CAEN
Tools for Discovery

Present and Future CAEN Instrumentation 2019

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Introduction

• Founded in 1979, for almost 40 years CAEN has been providing Scientists and Engineers with the most advanced electronic instrumentation designed for radiation & low light detectors

• Strong of an extremely close collaboration with the world major research laboratories CAEN is proud to produce the best tools for:
  – High Energy Physics
  – Nuclear Physics
  – Neutrino Physics
  – Astrophysics
  – Dark Matter Investigation
  – Educational
  – Medical Applications
  – Homeland Security
  – Industrial Applications
  – and more ...
Worldwide sales network offices in Italy, Germany, USA, Distributors in more than 30 countries.

Portfolio: > 5000 Customers Include all world leading research centres as:
Europe: CERN, JINR, INFN, CEA, CNRS; GSI, ESO, ISIS, Ganil, PSI, ...
USA: FNAL, SLAC, Los Alamos, BNL, Jlab, ...
Asia: J-Park, KEK, Riken, IHEP, TIFR, ...
Africa: iThemba Labs, ...
And private companies: GE, Siemens, SAIC, L3, Raytheon, Lockheed, Bosch...
High Voltage & Low Voltage Power Supplies
- Multi-Channel CAEN Systems
- Multi-Channel NIM and VME Modules
- Stand-alone Power Supplies
- PCB mountable HV DC-DC converters

Signal Conditioning, Read-out Electronics & Emulation
- Waveform Digitizers & Digital Pulse Processing
- Digital MCA and instrumented PMT bases
- Digital Detector Emulators
- NIM and VME traditional electronics
- Preamplifiers

Powered Crates and Chassis
- Low Ripple Linear NIM powered Crates
- New Hi-End VME64/VME64x Crates

Educational Kit

Partnership

CAEN catalog includes more than 300 product categories (~1000 items)
Power Supplies

CAEN Power Supplies: a perfect blend of tradition and innovation
System Philosophy

Modularity
- Chassis: SY4527, SY5527, SY4527LC, SY5527LC
- CPU Units: Basic, Advanced, Full
- Power Units: Primary, Boosters
- Accessories: LCD Touchscreen, Wi-Fi, Advanced SW

Connectivity
- Control based on new CPU modules either Remote via Ethernet and Wi-Fi or Local via touchscreen LCD

Usability
- New Software tools have been designed to set and monitor all the parameters. Advanced features for Alarming, Logging and Scripting

Compatibility
- The new backplane is fully compatible with SY1527/2527 HV/LV Boards and Branch Controllers
CAEN introduces a large number of completely new families of both Low Voltage and High Voltage Multichannel Power Supply Boards for the new Universal Multichannel Systems.

The Boards have been divided by Maximum Output Voltage as follows:
- Low Voltage Family (up to 15V)
- Up to 500 V Family
- Up to 4 kV Family
- Up to 8 kV Family
- Up to 15 kV Family

Many channels available on each board: 6, 8, 12, 24, 32, 36, 48 in order to fit fine for any application.
VME HV Boards Family
V6519, V6533, V6534, V6521, V6521H

Overview
- 6 channels in 1 VME Unit
- From 500 to 6 kV, from 20 µA to 3 mA
- Common Floating Return
- SHV connectors
- Voltage ripple < 3 mVpp
- Internal Hardware protections
- Available with positive, negative or mixed polarity

Thanks to the GECO2020 control software and the multimaster capability of CAEN VME Bridges, CAEN VME HV power supplies become a System:
DAQ and HV in the same VME crate independently controlled!
NIM and NDT HV Boards Family
N14xx, NDT14xx and N14xxET

Overview:
- 4/2/1 channels in 1 NIM Unit
- From 500 to 8 kV, from 20 µA to 3 mA
- Common Floating Return
- SHV connectors
- **Voltage ripple** < 5 mVpp
- Internal Hardware protections
- Independently selectable channel polarity
- Local and Remote control
- **Now also with Ethernet connection!**
- 2.8” color touch screen display (only NDT)
- 110-220 Vac plug for desktop operation (Only NDT)
NIM 8 ch Boards Family
N803X

Overview:
• 8 independently controllable HV channels
• Very low ripple
• Four versions from 100 V up to 6kV, and from 1 mA to 10 mA
• BNC output connectors for the 100 V version and SHV coaxial connectors for the others
• Local control with a 2.8” touch screen display
• Remote control via Ethernet or USB 2.0
• Common ground
• Polarity P/N/M
• Autonomous cooling
• Interlock logic for board enable and individual channel kill
• The 100 V version has:
  ➢ Temperature probe input for SiPM gain stabilization (single/multi slope corrections)
  ➢ Fast recovery output
Rack-mountable HV Boards Family
R1419ET, R1470ET, R1471ET, R1471HET

Overview:

- 4/8/16 channels in 2U, 19” rack unit
- 2.8” color touch screen display
- 110-220 Vac plug for desktop operation
- from 500 to 8 kV, from 20 µA to 3 mA
- Common Floating Return
- SHV connectors
- Internal Hardware protections
- Independently selectable channel polarity (16ch version P/N/M)
- Local and Remote control (USB/Ethernet)
Solution for small setups: Desktop HV Boards Families
DT55xxE, DT14xxET, DT547x

Overview:
• 4/8 channels in desktop module
• from 0 V to 100V, up to 10mA (DT8031E)
• from 500 V to 8 kV, from 20 µA to 3 mA (DT14xxET)
• Common Floating Return
• SHV connectors
• Available with positive, negative or mixed polarity
• DT14xxET with individually selectable polarity
• Local and Remote control (USB/Ethernet)
• Individual channel enable
• 2.8” color touch screen display (DT14xxET)
• 110-220 Vac plug for desktop operation (DT14xxET)
• Independently selectable channel polarity (DT14xxET)

DT5485P
• 85 V/10 mA Digital Controlled SiPM Power Supply with USB
HiVolta

1kV/1mA 8 Ch HV Floating Stackable Power Supply
with Ethernet & Touchscreen

Features
- 8 independent HV channels
- Channels are reversible, fully floating up to 5 kV each and stackable in one or more groups
- SHV coaxial output connectors (3 for each channel) for easy channel-to-channel interconnection using standard SHV-SHV cables
- Synchronous or ordered ON/OFF/KILL operation of selected channels
- Dual Range Current monitoring with up to 100 pA resolution
- Very Low Ripple: typical < 5 mVpp
- Ramp-Up/Down rates independently programmable in the range 1÷100 V/s in 1 V/s steps
- Under/overvoltage alert, overcurrent and max. voltage protection
- Interlock logic for unit enable and individual channel kill
- Local control with 2.8” color touch screen display
- Remote control with USB2.0 / Ethernet connections

Simply the best Power Supply for your laboratory
A750x
PCB High Voltage Power Supply Family

A7501 1 Ch 2100 V/100 µA High Efficiency HV Power Supply Module
A7502 1 Ch 2100 V/100 µA High Efficiency HV Power Supply Module (5V in)
A7504 1 Ch 4 kV/100 µA High Efficiency HV Power Supply Module
A7505 1 Ch 1600 V/500 µA High Efficiency HV Power Supply Module
A7508 1 Ch 800 V/50 µA High Efficiency HV Power Supply Module (5V in)
A7560 2 Ch ±6000 V/10 µA High Efficiency HV Power Supply Module with Digital Control
A7585D 1 Ch. +85 V/10 mA Digital Controlled SiPM Power Supply
A7585DU 1 Ch +85 V/10 mA Digital Controlled SiPM Power Supply with USB
A864  +2100 V High Efficiency Power Supply Module

A7585x
A compact and reliable solution for your SiPM array
Modular Fast Pulse Electronics

CAEN Modular Pulse Processing Instrumentation: from traditional chains to digitization
A wide selection of multichannel waveform digitizers:

- From 1 to 64 channels
- From 62.5 MS/s to 5 GS/s
- From 8 to 14 bits
- Available in NIM, Desktop, VME
<table>
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<th>Model</th>
<th># channels</th>
<th>MS/s</th>
<th># bit</th>
<th>HV</th>
<th>LV</th>
<th>Wave</th>
<th>ZLE</th>
<th>DAW</th>
<th>PHA</th>
<th>PSD</th>
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730/725 Digitizer Family
14-bit 500/250 MS/s Digitizer

Overview:
- VME64/VME64X (16 ch.), NIM (8 ch.) and Desktop (8 ch.) modules
- 0.5 and 2 Vpp selectable input dynamic range
- VME64/VME64X, USB and Optical Link communication interfaces
- Multi-board synchronization features
- Daisy chain capability
- Demo software tools, DPP Control Software, C and LabVIEW libraries
- Algorithms for Digital Pulse Processing
  - Pulse Height Analysis (DPP-PHA)
  - Pulse Shape Discrimination (DPP-PSD)

Outstanding performance
742 Digitizer Family
12-bit 5/2.5/1 GS/s Switched Capacitor Array Digitizer

Overview:
• 1024 samples per event
• VME64/VME64X (32 ch.), NIM (16 ch.) and Desktop (16 ch.) modules
• Special analog inputs for fast trigger
• 1 Vpp input dynamic range with programmable DC offset
• VME64/VME64X, USB and Optical Link communication interfaces
• Multi-board synchronization features
• 16 programmable LVDS I/Os
• Daisy chain capability
• Demo software tools, C and LabVIEW libraries

Based on DRS4 chip (PSI)
743 Digitizer Family
12-bit 3.2/1.6/0.8/0.4 GS/s Switched Capacitor Array Digitizer

Overview:
• 1024 samples per event
• VME64/VME64X (16 ch.), NIM (8 ch.) and Desktop (8 ch.) modules
• 2.5 Vpp input dynamic range with programmable DC offset
• One discriminator per channel with programmable threshold
• Adjustable post-trigger delay (up to 1.25 µs @ 3.2 GS/s)
• One pulser per channel
• On-board charge calculation for fast histogramming
• VME64/VME64X, USB and Optical Link communication interfaces
• Oscilloscope software tools, C and LabVIEW libraries

Based on SAMLONG chip
(CEA/IRFU&IN2P3/LAL)
CoMPASS
Multiparametric DAQ Software for Physics Applications

Software for simultaneous DPP acquisition: PHA, PSD, CI, QDC

- Multi-board management
- Synchronization of multiple boards even from different families
- Correlation between different channels
- Simultaneous plot of waveform, energy, time, PSD, and TOF spectra
- Energy calibration
- Digital CFD for fine time stamp interpolation (pico second intrinsic resolution)
- Selectable filters on energy, PSD, and Time
- Data can be retrieved offline to make additional filters and analysis
- ROOT format data saving

Supporting 724, 725, 730, 751 Families and DT5790
Coming soon support for DT5780 & V1740D with DPP-PHA
Digitizers 2.0: the new digitizer line from April 2020

**Motivation**

- More density, faster sampling rate, higher resolution => improved performance
- Increase readout bandwidth: from 1 to 10 Gbit/s
- Communication through standard Interfaces: 1/10 Gb Ethernet, USB 3.0 (yet keeping proprietary CONET)
- Make the synchronization easier (clock and timing distribution)
- Increase memory size: from SSRAM to DDR4 (=> from MBs to GBs)
- Renovating obsolete components
- Single FPGA (Zync US+) architecture => more resources for DPP algorithms and support for “Open FPGA”
Digitizers 2.0: Roadmap

First New Digitizer will be the

V2740: 64 ch, 125 MS/s, 14 bit
- Replace V1740
- Possibility to implement 64 MCAs (PHA firmware) for high channel density spectroscopy solutions
- Good fit for Neutrino and Dark Matter experiments (For Dark Side Experiment in Gran Sasso)

Then the other will be

V2751: 16 ch, 1 GS/s, 14 bit
- Replace V1751
- Potential upgrade up to 2.5 GS/s
- Ultra fast detectors (diamonds, MCPs, SiPMs) with ps timing applications

V2725/V2730: 16 ch, 250/500 MS/s, 14 bit
- Replace V1725/V1730/V1720
- Optimal trade-off between cost and performances
- Covers most applications with medium-fast detectors
- Sub ns timing combined with high energy resolution

V2724: 32 ch, 125 MS/s, 16 bit
- Replace V1724 (mainly for spectroscopy & MCA)
- Advanced Front-End (programmable gain, shaping, AC or DC coupling, etc...)
- Best suited for semiconductor detectors (HPGe, Clover, SDD...)
- Typically connected to Charge Sensitive Preamplifiers
Spectroscopy Solutions

CAEN introduces complete Digital Systems for X-ray, Gamma Spectroscopy and other applications
DT5780/DT5781
Dual/Quad Digital Multi Channel Analyzer

DT5790
Dual Digital Acquisition System for Charge Integration and Pulse Shape Discrimination

DT5770
Compact Digital Multichannel Analyzer

MC² Analyzer (MC²A)
Graphical software tool for digitizers running DPP-PHA firmware

Coming Soon
- Fully integrated, digital MCA operating in PHA mode (up to 32k), Time stamped List mode, MCS\(^*\), SCA\(^*\), Multi-PHA\(^*\).
- Suitable for HPGe, Si, NaI, CsI, LaBr\(_3\), CdTe, CZT and other detectors. Accepts RC and TRP preamps and PMT anode signals.
- Embedded Linux (ARM) for unattended acquisition, data logging (SDD), user programmable routines (SDK provided).
- Triple range HV: 5kV/20\(\mu\)A (HPGe mode), 2kV/1mA (PMT mode), 500V/50\(\mu\)A (Si mode) positive/negative.
- 10/100T Ethernet and USB 2.0 interfaces. OLED Display. Configurable digital I/Os and Sync bus.
- Coincidence and Anti-Coincidence mode (e.g. Anti-Compton or Background Active Shields)
From Digital MCA to Digital Portable Instruments

- Fully stand-alone MCA including high voltage power supply, preamplifier, battery and data-storage on SSD
- Embedded computer (ARM based CPU) for unattended operations
- Wired and wireless connectivity through USB, Ethernet, Bluetooth and WiFi
- Compatible with scintillation detectors using standard 14-pin PMTs
- Different acquisition modes available: PHA, PHA with time stamp, MCS, SCA and waves
- Software selectable coarse and fine gain
- Front panel auxiliary digital I/O connectors for synchronization, external trigger, coincidence/anticoincidence modes, veto. MCS, SCA

γ stream is an active, stand-alone, fully featured MCA tube base for scintillation spectroscopy
i-Spector Digital

Intelligent Silicon Photomultiplier Tube with Digital MCA

- Replace existing systems where PMT where used
  - Lighter and Stronger
  - No HV required
  - Smaller: in 11cm x 5cm integrate HV and processing
  - No external electronics required:
    - Integrated PHA
    - Integrated TDC
    - Integrated PSD (coming)

- Best solution for new physics experiment
  - 0.5/0.75/1-inch standard sensor size
- Standard scintillator size:
  - 12x12x30 mm3
  - 18x18x30 mm3
  - 24x24x30 mm3 (nearly 1 in3)
- Can be coupled to NaI(TI), CsI(Ti), BGO, Lyso, LaBr
- Configurable onboard logic can replace external logic in several applications like trigger, veto systems, time tagging, time of flight spectrum
- Operate in strong magnetic field

- Radiation Monitoring Network
  - Integrated MCA with basic onboard isotope identification algorithm
  - Wireless communication with integrated LORA mode
V1782: octal digital MCA (32k)

- Based on V1724: 8 channel, 14 bit, 100 MS/s digitizer
- VME version (2U wide) of the DT5781
- BNC inputs (1 kΩ)
- Coarse gain (analog): x1, x2, x4, x8 software selectable (0.125, 0.25, 0.5, 1 Vpp)
- Dual range (jumper selectable): x1, x5
- AC/DC coupling (jumper selectable) => supports Transistor Reset Preamplifiers
- DPP-PHA firmware (Time stamped List Mode, Oscilloscope mode)
- Improved PHA and trigger algorithms (inherited from Hexagon)
- Coincidence/Anti-coincidence between channels. Ext Triggers (in and out, global and individual), veto, gate
- Supported by MC2-Analyzer and CoMPASS
- Best suited for Clover, Segmented Si/Ge detectors
V1741/DT5741: 64/32 ch, 16K peak sensing ADC

- Based on V1740: 64 channel, 12 bit, 62.5 MS/s digitizer
- Modified input stage: 4Vpp, 1 kΩ (3.75 Vpp with sliding scale enabled) or 8 Vpp (default) SW selectable
- Conversion Gain: 1k, 2k, 4k, 8k, 16k
- Almost dead timeless (< 100 ns between gates)
- Accepts negative and positive signals
- Sliding scale (1/16 of the FSR) to reduce DNL (~1% @ 4K, t.b.d.)
- Very good INL: <0.05% over 99% FSR
- Multi Event Buffer (1K events per channel)
- Zero Suppression with programmable threshold
- Dedicated input for Event Rejection (PUR, Veto, etc...)
- Three operating modes:
  - External common gate
  - External common trigger (gate generated internally with a programmable window)
  - Independent self-triggering channels (future development on request)
- Cable adapters for ERNI connector: 32 LEMO cables or two 34 wire ribbon cables (coming soon)
- Works with N1068/N568
V2495/DT5495: user programmable logic unit

- FPGA based Logic and Trigger Unit with customizable firmware
- Up to 162 inputs, up to 130 outputs LVDS/ECL/PECL/NIM/TTL
- Three expansion slots for digital I/Os and DACs
- VME, USB2 and Ethernet\(^{(1)}\) interfaces
- 32 programmable Gate & Delay lines
- **Sci-Compiler:** Automatic VHDL generation starting from logic blocks and virtual instruments
- Typical applications:
  - Complex Trigger/Coincidence Logic (typically with Digitizers)
  - Counters (Scalers) or Time stampers
  - Low resolution TDCs (~ 0.5 ns)
  - Replacement of NIM units (AND, OR, Timer, Fan In-Out, Translators)
  - Programmable I/O register
  - Pattern recorder/generator
  - Threshold setting

\(^{(1)}\) VME, USB2, and Ethernet interfaces are optional.
Partnership
CAEN is the **worldwide distributor** of the Weeroc ASICs

Weeroc is a spin-off company from Omega laboratory (IN2P3/CNRS, french governmental agency for fundamental research in astrophysics, particle physics and nuclear physics). Weeroc designs and provides analogue and mixed ASICs for industry and research.

**Applications:**

- Medical imaging
- Homeland security
- Nuclear protection
- Scientific instrumentation
- Space (launchers and satellites)
CATIROC is a 16-channel front-end ASIC designed to readout photomultiplier tubes (PMTs) in large scale applications such as Water Cerenkov experiments.

CITIROC is a 32-channel front-end ASIC designed to readout silicon photo-multipliers (SiPM). *Used in the A1702/DT5702*

MAROC3 is a 64-channel chip designed to readout negative fast input current pulses such as those provided by Multi Anode Photo Multipliers.

PETIROC2 is a 32-channel front-end ASIC designed to readout silicon photomultipliers (SiPMs) with both polarities for particle time-of-flight measurement applications.

SKIROC2 is a 64-channel front-end ASIC designed to readout silicon PIN diodes.

CAEN will also provide an **evaluation board** based on the DT5550.
DT5550W : ASIC Based Digital Acquisition system

- PIGGY BACK BOARD
- MOTHERBOARD
- LEMO I/O
- USB 3
- FPGA with OPEN SOURCE FIRMWARE

Supported by:
DT5550W + PETIROC PIGGY-BACK:

- Up to 128 channels
- Multiple boards can operate synchronized in order to extend channel count
- Provide Bias to SiPM between 20 and 85V 10mA individually regulable
- Amplification and programmable shaping of the SiPM output
- Discriminator with independent threshold for each channel
- Integrated TDC with 75 ps resolution
- Charge measurements with 1024 channels energy spectrum generation
- Configurable trigger logic:
  - Or of all channels also between different ASICs
  - Or of all channels of an ASIC
  - Specific channel
  - External trigger
  - USER CONFIGURABLE TRIGGER/COINCIDENCE LOGIC USING SCI-COMPLIER
- USB 3 fast readout
- Monitor of digital/analog probe signal with on-board ADC
DT5702: 32 channels SiPM readout system based on CITIROC

- Provides bias voltage in the range of 20-90 V individually adjustable for each of 32 SiPMs
- Amplification and shaping of the SiPMs output pulse on each of 32 channels
- Discrimination of shaped signal at configurable level from 0 to 50 SiPMs photo-electrons
- Ethernet communication
**FERS Distributed Front End Readout System**

- Front End Preamplifiers, A/D conversion and data processing in small **FE card**
- **TDlink**: synchronization, readout and slow control over optical fibers
- Concentrator Board: provides global synch + data sorting, formatting and storage for up to 128 FERS cards
- Easy scalability to thousands channels
- Reduced cable cost, noise pickup, signal attenuation, bulkiness, contact failures...

![Diagram of FERS units and TDlink network](image)
FERS Distributed Front End Readout System

Concentrator Board

USB3.0, 1/10 GbE

Stand-alone FERS unit

1 GbE

up to 128 FERS units with a single Concentrator

Detector Array

up to 8192 channels

FERS units
FERS Distributed Front End Readout System

- **FERS unit**: single card housing Front End ASICs, ADC and/or TDC, FPGA, I/Os, interfaces and, in some cases, detector power supply
- **FERS communication interfaces**: TDlink (sync + commands + data) or Ethernet, USB 2.0 (data only, mainly used for evaluation)
- Auxiliary I/Os for sub-ns timing and low latency trigger distribution (alternative to TDlink)
- Different FERS units will be part of a unique **family**, all sharing the same architecture and readout protocols
- **A5202**: first member of the family, based on **Citiroc-2A** (by Weeroc). 64 channel readout for SiPMs.
- Potential future developments:
  - **Maroc** (PMTs)
  - **Petiroc** (SiPM readout with high timing resolution)
  - **Sampic** (10 GS/s SCA waveform digitizer and ps TDC) from LaL, D. Breton
  - **AARDVARC** (13 GS/s) and **ASOC** (3.2 GS/s) SCA waveform digitizer and ps TDC from Nalu Scientific
  - Digital readout for discrete components preamps (e.g. **A1442**, 16 channel preamp for Silicon Strip Detectors)
  - and others...
Thank you!

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