adjust
- 100 mV to + 100 mV

ADC Principle
- 50 ns Flash ADC with Error Correction
- < 0.5% rms, typ. <1% peak-peak

Data Acquisition (Histogram Mode)

Method
- on-board multi-dimensional histogramming process
- 125ns, independent of computer speed

Dead Time
128 ns
8 MHz

Dead Time Saturated Count Rate, per TCSPC channel / total

Useful count rate, per TCSPC channel / total

Number of Time Channels / Pixel

Image Resolution (pixels), 1 Detector Channel

Image Resolution (pixels), 4 Detector Channels

Image Resolution (pixels), 16 Detector Channels

max. Counts / Time Channel

Overflow Control

Collection Time

Display Interval Time

Repeat Time

Sequential recording

Synchronisation with scanning

Count Enable Control

Experiment Trigger

Data Acquisition (FIFO / Time-Tag Mode)

Method
- Time-tagging of individual photons and continuous writing to disk

Dead Time
- 125 ns
- 12 / 12 / 3
- 8 M
- 50ns, 12bit
- 10ns to 100ns, 12bit
- 3 bit TTL
- 1 bit TTL

Output Data Format (ADC / Macrotime / Routing)

Macro Timer Resolution, external clock

Macro Timer Resolution, clock from SYNC input

Curve Control (external Routing)

Count Enable Control

Detector control

Number of independently controlled detectors

Resolution of gain control

Voltage Range Pin 12 of connector 1 and 3

Voltage Range Pin 13 of connector 1 and 3

Output Time Constant

Detector overload shutdown

Reset of overload shutdown

Shutter control

Max. Switch Current, Single Switch

Max. Switch Current, Sum of all Switches

Max. turn-off Voltage at Switches

Control of thermolectric coolers

Total output voltage

Output Current

Resolution of Output Voltage and Current

Detectors, see individual data sheets

Standard detector

Optional

Optional

Optional

Related Products and Accessories

SPC-134 through SPC-830 TCSPC boards, Detector Heads (MCPs, PMTs), Multichannel Detector Heads, Routing Devices for Multichannel Measurements, Step Motor Controllers, Preamplifiers, PIN and Avalanche Photodiode Modules, ps Diode Lasers, Adapter Cables for Scanning Microscopes. Please download or call for individual data sheets.

Please visit our web site to download the manuals, the device software and application notes.
Simple-Tau 140  Table-Top TCSPC Systems

Ultra-fast time-correlated single photon counting systems in laptop format

- Complete TCSPC system and detector control
- Cooled fast PMT module
- Picosecond resolution
- Unprecedented count rate
- Unprecedented timing stability
- Time channel width down to 813 fs
- Multi-dimensional on-board data acquisition
- Lifetime imaging capability
- Optional multi detector operation
- Optional multi-spectral operation
- Standard fluorescence lifetime applications
- On-line FCS recording
- Fast triggered sequential recording
- Lifetime imaging with scanning microscopes
- Works at any scan rate of microscope
- High-resolution steady-state imaging
- Diffuse optical tomography
- Single molecule spectroscopy
- Works under windows 2000, NT or XP

Covered by patents DE 43 39 784 and DE 43 39 787
Simple-Tau 140 Table-Top TCSPC Systems

Photon Channel

- **Principle:** Constant Fraction Discriminator (CFD)
- **Time Resolution (FWHM / RMS, electr.):** 8 ps / 5 ps
- **Opt. Input Voltage Range:** - 50 mV to - 1 V
- **Min. Input Pulse Width:** 400 ps
- **Lower Threshold:** - 20 mV to - 500 mV
- **Upper Threshold:** - 100 mV to + 100 mV
- **Zero Cross Adjust:** - 100 mV to + 100 mV

Synchronisation Channel

- **Principle:** Constant Fraction Discriminator (CFD)
- **Opt. Input Voltage Range:** - 50 mV to - 1 V
- **Min. Input Pulse Width:** 400 ps
- **Threshold:** - 20 mV to - 500 mV
- **Frequency Range:** 0 to 200 MHz
- **Frequency Divider:** 1-2-4
- **Zero Cross Adjust:** - 100 mV to + 100 mV

Time-to-Amplitude Converters / ADCs

- **Principle:** Ramp Generator / Biased Amplifier
- **TAC Range:** 50 ns to 2 us
- **Biased Amplifier Gain:** 1 to 15
- **Biased Amplifier Offset:** 0 to 100% of TAC Range
- **Time Range incl. Biased Amplifier:** 2.7 ns to 2 us
- **Minimum Time / Channel:** 813 fs
- **ADC Principle:** 50 ns Flash ADC with Error Correction
- **Diff. Nonlinearity:** < 0.5% rms, typ. < 1% peak-peak

Data Acquisition (Histogram Mode)

- **Method:** on-board multi-dimensional histogramming process
- **Dead Time:** 100ns, independent of computer speed
- **Saturation Count Rate:** 10 MHz
- **Useful count rate:** 5 MHz
- **Number of Time Channels / Pixel:** 1
- **Image Resolution (pixels), 1 Detector Channel:** 2048 x 2048
- **2048 x 2048**
- **1024 x 1024**
- **256 x 256**
- **128 x 128**
- **64 x 64**
- **32 x 32**
- **Total output voltage:** 0 to 5 V
- **Resolution of Output Voltage and Current:** 0 to 2 A

Data Acquisition (FIFO / Time-Tag Mode)

- **Method:** Time-tagging of individual photons and continuous writing to disk
- **Time Tag:** 125 ns
- **Output Data Format:** 12 / 12 / 3, Macrotime / Routing
- **FIFO buffer Capacity:** 50ns, 12 bit
- **Macro Timer Resolution, clock from SYNC input:** 12 bit TTL
- **Curve Control (external Routing):** 3 bit TTL
- **Total output voltage:** 0 to 5 V
- **Resolution of Output Voltage and Current:** 0 to 2 A

Detector control

- **Number of independently controlled detectors:** one or two
- **Resolution of gain control:** 12 bit
- **Voltage Range Pin 12 of connector 1 and 3:** 0 to +10 V
- **Voltage Range Pin 13 of connector 1 and 3:** 0 to -10 V
- **Output Time Constant:** 100 ms
- **Detector overload shutdown:** via TTL signal from PMC-100 detector module or preamplifier
- **Reset of overload shutdown:** 8 independent high-current switches
- **Shutter control:** for one or two detectors
- **Max. Switch Current, Single Switch:** 2 A
- **Max. Switch Current, Sum of all Switches:** 5 A
- **Max. turn-off Voltage at Switches:** 20 V
- **Control of thermo-electric coolers:** 8 independent high-current switches

Detectors, see individual data sheets

- **Standard detector:** PMC-100-1 cooled PMT module
- **PMC-100-20 cooled NIR PMT module**
- **R3809U MCP PMT with FUG HCN3500-14 power supply and HFA26-01 preamplifier**
- **id100-20 and id100-50 single-photon APD modules**
- **PMC-100, R3809U, or id100 multi-detector systems**
- **PML-SPEC multi-wavelength detector**

Related Products and Accessories

- **SPC-134 through SPC-890 TCSPC boards, Detector Heads (MCPs, PMTs), Multichannel Detector Heads, Routing Devices for Multichannel Measurements, Step Motor Controllers, Preamplifiers, PIN and Avalanche Photodiode Modules, ps Diode Lasers, Adapter Cables for Scanning Microscopes. Please download or call for individual data sheets.**

Please visit our web site to download the manuals, the device software and application notes.

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Massachusetts 02445 USA
Tel: (800) 347 5445 or (617) 566 3821, Fax: (617) 731 0935
www.boselec.com tcspc@boselec.com
MSA-1000

1ns Photon Counter / Multiscaler

Ultra-fast accumulation
High repetition rate
No dead time between sweeps
No dead time between channels
Fast on-board discriminators

Input pulse width down to 800 ps
Time / channel 1 ns
Count rate up to 1000 MHz
Up to 128 k points / curve
Software for Windows 95 / 98 / 2000 / NT

The MSA-1000 is an ultra-fast multiscaler for photon counting, Lidar measurements or other fast particle detection applications. By using a 128 bit memory structure a dead-time-free accumulation of subsequent sweeps is achieved. This makes the MSA-1000 exceptionally useful for a wide variety of high-repetition rate signal recording applications.

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 12277 Berlin
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 Fax. 030 / 787 57 34

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Tel: (800) 347 5445 or (617) 566 3821
Fax: (617) 731 0935
www.boselec.com  tcspc@boselec.com
**Specification**

- **Time per Channel**: min. 1 ns
- **Count Rate**: up to 1000 MHz
- **No of Points / Curve**: up to 128 k
- **Overall Recording Length**: up to 131 µs
- **Accumulation (up to 256 events/point)**: Hardware, no dead time between recording cycles
- **Accumulation (> 256 events/point)**: Software
- **Count Input Impedance**: 50 Ω
- **Count Input Amplitude**: ±20 mV to ±1 V
- **Count Input Threshold**: 0 to ±200 mV, ± 8 bit resolution
- **Min. Count Input Pulse Width**: 800 ps
- **Trigger Input Impedance**: 50 Ω
- **Trigger Input Amplitude**: ±20 mV to ±1 V
- **Trigger Input Threshold**: 0 to ±1 V, ± 8 bit resolution
- **Min. Trigger Pulse Width**: 800 ps
- **Data Readout**: subsequent data points are read by subsequent input instructions
- **Typical readout rate (Pentium 166 MHz)**: 1 µs/point (C++, read 1 point and store into a data array)

**Luminescence Decay Measurements**

The sample is excited by laser pulses and the luminescence signal is detected by a PMT in the photon counting mode. Due to the deep memory a time scale from ns to ms can be covered in one measurement.

**Lidar Measurements**

Laser pulses are sent through a telescope and backscattered light from distant objects is detected. Due to the high accumulation speed of the MSA-1000 very high repetition rates and short overall measurement times are achieved.

Accessories: PMTs, PMT detector heads with internal HV supply, preamplifiers, diode lasers, pulse generators for experiment control, step motor controllers. Please see individual data sheets.

Please visit our web site to download the manual, the device software and application notes.
MSA-300

5ns Photon Counter / Multiscaler

Ultra-fast accumulation
High repetition rate
No dead time between sweeps
No dead time between channels
Fast on-board discriminators

Input pulse width down to 800 ps
Time / channel down to 5 ns
Count rate up to 100 MHz
Up to 512 k points / curve
Software for Windows 95 / 98 / 2000 / NT

The MSA-300 is a fast multiscaler for photon counting, time-of-flight measurements or other fast particle detection applications. By using a 128 bit memory structure a dead-time-free accumulation of subsequent sweeps is achieved. This makes the MSA-300 exceptionally useful for a wide variety of high-repetition rate signal recording applications.
**Specification**

- **Time per Channel**: min. 5 ns
- **Count Rate**: up to 100 MHz
- **No of Points / Curve**: up to 512 k
- **Overall Recording Length**: up to 2.62 ms
- **Accumulation (up to 256 events/point)**: Hardware, no dead time between recording cycles
- **Accumulation (> 256 events/point)**: Software
- **Count Input Impedance**: 50 Ω
- **Count Input Amplitude**: ±20 mV to ±1 V
- **Count Input Threshold**: 0 to ±200 mV, ± 8 bit resolution
- **Min. Count Input Pulse Width**: 800 ps
- **Trigger Input Impedance**: 50 Ω
- **Count and Trigger Input Connectors**: MCX
- **Trigger Input Amplitude**: ±20 mV to ±1 V
- **Trigger Input Threshold**: 0 to ±1 V, ± 8 bit resolution
- **Min. Trigger Pulse Width**: 800 ps
- **Data Readout**: subsequent data points are read by subsequent input instructions
- **Typical readout rate (Pentium 166 MHz)**: 1μs/point (C++, read 1 point and store into a data array)

**Luminescence Decay Measurements**

The sample is excited by laser pulses and the luminescence signal is detected by a PMT in the photon counting mode. Due to the deep memory a time scale from ns to ms can be covered in one measurement.

**Time-of-Flight Measurements**

Packages of ions are released by a pulsed source, sent through a drift tube and detected by an MCP. Due to the high accumulation speed of the MSA-300 very high repetition rates and short overall measurement times are achieved.

Accessories: PMTs, PMT detector heads with internal HV supply, preamplifiers, diode lasers, pulse generators for experiment control, step motor controllers. Please see individual data sheets.

**Please visit our web site to download the manual, the device software and application notes.**

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www.boselec.com tcspc@boselec.com
800 MHz Gated Photon Counter / Multiscaler

- 2 Counter Channels
- 800 MHz Count Rate, 32 bit Resolution
- Direct Interfacing to most Detectors
- Multiscaler Mode: Up to 64k Time Channels, min. 250ns / Channel
- Gated Photon Counting: 1.5 ns min. Gate Pulse Width
- Event Recording Mode: Up to 32 k Events
- 32 bit Accumulation Counter for ultra-fast Accumulation
- On-Board Discriminators, Timing and Control Logics
- PCI Board with fast DMA (Bus Master),
- Software for Windows 98, NT, 2k and XP, Parallel Operation of Several Modules Supported

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www.boselec.com tcspc@boselec.com
Optical Transient Waveform Recording

The waveform of the light is measured with a resolution down to 250ns. Two signals can be recorded simultaneously. Applicable to luminescence decay of inorganic samples, phosphorescence, delayed fluorescence, chemiluminescence, LIDAR.

New: The PMS-400A provides a 32 bit accumulation counter which enables accumulation with virtually no dead time between sweeps (< 100 ns).

Recording of Luminescence Spectra

The luminescence and the excitation light are recorded simultaneously. Corrected excitation spectra are obtained by calculating B/A.

Single Molecule Detection

Recording of photon bursts. If the count rate inside a programmed time interval exceeds a programmed value, the number of photons and the time of the event is stored.

Gated Detection

The gate is opened during the laser pulse only. Events outside the laser pulses are suppressed. Exceptionally low background count rate.

Gating off Scattering Pulses

The gate is closed during the laser pulses. Scattered photons during the laser pulses are suppressed, the luminescence photons outside the laser pulses are recorded.

Specification (Typical Values)

- Counter Channels: 2
- Count Rate (Input Amplitude 50mV, peak-peak): 800 MHz
- min. Count Pulse Width: 800 ps
- min. Gate Width (Input Amplitude 200mV, peak-peak): 1 ns
- min Trigger Pulse Width: 1 ns
- Discriminator Threshold (Count Inputs): -1 V to +1 V in steps of 4 mV
- Discriminator Threshold (Gate Inputs): -2 V to +2 V in steps of 16 mV
- Discriminator Threshold (Trigger Input): -2 V to +2 V in steps of 16 mV
- Input Connectors: MCX, 50 Ω
- Counter Width: 32 bit
- Accumulation Counter: 32 bit
- Dead time between sweeps: < 100ns
- No. of Time Bins: 64 k for each counter channel
- Time / Bin: 250 ns to 100 000 s
- Hardware Environment: Pentium PC
- Software Environment: Windows 95, 98, 2000 or NT
- Dimensions: 180 mm x 108 mm x 15 mm
High Speed Boxcar Modules

Gate Width 120 ps for PCS-150
Gate Width 2 ns to 50 ns for PCI-200
2 Synchronously Sampling Signal Channels
Internal Delay Generator
Delay Stepping down to 5 ps
Boxcar Measurements in the sub-ns Range
Recovery of Signals from Noise
Scanned Delay Mode: Recording of Waveforms
Fixed Delay Mode: Single Point Analysis
### PCS-150 vs PCI-200

<table>
<thead>
<tr>
<th>Feature</th>
<th>PCS-150</th>
<th>PCI-200</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Signal Channels</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Gate Width (PCS-150)</td>
<td>120 ps</td>
<td>2 ns to 50 ns</td>
</tr>
<tr>
<td>Input Impedance</td>
<td>50 Ω (SMA Connector)</td>
<td></td>
</tr>
<tr>
<td>Input Voltage Ranges</td>
<td>50  100  200  500 mV</td>
<td></td>
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<tr>
<td>Amplitude Resolution</td>
<td>9  10  11  12 bit (without averaging)</td>
<td>12 bit (100 samples averaged)</td>
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<tr>
<td>Internal Noise (rms)</td>
<td>1 mV</td>
<td>&lt; 0.25 mV</td>
</tr>
<tr>
<td>Channel Arithmetics</td>
<td>A+B, A-B, A*B, A/B</td>
<td></td>
</tr>
<tr>
<td>No of Samples Averaged</td>
<td>1 to 4096</td>
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<tr>
<td>Averaging Modes</td>
<td>Repeated Sampling or Boxcar Mode</td>
<td></td>
</tr>
<tr>
<td>Delay Range</td>
<td>10 ns to 20 us</td>
<td></td>
</tr>
<tr>
<td>Delay Step Width</td>
<td>5 ps to 312 ns</td>
<td></td>
</tr>
<tr>
<td>Virtual Sample Rate</td>
<td>up to 200 GS/s</td>
<td></td>
</tr>
<tr>
<td>X-Axis Resolution</td>
<td>64 to 1024 points</td>
<td></td>
</tr>
<tr>
<td>Scan Modes</td>
<td>Fixed Delay and Scanned Delay</td>
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</tr>
<tr>
<td>Trigger</td>
<td>external or internal on channel A</td>
<td></td>
</tr>
<tr>
<td>Ext. Trigger Input</td>
<td>50 Ω (SMA Connector)</td>
<td></td>
</tr>
<tr>
<td>Trigger Input Frequency</td>
<td>0 to 500 MHz</td>
<td></td>
</tr>
<tr>
<td>min. Trigger Pulse Width</td>
<td>1 ns</td>
<td></td>
</tr>
<tr>
<td>Trigger Threshold</td>
<td>-1V to + 1V</td>
<td></td>
</tr>
<tr>
<td>Max. Internal Trigger Rate</td>
<td>up to 100 kHz dep. on mode and PC speed</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>120 x 337 mm</td>
<td>12 W at + 5 V</td>
</tr>
</tbody>
</table>

**Accessories**

AC coupled preamplifiers up to 2.2 GHz, DC coupled preamplifiers up to 250 MHz, high speed pin and avalanche photodiode modules, low noise integrating photodiode modules, PMT modules, optical trigger devices, step motor controllers, DLL and DOS library for user specific programming

**Also Available:**

Stand alone boxcar devices BCI-150 and BCI-200 with IEEE interface, gate width 120 ps or 2 ns to 50 ns.
PMS-300

800 MHz Gated Photon Counter / Multiscaler

- 2 Counter Channels
- 800 MHz Count Rate, 32 bit Resolution
- Direct Interfacing to most Detectors
- Multiscaler: Up to 64k Time Channels, min. 250ns / Channel
- Gated Photon Counting: 1.5 ns min. Gate Pulse Width
- Event Storage Mode: Up to 32 k Events
- On-Board Timing and Control Circuitry
- PC-Plug-in-Board
- Parallel Operation of several Modules supported
**Optical Transient Waveform Recording**

The waveform of the light is measured with a channel resolution down to 250ns. Two signals can be recorded simultaneously.

**Recording of Luminescence Spectra**

The luminescence and the excitation light are recorded simultaneously. Corrected excitation spectra are obtained by calculating B/A.

**Single Molecule Detection**

If the count rate inside a programmed time interval exceeds a programmed value, the number of photons and the actual time of the event is stored.

**Gated Detection**

The gate is opened during the laser pulse only. Background events outside the laser pulses are suppressed.

**Gating off Straylight Pulses**

The gate is closed during the laser pulses. The straylight during the laser pulses is suppressed, the fluorescence photons outside the laser pulses are recorded.

**Specification (Typical Values)**

- **Counter Channels**: 2
- **Count Rate (Input Amplitude 50mVss)**: 800 MHz
- **min. Count Pulse Width**: 800 ps
- **min. Gate Width (Input Amplitude 200mVss)**: 1 ns
- **Discriminator Threshold (Count Inputs)**: 0...-1024 mV in steps of 2mV
- **Discriminator Threshold (Gate Inputs)**: -2048mV ... 2048 mV in steps of 8mV
- **Data Width**: 32 bit
- **No. of Memory Channels**: 64 k for each counter channel
- **Time / Channel**: 250 ns to 100 000 s
- **Hardwared Environment**: PC 486 or Pentium with 1 available ISA slot
- **Software Environment**: Windows 3.1, Windows 95, Windows NT
8 to 32 Channel 100 MHz Photon Counter / Multiscaler

- 8 Counter Channels per Module, 32 Counter Channels with 4 Modules
- 100 MHz Channel Count Rate
- 16 bit Counter Resolution
- Up to 32 k Points / Channel
- Multiscaler Operation down to 250 ns / Point
- Gated Photon Counting down to 2 ns Gate Width
- Optional Step Motor Controller for Experiment Control
**Multichannel Optical Waveform Recording**

The waveform of the light is recorded with a channel resolution down to 250ns. Up to eight light signals can be recorded simultaneously in one module.

**Sample Scanning**

A sample is scanned in X-Y direction by two step motors controlled by the STP-240 step motor controller. Up to eight light signals can be recorded in one PMM module.

**Measurement of Luminescence Spectra**

The luminescence and the excitation light are recorded simultaneously. Corrected excitation spectra are obtained by calculating Inp1 / Inp2.

**Gated Detection**

The gate is opened during the laser pulse only. Background events outside the laser pulse are suppressed.

**Specification**

- Counter Channels per Module: 8
- Input Pulse Polarity: positive or negative
- Input Threshold: ± 10 mV to ± 200 mV, Resolution 8 bit
- Minimum Input Pulse Width: 800 ps
- Maximum Count Rate: > 100 MHz
- Counter Resolution: 16 bit
- Memory Channels: 32 k for each counter channel
- Gate Input Pulse Polarity: positive or negative
- Gate Threshold: ± 10 mV to ± 200 mV, Resolution 8 bit
- Minimum Gate Pulse Width: 2 ns
- Time / Point (Multiscaler): 250 ns to 100 000 s
- Collection Time: 200 ns to 100 000 s
- Software: for Windows 3.1 / 95 / 98 / NT

For Detectors, Preamplifiers, Photodiode Modules, Optical Trigger Devices, Step Motor Controllers please see individual data sheets.

**Authorized Agents:**

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800 MHz Gated Photon Counter / Multiscaler

- 2 Counter Channels
- 800 MHz Count Rate, 32 bit Resolution
- Direct Interfacing to most Detectors
- Multiscaler Mode: Up to 64k Time Channels, min. 250ns / Channel
- Gated Photon Counting: 1.5 ns min. Gate Pulse Width
- Event Recording Mode: Up to 32 k Events
- On-Board Discriminators, Timing and Control Logics
- PCI Board, Software for Windows 95, 98, 2000 and NT
- Parallel Operation of Several Modules Supported
Optical Transient Waveform Recording

The waveform of the light is measured with a resolution down to 250ns. Two signals can be recorded simultaneously. Applicable to luminescence decay of inorganic samples, phosphorescence, delayed fluorescence, chemoluminescence, LIDAR.

Recording of Luminescence Spectra

The luminescence and the excitation light are recorded simultaneously. Corrected excitation spectra are obtained by calculating B/A.

Single Molecule Detection

Recording of photon bursts. If the count rate inside a programmed time interval exceeds a programmed value, the number of photons and the time of the event is stored.

Gated Detection

The gate is opened during the laser pulse only. Events outside the laser pulses are suppressed. Exceptionally low background count rate.

Gating off Scattering Pulses

The gate is closed during the laser pulses. Scattered photons during the laser pulses are suppressed, the luminescence photons outside the laser pulses are recorded.

Specification (Typical Values)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counter Channels</td>
<td>2</td>
</tr>
<tr>
<td>Count Rate (Input Amplitude 50mV, peak-peak)</td>
<td>800 MHz</td>
</tr>
<tr>
<td>min. Count Pulse Width</td>
<td>800 ps</td>
</tr>
<tr>
<td>min. Gate Width (Input Amplitude 200mV, peak-peak)</td>
<td>1 ns</td>
</tr>
<tr>
<td>min Trigger Pulse Width</td>
<td>1 ns</td>
</tr>
<tr>
<td>Discriminator Threshold (Count Inputs)</td>
<td>-1 V to +1 V in steps of 4 mV</td>
</tr>
<tr>
<td>Discriminator Threshold (Gate Inputs)</td>
<td>-2 V to +2 V in steps of 16 mV</td>
</tr>
<tr>
<td>Discriminator Threshold (Trigger Input)</td>
<td>-2 V to +2 V in steps of 16 mV</td>
</tr>
<tr>
<td>Input Connectors</td>
<td>MCX, 50 Ω</td>
</tr>
<tr>
<td>Counter Width</td>
<td>32 bit</td>
</tr>
<tr>
<td>No. of Time Bins</td>
<td>64 k for each counter channel</td>
</tr>
<tr>
<td>Time / Bin</td>
<td>250 ns to 100 000 s</td>
</tr>
<tr>
<td>Hardware Environment</td>
<td>Pentium PC</td>
</tr>
<tr>
<td>Software Environment</td>
<td>Windows 95, 98, 2000 or NT</td>
</tr>
<tr>
<td>Dimensions</td>
<td>180 mm x 108 mm x 15 mm</td>
</tr>
</tbody>
</table>

For manual, application notes and software please see www.becker-hickl.de
8 Channel Sample & Hold Module SHM-180

Parallel sampling of signals from PMT arrays, multi-anode PMTs, or photodiode arrays

♦ 8 parallel sampling channels in one SHM-180 module
♦ Up to 32 channels in four parallel SHM-180 modules
♦ On-board sample delay generator
♦ Low noise due to selectable input filtering
♦ Wide, adjustable input voltage range
♦ 12 bit single-shot conversion accuracy
♦ Accumulation of up to 65.535 samples
♦ Accumulation rate up to 1 MS / s
♦ Operation software for Windows 95, 98, NT4 and 2000
8 Channel Sample & Hold Module SHM-180

System Architecture

Signal Channels
- Input Impedance: 1 kΩ or 50 Ω, jumper selectable
- Input Coupling: DC or AC, jumper selectable
- Input Connectors: MCX
- Low Pass Filter: 30 ns - 100 ns - 300 ns - 1 µs
- High Pass Filter: 1 µs - 10 µs - 100 µs - 'off'
- Channel Gain: 1 to 56
- Full scale input voltage: ±45 mV to ±2.5V
- Max. Sample Rate: 1 MS/s
- ADC Resolution: 12 bit

Trigger Input
- Input Impedance: 50 Ω
- Input Coupling: DC
- Input Connector: MCX
- Trigger Threshold: -1 V to +1 V
- Min. Trigger Pulse Width: 1 ns
- Max. Trigger Input Frequency: 100 MHz
- Max. Trigger Rate: 1 MHz

Sample Delay Generator
- Delay Range: 0 to 655 µs
- Delay Step Width: 10 ns
- Delay Jitter: 2.5 ns
- Delay Stability: < 50 ppm

Multi Module Systems
- Number of modules operable parallel: 4

Operation Environment
- Computer System: PC Pentium
- Bus Connector: PCI
- Power Consumption: approx. 10 W at +5V
- Dimensions: PCI card, 235 x 110 mm

Related Products and Accessories
- PMT modules, pin and avalanche photodiode modules, integrating photodiode modules, preamplifiers, step motor controllers, delay generators, programmable pulse generators, ps Diode Lasers, gated and time-correlated photon counters, photon-multiscalers. To control detectors and shutters please see DCC-100 detector controller. Please download or call for individual data sheets and manuals.
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Time-Correlated Single Photon Counting

Time-Correlated Single Photon Counting (TCSPC) is a technique to record low level light signals with ps time resolution. Typical applications are

- Ultra-Fast Recording of Optical Waveforms
- Fluorescence Lifetime Measurements
- Detection and Identification of Single Molecules
- Fluorescence Correlation Spectroscopy (FCS)
- DNA Sequencing
- Optical Tomography
- Photon Correlation Experiments
- Fluorescence Lifetime Imaging (FLIM)
- Fluorescence Resonance Energy Transfer (FRET)

The method has some striking benefits:

- Ultra-High Time Resolution - 25 ps fwhm with the best detectors
- Ultra-High Sensitivity - down to the Single Photon Level
- Short Measurement Times
- High Dynamic Range - Limited by Photon Statistics only
- High Linearity
- Excellent Signal-to-Noise Ratio
- High Gain Stability

TCSPC works best for

- High Repetition Rate Signals
- Wavelength from 160 nm to 1000 nm

Principle of TCSPC Technique

Time-Correlated Single Photon Counting (TCSPC) is based on the detection of single photons of a periodical light signal, the measurement of the detection times of the individual photons and the reconstruction of the waveform from the individual time measurements.

The method makes use of the fact that for low level, high repetition rate signals the light intensity is usually so low that the probability to detect one photon in one signal period is much less than one. Therefore, the detection of several photons can be neglected and the principle shown in the figure below be used:
The detector signal consists of a train of randomly distributed pulses due to the detection of the individual photons. There are many signal periods without photons, other signal periods contain one photon pulse. Periods with more than one photons are very rare.

When a photon is detected, the time of the corresponding detector pulse is measured. The events are collected in a memory by adding a ‘1’ in a memory location with an address proportional to the detection time. After many photons, in the memory the histogram of the detection times, i.e. the waveform of the optical pulse builds up.

Although this principle looks complicated at first glance, it has a number of striking benefits:

- The time resolution of TCSPC is limited by the transit time spread, not by the width of the output pulse of the detector
- TCSPC has a near-perfect counting efficiency and therefore achieves optimum signal-to-noise ratio for a given number of detected photons
- TCSPC is able to record the signals from several detectors simultaneously
- TCSPC can be combined with a fast scanning technique and therefore be used as a high resolution high efficiency lifetime imaging (FLIM) technique in confocal and two-photon laser scanning microscopes
- TCSPC is able to acquire fluorescence lifetime and fluorescence correlation data simultaneously
- State-of-the-art TCSPC devices achieve count rates in the MHz range and acquisition times down to a few milliseconds

**Time resolution**

The TCSPC technique differs from methods with analog signal processing in that the time resolution is not limited by the width of the detector impulse response. Instead, for TSPC the timing jitter in the detection channel is essential. This accuracy is determined by the transit time spread of the single photon pulses in the detector and the timing jitter in the electronic system. When photomultipliers are used as detectors the half-width of the instrument response function (IRF) is usually 10 times shorter than the half width of the detector impulse response. Some typical values for different detector types are given below.
conventional photomultipliers  
standard types 0.6 ... 1 ns  
high speed (XP2020) 0.35 ns  
Hamamatsu TO8 photomultipliers  
R5600, H5783 140 ... 220 ps  
micro channel plate photomultipliers  
Hamamatsu R3809 25 ... 30 ps  
single photon avalanche photodiodes 60 ... 500 ps

Efficiency

Different time-resolved optical signal recording techniques differ considerably in terms of recording efficiency, i.e. in the exploitation of the detected photons. Taking into regard that the available number of photons is limited by the photostability of the sample or by the acceptable acquisition time, recording efficiency is the most important parameter next to time resolution. The efficiency is defined by the ratio of the number of photons actually recorded, \( N_{\text{recorded}} \), and the number of photons seen by the detector, \( N_{\text{detected}} \):

\[
E = \frac{N_{\text{detected}}}{N_{\text{recorded}}}
\]

Since the SNR is proportional to the square root of the number of detected photons the efficiency is also

\[
E = \left( \frac{\text{SNR}_{\text{real}}}{\text{SNR}_{\text{ideal}}} \right)^2
\]

A comparison of the efficiency for TCSPC with one channel and four parallel channels, for single channel modulation techniques with sine wave and square wave modulation, modulated and gated image intensifiers, boxcar, and dual-gate photon counting is given in the figure right. TCSPC features a near-perfect counting efficiency up to a detector count rate of 1 MHz. The reason is that TCSPC does not involve any gating process or gain modulation. Surprisingly, TCSPC beats the other methods in efficiency even for detector count rates of the order of 5 to 10 MHz.

Sensitivity

The sensitivity of the SPC method is limited mainly by the dark count rate of the detector. Defining the sensitivity as the intensity at which the signal is equal to the noise of the dark signal the following equation applies:

\[
S = \frac{(R_d \times N/T)^{1/2}}{Q}
\]

(R\(d\) = dark count rate, \(N\) = number of time channels, \(Q\) = quantum efficiency of the detector, \(T\) = overall measurement time)

Typical values (PMT with multialkali cathode without cooling) are \(R_d=300s^{-1}\), \(N=256\), \(Q=0.1\) and \(T=100s\). This yields a sensitivity of \(S=280\) photons/second. This value is by a factor of \(10^{15}\) smaller than the intensity of a typical laser (\(10^{18}\) photons/second). Thus, when a sample is excited by the
laser and the emitted light is measured, the emission is still detectable for a conversion efficiency of $10^{-15}$.

**Accuracy**

The accuracy of the measurement is given by the standard deviation of the number of collected photons in a particular time channel. For a given number of photons $N$ the signal-to-noise ratio is $\text{SNR} = \frac{1}{\sqrt{N}}$. If the light intensity is not too high, all detected photons contribute to the result. Therefore, TCSPC yields an ideal signal-to-noise ratio for a given intensity and measurement time. Furthermore, in the TCSPC technique noise due leakage currents, gain instabilities, and the random gain mechanism of the detector does not appear in the result. This yields an additional SNR improvement compared to analog signal processing methods.

**Acquisition Time**

The TCSPC method is often thought to suffer from slow recording speed and long measurement times. This ill reputation comes from traditional TCSPC devices built up from nuclear instrumentation modules which had a maximum count rate of some $10^4$ photons per second. Due to a proprietary AD conversion principle the TCSPC devices from Becker & Hickl achieve count rates of several $10^6$ photons per seconds. Thus, 1000 photons can be collected in less than 1 ms, and the devices can be used for high speed applications as the detection of single molecules flowing through a capillary, fast image scanning, for the investigation of unstable samples or simply as optical oscilloscopes.

**Multidetector Capability**

Becker & Hickl have introduced a proprietary TCSPC multidetector technique. Multidetector operation makes use of the fact that at the low light intensities typical for TCSPC the detection of several photons in the same laser period is unlikely.

Thus, the output pulses of several detectors can be combined into one common timing pulse line and sent through the timing and histogramming circuitry of one TCSPC channel. An external ‘Routing’ device determines in which detector a particular photon was detected. This information is used to route the photons from different detectors into different memory blocks of the TCSPC module. As a result, separate histograms build up containing the waveforms for the individual detectors.
Multidetector operation can increase the efficiency of a TCSPC measurement considerably since photons from different wavelength intervals or from different spots of the sample are recorded simultaneously. Moreover, multidetector operation reduces classic pile-up-effects because multi-photon events are recognised and rejected by the routing electronics. Typical applications are optical tomography, multi-wavelength lifetime imaging and single molecule experiments.

**Fluorescence Lifetime Imaging with Laser Scanning Microscopes**

The SPC-730 and SPC-830 modules can be connected directly to a confocal or two-photon laser scanning microscope. The modules employ an advanced three-dimensional TCSPC technique and build up the photon density over the time, t, within the fluorescence decay, the image coordinates, x,y, and the detector number or wavelength, n or \( \lambda \). The principle is shown in the figure below.

The TCSPC module receives the single photon pulses from the photomultiplier (PMT) of the microscope, the reference pulses from the laser and the Frame Sync, Line Sync and Pixel Clock signals from the scanning unit of the microscope. For each PMT pulse, i.e. for each photon, the TCSPC module determines the time of the photon within the laser pulse sequence and the location within the scanning area. These values are used to address the histogram memory in which the events are accumulated. Thus, in the memory the distribution of the photon density over the scan coordinates, x, y, and the time, t, within the fluorescence decay function builds up. The result can be interpreted as a two-dimensional (x, y) array of fluorescence decay curves or as a sequence of fluorescence images for different times (t) after the excitation pulse. Several such arrays exist depending on the number of detector or wavelength channels.

As for the basic TCSPC technique, there is virtually no loss of photons in the TCSPC imaging process. As long as the photon detection rate is not too high all detected photons are processed and accumulated in the histogram, thus providing near-ideal signal-to-noise ratio and maximum sensitivity. This is a key advantage of TCSPC imaging compared to gated photon counting, gated image intensifiers and modulation techniques.
The figure right shows a TCSPC image of a single cell layer (double staining with Hoechst for DNA and Alexa 488) obtained by two-photon excitation at 800 nm in a Zeiss LSM-510 microscope. The intensity image (containing the photons of all time channels) is shown left. Deconvolution analysis delivers the fluorescence lifetime $\tau$ in the individual pixels of the image. This allows to generate intensity-$\tau$ images that display the fluorescence intensity and the fluorescence time as brightness and colour (figure right). The quality of the fit is shown for two selected pixels (right, bottom).

Main applications of TCSPC lifetime imaging are fluorescence quenching, fluorescence resonance transfer (FRET) and the separation of autofluorescence components in cells.

**Simultaneous Lifetime and FCS data acquisition**

Fluorescence Correlation Spectroscopy (FCS) exploits intensity fluctuations in the emission of a small number of chromophore molecules in a femtoliter sample volume. The fluorescence correlation spectrum is the autocorrelation function of the intensity fluctuation. FCS yields information about diffusion processes, conformational changes of chromophore - protein complexes and intramolecular dynamics. These effects can be accompanied by lifetime fluctuations which, of course, should be recorded simultaneously from the same sample volume. The ‘FIFO’ mode of the SPC-630, SPC-134, and SPC-830 modules can be used for such measurements. This mode does not build up a histogram as the TCSPC imaging techniques do. Instead, it records the full information about each photon. Each entry contains the time of the photon in the laser pulse sequence, the time from the start of the experiment, and the detector channel. The data structure is shown in the figure right. For each detector an individual correlation spectrum and a fluorescence decay curve can be calculated. If several detectors are used to record the photons from different chromophores, the signals of these chromophores can be cross-correlated. The fluorescence cross-correlation spectrum shows whether the molecules of both chromophores and the associated protein structures are linked or diffuse independently.
BH TCSPC Modules

BH has developed and manufactures a wide variety of TCSPC modules for different applications. The most common modules are listed below.

<table>
<thead>
<tr>
<th>Module</th>
<th>Count Rate MHz</th>
<th>Saturated 50% loss</th>
<th>Useful</th>
<th>Memory Histogram curves</th>
<th>FIFO Buffer photons</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-300</td>
<td>5</td>
<td>2.5</td>
<td>-</td>
<td>131,072</td>
<td>-</td>
<td>traditional fluorescence</td>
</tr>
<tr>
<td>SPC-330</td>
<td>5</td>
<td>2.5</td>
<td>-</td>
<td>-</td>
<td></td>
<td>lifetime measurement</td>
</tr>
<tr>
<td>SPC-400</td>
<td>8</td>
<td>4</td>
<td>-</td>
<td>262,144</td>
<td>-</td>
<td>fluorescence lifetime, single molecule detection</td>
</tr>
<tr>
<td>SPC-430</td>
<td>8</td>
<td>4</td>
<td>-</td>
<td>262,144</td>
<td>-</td>
<td>multi-parameter measurements FLIM</td>
</tr>
<tr>
<td>SPC-500</td>
<td>3</td>
<td>1.5</td>
<td>-</td>
<td>4,194,304</td>
<td>-</td>
<td>fluorescence lifetime, multi-parameter measurements</td>
</tr>
<tr>
<td>SPC-530</td>
<td>3</td>
<td>1.5</td>
<td>-</td>
<td>4,194,304</td>
<td>-</td>
<td>multi-parameter measurements correlation experiments, stopped flow</td>
</tr>
<tr>
<td>SPC-630</td>
<td>8</td>
<td>4</td>
<td>-</td>
<td>262,144</td>
<td>131,072</td>
<td>fluorescence lifetime, single molecule detection, FCS, correlation experiments optical tomography stopped flow</td>
</tr>
<tr>
<td>SPC-730</td>
<td>5.5</td>
<td>2.25</td>
<td>-</td>
<td>4,194,304</td>
<td>-</td>
<td>fluorescence lifetime, TCSPC imaging, laser scanning microscopy, FLIM, FRET, multi-parameter measurements, correlation experiments, stopped flow</td>
</tr>
<tr>
<td>SPC-134</td>
<td>32</td>
<td>16</td>
<td>-</td>
<td>1,485,576,262,144</td>
<td>262,144</td>
<td>4 fully parallel TCSPC channels, optical tomography, photon migration single molecule detection, FCS correlation experiments, stopped flow</td>
</tr>
<tr>
<td>SPC-830</td>
<td>8</td>
<td>4</td>
<td>-</td>
<td>16,777,216</td>
<td>8,388,608</td>
<td>fluorescence lifetime, TCSPC imaging, laser scanning microscopy, FLIM / FRET, single molecule detection, FCS correlation experiments, multi-parameter measurements, stopped flow</td>
</tr>
</tbody>
</table>

Literature

General


Hidehiro Kume (Chief Editor), Photomultiplier Tube, Principle to Application., Hamamatsu Photonics K.K., 1994

Multi-Detector Operation


General Fluorescence Lifetime


Single Molecule Detection


TCSPC Imaging


Wolfgang Becker, Axel Bergmann, Christoph Biskup, Thomas Zimmer, Nikolaj Klöcker, Klaus Benndorf, Multi-wavelength TCSPC lifetime imaging. BIOS 2002, San Jose, SPIE Proceedings 4620


S. Ameer-Beg, P.R. Barber, R. Locke, R.J. Hodgkiss, B. Vojnovic, G.M. Tozer, J. Wilson, Application of multiphoton steady state and lifetime imaging to mapping of tumor vascular architecture in vivo, BIOS 2002, San Jose, SPIE Proceedings 4620


Optical Tomography


V. Ntziachristos, XH. Ma, M. Schnall, B. Chance, A multi-channel single photon counting NIR imager for coregistration with MRI. BIOS ’97 San Remo


Rinaldo Cubeddu, Antonio Pifferi, Paola Taroni, Alessandro Torricelli, Gianluca Valentini, Compact tissue oximeter based on dual-wavelength multichannel time-resolved reflectance, Applied Optics, 1999, 38, 3670-3680


Multi-Parameter Measurement

R. Brandenburg, K.V. Kozlov, P. Michel, H.-E. Wagner, Diagnostics of the single filament barrier discharge in air by cross-correlation spectroscopy. 53-rd annual gaseous electronics conference, Houston (Texas) 24-27.10.2000

Laser Ranging

### Target Application

- **SPC-630**
  - Standard lifetime experiments,
  - Lifetime imaging, Confocal
  - Two-photon scanning microscopy
  - Multi-parameter experiments
  - Stopped Flow

- **SPC-730**
  - Standard lifetime experiments,
  - Lifetime imaging, Confocal
  - Two-photon scanning microscopy
  - Multi-parameter experiments
  - Stopped Flow
  - Single Molecule Detection
  - Correlation Experiments
  - FCS Experiments

- **SPC-830**
  - Standard lifetime experiments,
  - Lifetime imaging, Confocal
  - Two-photon scanning microscopy
  - Multi-parameter experiments
  - Stopped Flow
  - Single Molecule Detection
  - Correlation Experiments
  - FCS Experiments

- **Time Harp 200**
  - Standard lifetime experiments,
  - Lifetime imaging, Confocal
  - Multi-parameter experiments
  - Stopped Flow
  - Single Molecule Detection
  - Correlation Experiments
  - FCS Experiments

### No. of TCSPC Channels
- **SPC-630**: 1
- **SPC-730**: 1
- **SPC-830**: 1
- **Time Harp 200**: 4

### Modules Operable in Parallel
- **SPC-630**: 4 x SPC-630
- **SPC-730**: 4 x SPC-730
- **SPC-830**: 4 x SPC-830
- **Time Harp 200**: 1 x SPC-134

### Time-to-Digital Converter
- **SPC-630**: 820 fs per time channel
- **SPC-730**: 820 fs per time channel
- **SPC-830**: 820 fs per time channel
- **Time Harp 200**: 40 ps per time channel

### Detectable Lifetimes
- **SPC-630**: 2 ps to 2 µs
- **SPC-730**: 2 ps to 2 µs
- **SPC-830**: 2 ps to 2 µs
- **Time Harp 200**: <100 ps to 4.5 µs

### Dead Time
- **SPC-630**: 125 ns
- **SPC-730**: 180 ns
- **SPC-830**: 125 ns
- **Time Harp 200**: <350 ns

### Continuous Count Rate, Time-Tag Modes
- **SPC-630**: 0.4...0.8 MHz, depends on computer speed and background activity
- **SPC-730**: 3...4 MHz, depends on computer speed and background activity
- **SPC-830**: 0.4...0.8 MHz, depends on computer speed and background activity
- **Time Harp 200**: Depends on computer speed and background activity
### Available Multi-Detector Extension Devices

<table>
<thead>
<tr>
<th></th>
<th>SPC-630</th>
<th>SPC-730</th>
<th>SPC-830</th>
<th>SPC-134</th>
<th>Time Harp 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-Detector</td>
<td>4 MCPs, 4 PMTs</td>
<td>8 MCPs, 8 PMTs</td>
<td>8 APDs</td>
<td>16 Channel PMT Head</td>
<td></td>
</tr>
</tbody>
</table>

### Operating Modes

<table>
<thead>
<tr>
<th></th>
<th>Single Oscilloscope</th>
<th>2 Dimensional $f(x,y,t)$</th>
<th>Sequence $f(t,T)$, $f_i(t,ext)$</th>
<th>Spectrum $f_i(T)$, $f_i(\text{ext})$</th>
<th>Continuous Flow (unlimited seq.)</th>
<th>Time Tag (FIFO)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Experiment Trigger

- Start of measurement
- Start of sequence
- Each step of sequence
- Frame Clock, Line Clock, Pixel Clock

### Free Documentation Available on Website

- SPC Manual: 165 pages; TCSPC Introduction, 5 pages; Upgrading laser scanning microscopes for lifetime imaging; Controlling SPC modules; Protecting Photomultipliers; FRET measurements by TCSPC lifetime microscopy; Multi-wavelength TCSPC lifetime imaging; High count rate multichannel TCSPC for optical tomography; Optical Tomography: TCSPC Imaging of Female Breast; Setting up High Gain Detector Electronics for TCSPC Applications; Testing SPC Modules; 16 Channel Detector Head for TCSPC Modules; Routing Modules for Time-Correlated Single Photon Counting; Detector Control Module DCC-100 Manual; TCSPC Software is available and FREE; Manual: Multi-SPC 32 bit Dynamic Link Library

### Related Products (Own Products Only)

- SPC-300, SPC-330 TCSPC
- SPC-400, SPC-430 TCSPC
- SPC-500, SPC-530 TCSPC
- MSA-100 1ns multiscaler
- MSA-300 5ns multiscaler
- PMS-400 and PMM-328 gated photon counters/multiscalers
- Picosecond Diode Lasers

### Designation Notes

- Free Documentation available on website
- Software is available and FREE
- Multi-SPC 32 bit Dynamic Link Library