Demonstration of a simple experimental setup using fast electronics

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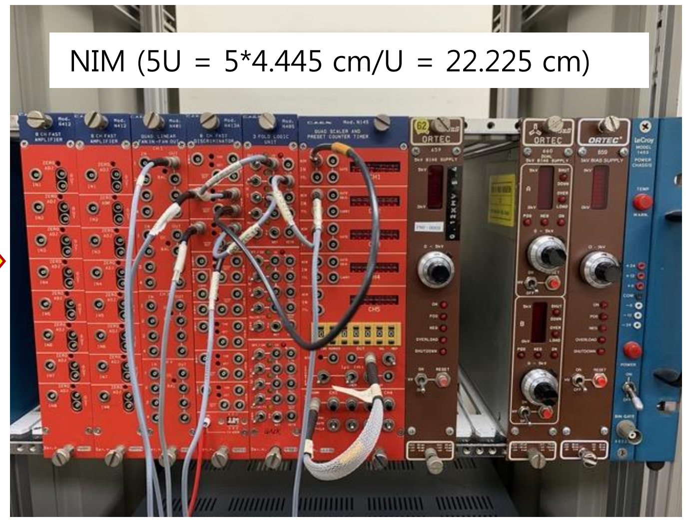
RISP/IBS

BICRON BC408 + PMT



CAEN (www.caen.it)
N412 8ch Fast amplifier
N401 Quad Linear Fan-in Fan-out
N413 8ch Fast discriminator
N405 Triple 4-fold logic unit
N145 Quad scaler and counter timer

ORTEC (www.ortec-online.com)
659 5kV Bias supply
660 Dual Bias supply

LeCroy Research Systems
(https://teledynelecroy.com/lrs/dsheets/dslib.htm)
1403 Power chassis

TEST SETUP: Scintillation counter

J. PHYS. A: GEM. Phys. 1 584 (1968), I. S. Jones et al,
Ionization energy loss of muons in a plastic scintillator

BICRON BC408 + PMT
(or Voltage Divider)

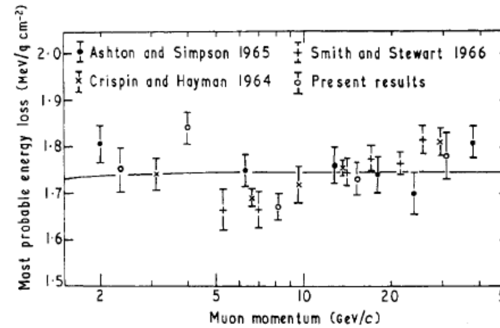
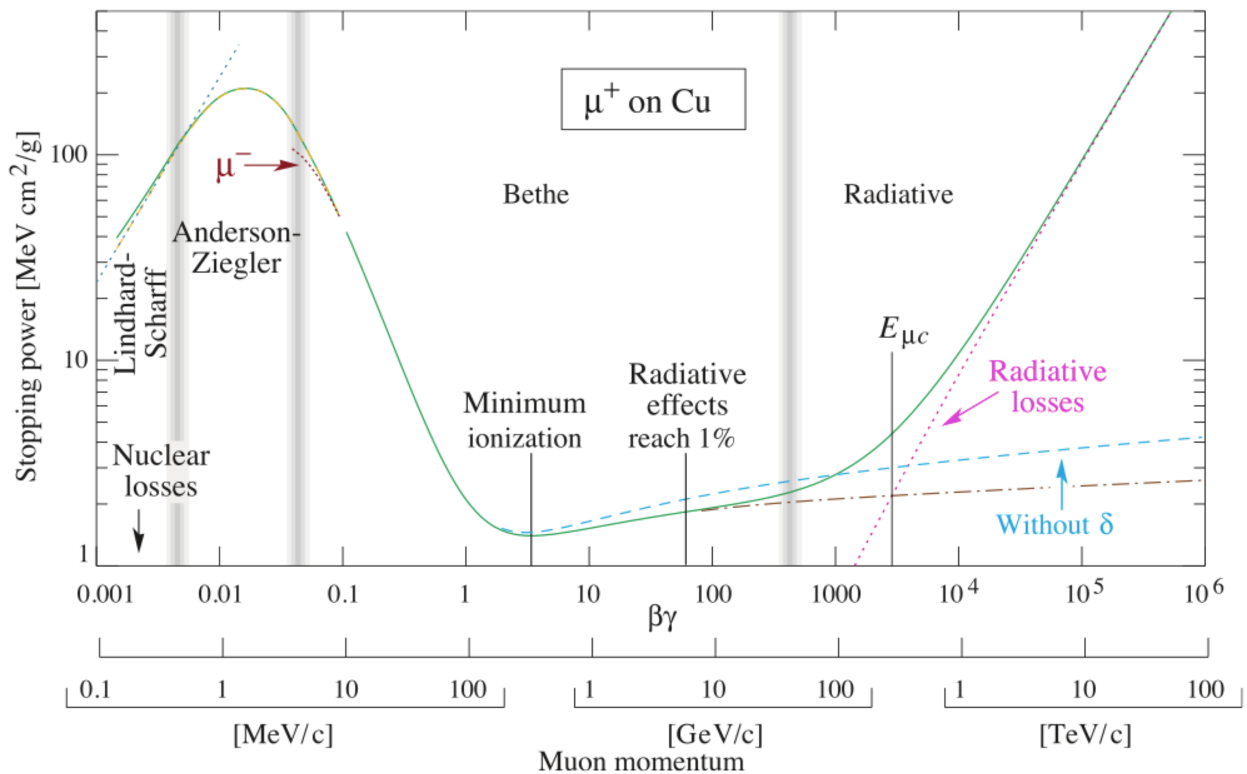


Figure 3. The results of Ashton and Simpson (1965), Crispin and Hayman (1964), Smith and Stewart (1966) and the present work, showing the consistently observed increase in energy loss over the momentum range 5–30 GeV/c.

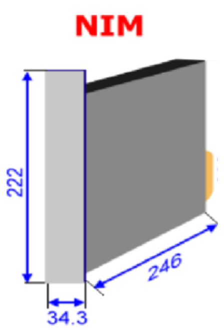


TEST SETUP: NIM bin/crate

Nuclear Instrumentation Module (NIM): mechanical and electrical specifications for electronics modules used in experimental particle and nuclear physics.

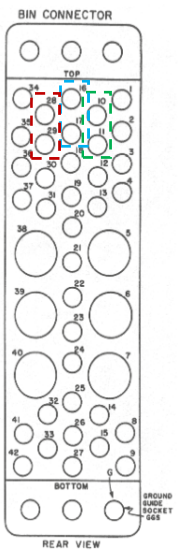
First defined by the U.S. Atomic Energy Commission's report TID-20893 in 1968-1969, NIM was most recently revised in 1990 (DOE/ER-0457T).

Output voltage: ±6V, ±12V, and ±24V DC
Size: H222xW34.3xD246 mm (except backplane power connector)



NIM standard module connector pins

Pin #	Function	Pin #	Function
1		2	
3		4	
5		6	
7		8	
9		10	+6 V
11	-6 V	12	
13		14	
15		16	+12 V
17	-12 V	18	
19		20	
21		22	
23		24	
25		26	
27		28	+24 V
29	-24 V	30	
31		32	
33	117 Vac (hot)	34	Power Rtn Gnd
35		36	
37		38	
39		40	
41	117 Vac (neutral)	42	High Quality Gnd
G	Gnd Guide Pin		



LeCroy Research Systems
(https://teledynelecroy.com/lrs/dsheets/dslib.htm)
1403 Power chassis

Input voltage: 115/230 VAC ± 19% at 47-65 Hz

Operating range: 5-60 ℃

Max. power: 200 W

Output voltage (max. current):
±6V (10 A) DC
±12V (6 A) DC
±24V (2 A) DC

Ripple: 3 mV peak-to-peak (50 MHz bandwidth)

Regulation: ±(0.01% + 0.5 mV) line or load

Temperature coefficient: <100 ppm/℃

Long term stability: <0.1%/day at constant load temperature. Measured after 1 hour warm-up.

Response time: settles to within 0.1% of final value in less than 50 μs for 10-100% load change

TEST SETUP: High Voltage Power Supply (HVPS)

ORTEC (www.ortec-online.com)
659 5kV Bias supply

±6 V ±12 V

Bias voltage ranges: 0~5 kV, or 0-500 V, on separate outputs

Bias voltage polarity: Positive or negative, internally selectable

Rated output current: 0-100 μA (?)

Output linearity: within ±3% of dial setting in range (10-100%)

Temperature sensitivity of output voltage: < ±0.08%/℃ in 10-50 ℃

Voltage stability: <±0.1%/h variation in output voltage with constant temperature, constant load, and constant input voltages from the NIM bin

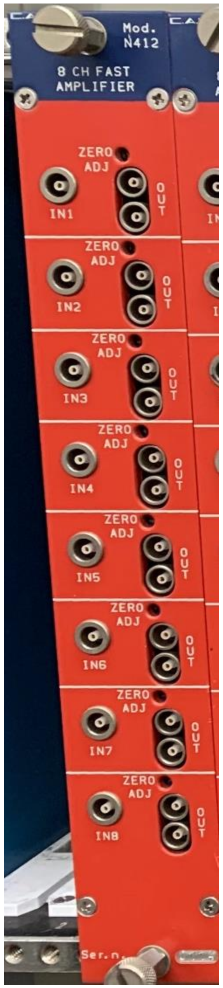
Noise and ripple: <10 mV peak-to-peak in range (2 Hz – 50 MHz)

Output voltage rise time: normally 500 ms

Bias shutdown input: Rear-panel **BNC connector** accepts signals from warmup sensors in cooled germanium detectors. When a warmup is signaled, **this input turns off the detector bias voltage** in order to protect the preamplifier FET input. The **ORTEC/TTL/ BYPASS jumper selects** the operating mode of the BIAS SHUTDOWN input for compatibility with the warmup sensor in the associated Ge detector.

660 Dual Bias supply

TEST SETUP: Amplifier



CAEN (www.caen.it)
N412 8ch Fast amplifier

2.1 PACKAGING

1-unit wide NIM module.

2.2 EXTERNAL COMPONENTS

CONNECTORS:
- No. 8 LEMO 00 type "IN1..IN8". Input connectors 1 to 8.
- No. 16 LEMO 00 type "OUT". Output connectors 1 to 8 (two per channel).

TRIMMERS:
- No. 8 screwdriver trimmers "ZERO ADJ" (one per channel). For the output offset adjustment.

2.3 CHARACTERISTICS OF THE SIGNALS

INPUTS:
- 50Ω impedance.
- Reflection coefficient: ≤ 6% over input dynamic range.
- Quiescent voltage: < ± 5 mV.

OUTPUTS:
- Risetime: ≤ 3.0 ns.
- Falltime: ≤ 2.0 ns.
- Maximum positive amplitude (linear): 400 mV (50Ω impedance).
- Maximum negative amplitude (linear): -4 V (50Ω impedance).
- Overshoot: ± 10% for input risetimes of 2 ns and with the 2nd output terminated in 50Ω.
- Quiescent voltage adjustable (via front panel trimmer for each channel) in the range from -20 mV to +50 mV.

GENERAL:
- Gain: fixed 10 ± 3%, non-inverting.
- Coupling: direct.
- I/O delay: ≤ 12 ns.
- Noise: less than 1 mV, referred to input.
- Interchannel crosstalk: better than -56 dB in the worst test condition, and with both the outputs of the tested channel terminated in 50Ω.
- Bandwidth:
  - 160 MHz (with both the channel's outputs terminated in 50Ω);
  - 180 MHz (single ended output).

2.4 POWER REQUIREMENTS (quiescent conditions)

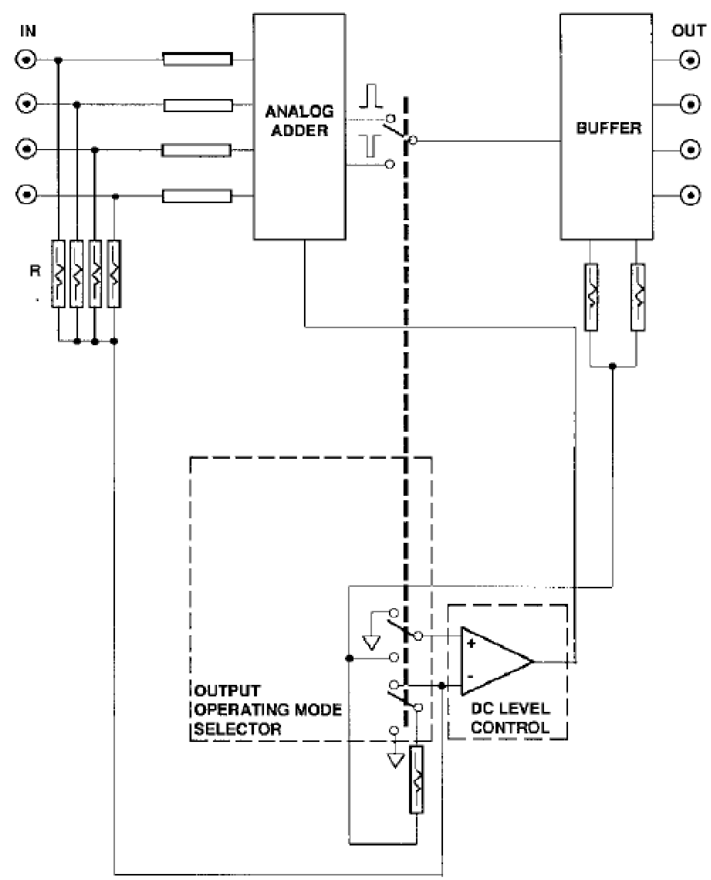
+ 12 V at 400 mA
- 12 V at 300 mA.

TEST SETUP: Fan-In Fan-Out

CAEN (www.caen.it)
N401 Quad Linear Fan-in Fan-out

Single input → 4 identical output signals (±1 x Gain)

Several inputs → output signals (sum of all input's amplitude)



Single width NIM module

Power requirements
+12 V at 750 mA, -12 V at 750 mA
+6 V at 550 mA, -6 V at 330 mA

Bandwidth
For small signal, DC to 170 MHz, at -3 dB with and inputs of 0.1 $V_{P\text{-}P}$ and the unused outputs (50 Ω termination)
For large signal, DC to 110 MHz, at -3 dB with and inputs of 2 $V_{P\text{-}P}$ and the unused outputs (50 Ω termination)

4 independent sections

INPUT: negative, positive, or bipolar
DC-coupled linear signal, linear range ±1.5 V
Impedance: 50 Ω ± 1%
Reflection: less than 10% for inputs of 2 ns rise time
DC level: less than ±2 mV

OUTPUT: integral non linearity: ±1% up to 1 V
dynamics ±1.5 V
rise/fall time: <=2.5 ns in 10-90% of outputs
(unused = terminated in 50 ohm)
Gain: 1.0±2% in the linear range
Crosstalk: better than 40 dB
noise: <=300 μV RMS
Stage delay: <= 7 ns

4 input/output connectors per a section: LEMO 00 type

DC BAL: external screwdriver trimmer
adjust output offset within ±100 mV

Inverting or non inverting mode: internal 3-jumper switch

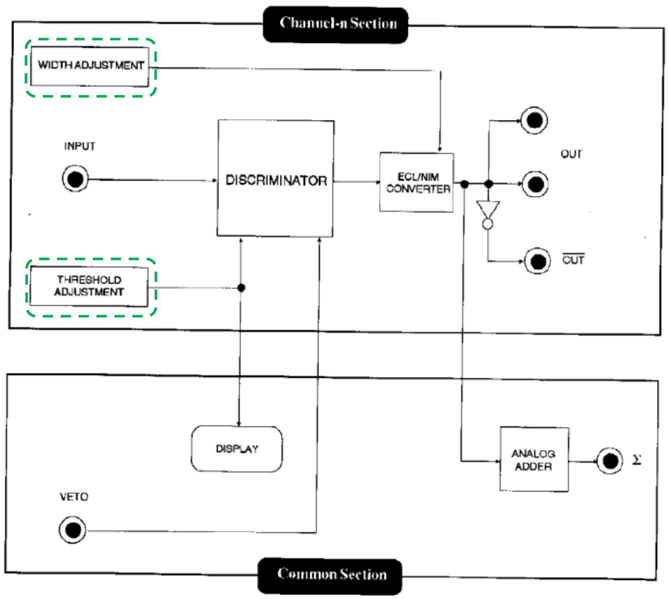
Both the input and output signals are DC coupled, with no duty-cycle limitation.

Input/Output delay: < 11 ns

TEST SETUP: Discriminator

CAEN (www.caen.it)
N413A 8ch Fast discriminator

Analog or digital inputs → threshold & width → NIM pulse



150 MHz maximum operating frequency

Adjustable output width per channel

Thresholds independently adjustable via front panel trimmer and 3 digit voltmeter

Common VETO input

Current Sum output

Single width NIM module

8 independent non-updating discriminator

For each channel chosen by three DIP switches on the front panel,
Threshold: -20 mV to -1 V via front panel trimmers
display value on front panel
Output width: 5 ns to 150 ns via front panel trimmer.

two NIM outputs per channel
normal logic and 1 NIM output in complementary logic

"SCOMM": analog output which supplies a current of -2 mA per channel over the relevant threshold.

A common VETO input signal disables the output signals of all the channels.

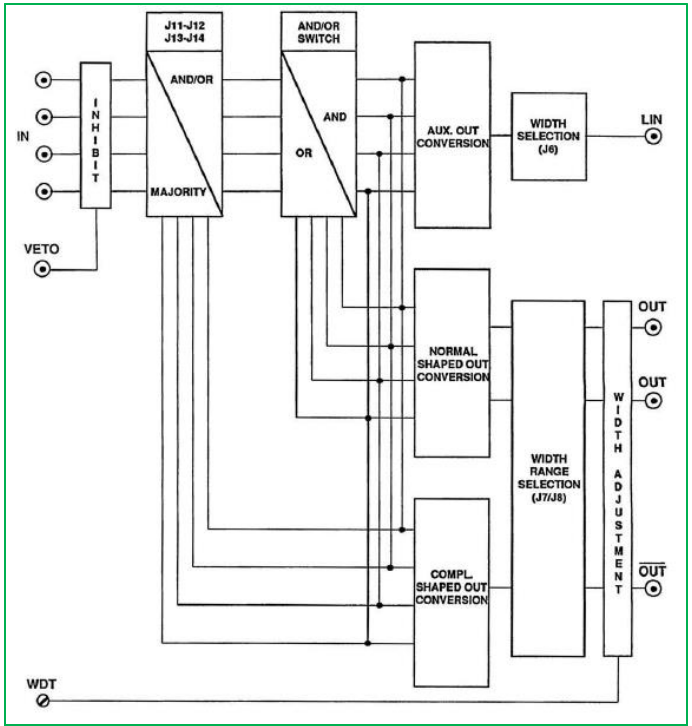
INPUTS: 50 ohm impedance
Polarity: Negative
Max. Input: 0 to -3.5 V
Max. Frequency: 150 MHz
Min. VETO Width: 3 ns

OUTPUTS: Std. NIM level.
Rise/Fall Time: 2.5 ns
Width: adjustable in the range 5 ns to 150 ns
SCOMM: - 2 mA for each channel over threshold

TEST SETUP: Logic Unit

CAEN (www.caen.it)
N405 Triple 4-fold logic unit/Majority with VETO

AND or OR logic with digitized pulse (ex, NIM pulse)



Three independent sections with 4 standard NIM inputs each

AND, OR, MAJORITY function selectable for each section

One auxiliary NIM output per section whose width is equal to the coincidence duration

NIM shaped outputs with Fan Out of two

One negated NIM shaped output per section

One VETO input per section

Front panel trimmer for output width adjustment on each section

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Single width NIM module

Three independent sections

Logic unit or majority selectable via internal DIP switches

For each section,
4 input signals
4 outputs (2 normal and 1 complementary, shaped, plus 1 linear)
1 VETO input

Linear output (same time width of input signals)

Shaped output widths: 6 ns to 800 ns

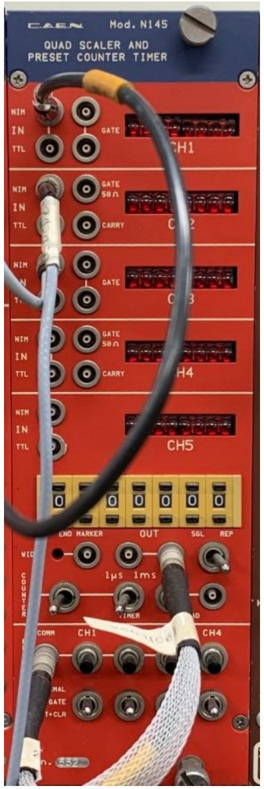
LOGIC UNIT MODE
The input signals can be disabled by means of a front panel lever switch.
Each section can be programmed to perform either the AND or the OR functions via front panel switches.
When only one input signal is enabled the section acts as a logic FAN-OUT independently from the selected mode.

MAJORITY MODE
The front panel enable/disable lever switches are used to set the majority level.
The AND/OR lever switch must be set in the AND position.

TEST SETUP: Scaler and counter timer

CAEN (www.caen.it)
N145 Quad scaler and counter timer

How many event occur in a certain time? → DAQ time set
with trigger pulse? → GATE
for a certain event? → 1000 events



SECTIONS 1 AND 3

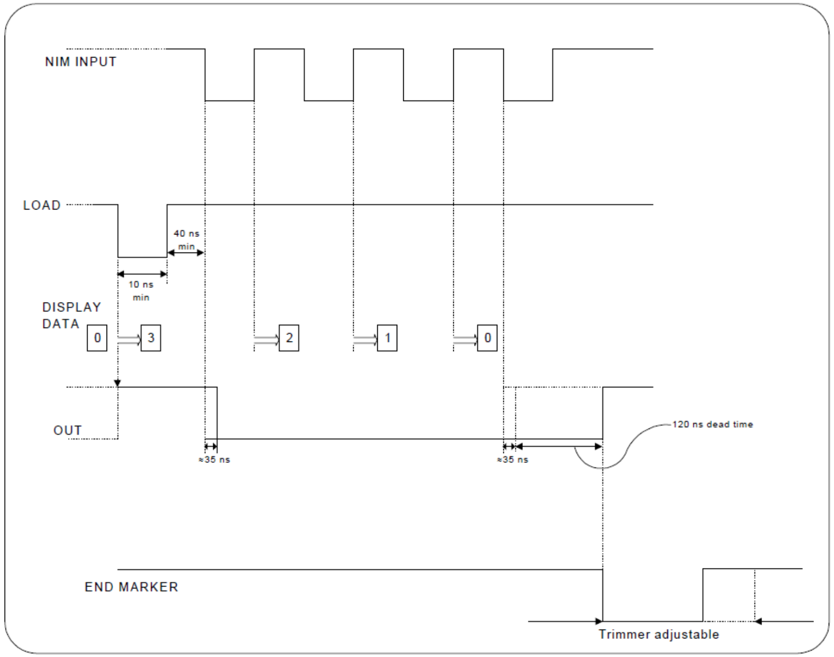
INPUTS	2, one NIM and one TTL, 50 Ω impedance.
GATE	2, NIM bridged input ports, high impedance, internally connected. Free port must be terminated on 50 Ω

SECTIONS 2 AND 4

INPUTS	2, one NIM and one TTL, 50 Ω impedance.
GATE	one NIM input, 50 Ω impedance.
CARRY	one NIM output. Generates apulse when counter has fully cycled (transition 99,999,999 to 0).
RESET	one NIM input, clears *sections 1 to 4*. Same effect is obtained, for each section, with the individual RESET pushbuttons.

SECTION 5

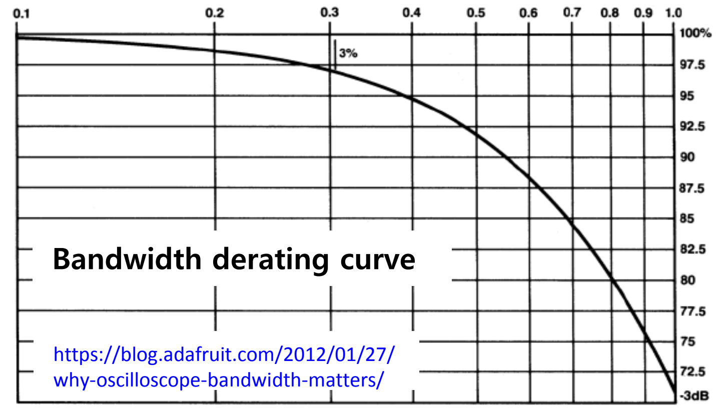
INPUTS	2, one NIM and one TTL, 50 Ω impedance.
LOAD	one NIM input. Loads counter with value preset on the thumb wheel switch display (same effect with LOAD pushbutton).
OUT	2, NIM outputs, these are true(*)as long as counter contents are different from zero.
END MARKER	one NIM output, a pulse generated when the counter contents become zero. Pulse width is adjusted with trimmer between 50 ns and 1 μs.



TEST SETUP: Oscilloscope

Bandwidth:

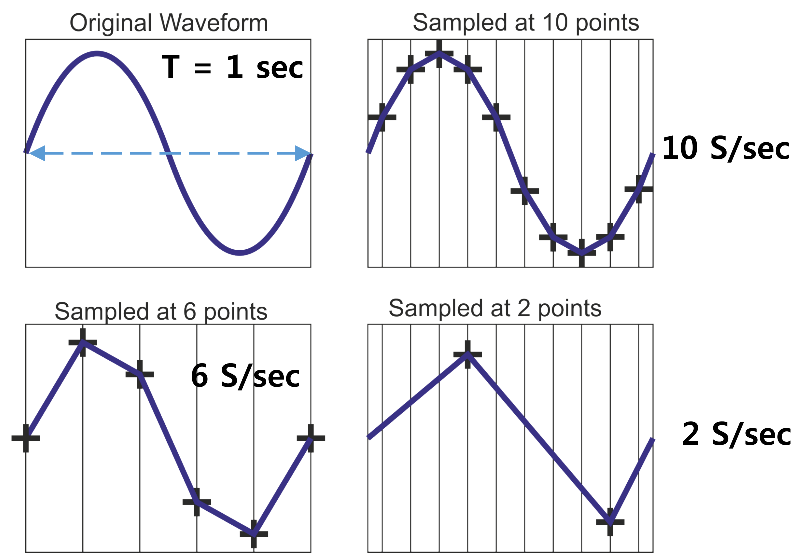
maximum frequency of an input signal which can pass through the analog front end of the scope with minimal amplitude loss



If you require 3% accuracy, you need to derate it by a factor of ~0.3x, so a **350 MHz scope** can **accurately measure 105 MHz to 3%**.

Sampling rate:

maximum number of samples per second



FAST ELECTRONICS: Radio Guide (RG) Cables

http://www.l-com.com/content/Article.aspx?Type=N&ID=10336

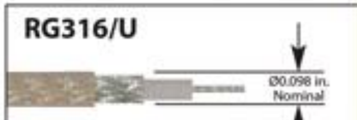
Signal transmission

RG174/U

50 Ohm Impedance

NOMINAL ATTENUATION		
MHz	db/100 ft	db/100m
50	5.8	19.0
100	8.4	27.6
200	12.5	41.0
400	19.0	62.3
1000	34.0	111.5

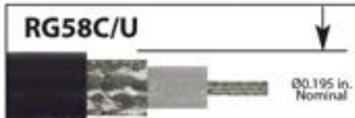
RG316/U



50 Ohm Impedance

NOMINAL ATTENUATION		
MHz	db/100 ft	db/100m
50	5.6	18.4
100	8.3	27.2
200	12.0	39.4
400	17.5	57.4
1000	29.0	95.1

RG58C/U

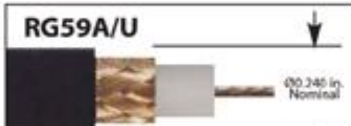


50 Ohm Impedance

NOMINAL ATTENUATION		
MHz	db/100 ft	db/100m
50	3.3	10.8
100	4.9	16.1
200	7.3	23.9
400	11.0	36.1
1000	20.0	65.6

HV transmission

RG59A/U



75 Ohm Impedance

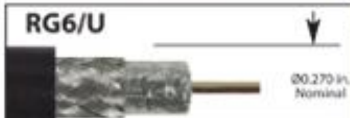
NOMINAL ATTENUATION		
MHz	db/100 ft	db/100m
50	2.8	9.2
100	4.0	13.1
200	5.9	19.4
400	8.5	27.9
1000	13.8	45.3

RG59B/U

75 Ohm Impedance

NOMINAL ATTENUATION		
MHz	db/100 ft	db/100m
50	2.4	7.9
100	3.4	11.1
200	4.9	16.1
400	7.0	23.0
1000	12.0	39.3

RG6/U



75 Ohm Impedance

NOMINAL ATTENUATION		
MHz	db/100 ft	db/100m
50	1.5	4.9
100	2.1	6.9
200	3.1	10.2
400	4.5	14.8
1000	7.3	23.9

How fast signals move in cables? v_{signal} = ~5 ns/m

	c (m/s)	Velocity Fraction (%)	v (m/s)	v (m/ns)	v (cm/ns)	Connector type
Vacuum	3.00E+08	1	3.00E+08	0.300	30.0	
RG174	3.00E+08	0.66	1.98E+08	0.198	19.8	**LEMO**
RG316	3.00E+08	0.79	2.37E+08	0.237	23.7	**LEMO**
RG58	3.00E+08	0.66	1.98E+08	0.198	19.8	**BNC**

Power loss $\alpha_P(dB/km) = \frac{10}{L} log_{10}^{(P_1/P_2)}$

α_P = power attenuation, or loss between source and destination, unit (dB/km)
P_1 = power at the beginning (Source), unit (W)
P_2 = power at the end (Destination), unit (W)
L = distance between P_1 and P_2, unit (km)

If P_1 = 1 W, P_2 = 0.5 W, and L = 0.1 km, $\alpha_P = \frac{10}{0.1} log_{10}^{(1/0.5)}$ = 3.01 dB/100m

Power at the distance (L) : $P_2 = P_1 \cdot \exp(-\alpha_P L)$

RG58/U: 20 AWG bare copper (28.5 pF/ft)
RG58A/U: 20 AWG standard thin copper (30.8 pF/ft)
RG58C/U: same as RG58A/U but not same outer jacket material

RG59A/U: 22 AWG bare compacted copper
RG59B/U: 22 AWG solid bare copper covered steel

U: Universal
AWG: American Wire Gauge

FAST ELECTRONICS: RG Cables

http://www.rfcafe.com/references/articles/Joe-Cahak/rf-connectors-cables-joe-cahak-6-2014.htm

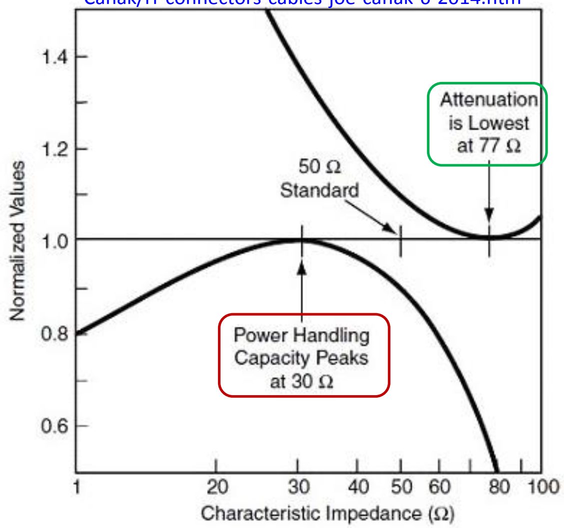


Figure 2 - Coaxial Cable Impedances

A typical question is why 50 ohms?

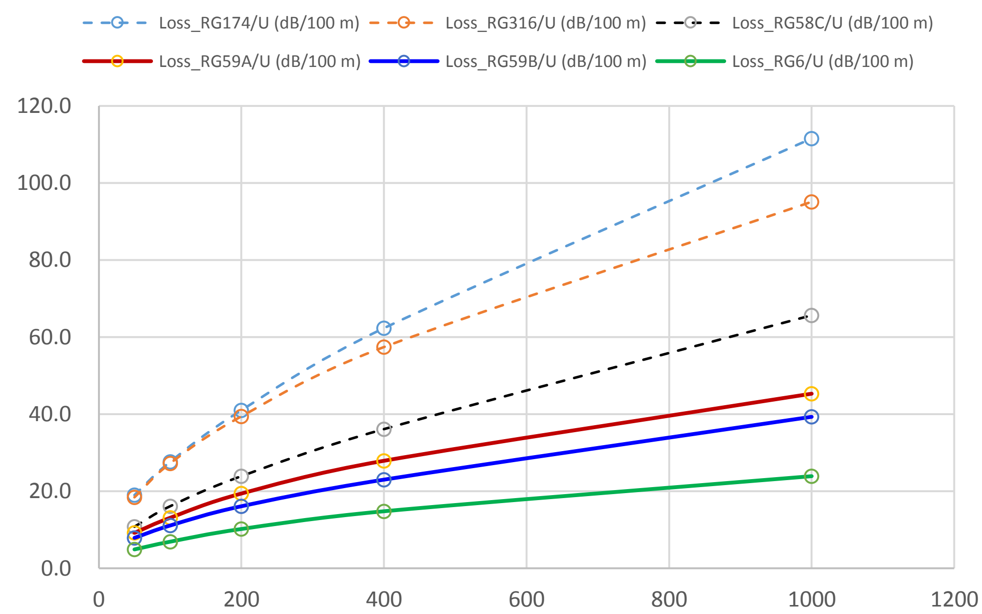
Minimum attenuation at 76.7 ohm.

When more common dielectrics are considered, best-loss impedance drops down to a value between 52-64 ohm.

Maximum power handling is achieved at 30 ohm. The arithmetic mean between 30 and 77 ohm is 53.5 ohm; the geometric mean is 48 ohm.

The selection of 50 Ω as a compromise between **power-handling capability** and **attenuation** is in general cited as the reason for the number.

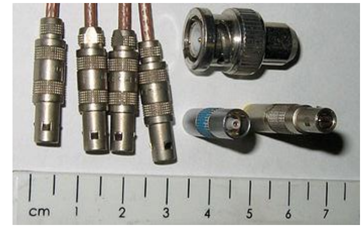
Power loss (dB/100 m) vs frequency (MHz) in coaxial cables



Power loss (dB/100 m) in coaxial cables

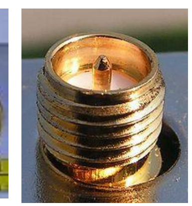
f (MHz)	Loss_RG174/U (dB/100 m)	Loss_RG316/U (dB/100 m)	Loss_RG58C/U (dB/100 m)	Loss_RG59A/U (dB/100 m)	Loss_RG59B/U (dB/100 m)	Loss_RG6/U (dB/100 m)
50	19.0	18.4	10.8	9.2	7.9	4.9
100	27.6	27.2	16.1	13.1	11.1	6.9
200	41.0	39.4	23.9	19.4	16.1	10.2
400	62.3	57.4	36.1	27.9	23.0	14.8
1000	111.5	95.1	65.6	45.3	39.3	23.9

FAST ELECTRONICS: Connectors for signal and high voltage



Signal connection
LEMO **(**company founder, engineer **Lé**on **Mo**uttet**)**
name of an electronic and fibre optic connector manufacturer
push-pull connectors
NIM, CAMAC, VME, detector, and etc

BNC (Bayonet Neill-concelman) connector: miniature quick connect/disconnect
50 or 75 ohm impedance
frequencies below 4 GHz
voltage below 500 V
NIM, audio, video, detector and etc

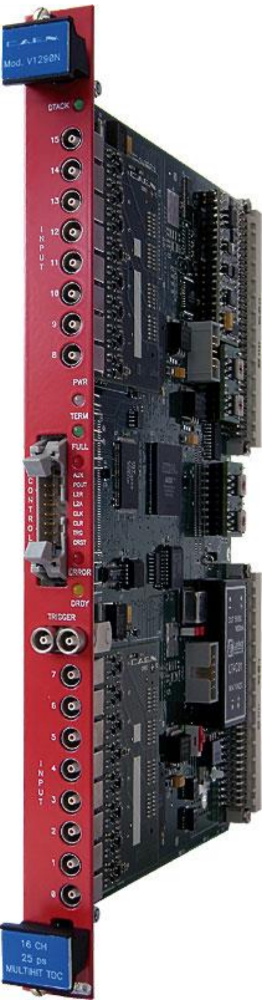


SMA (Sub Miniature version A): semi-precision coaxial RF connectors
screw-type coupling mechanism
male Φ0.312 in (Φ7.9 mm)
0-18 GHz passband (some up to 26.5 GHz)
detector and etc

High voltage connection
MHV (miniature high voltage): type of RF connector used for terminating a coaxial cable

SHV (**safe high voltage**) **connector:** safer handling HV than other connectors
standard: up to5 kV (5 A)
higher-version: 20 kV or more
NIM, detector, and etc

FAST ELECTRONICS: TDC and ADC



CAEN V1290N-2eSST

16 ch Multihit TDC (25 ps)

25 ps LSB (Least significant bit)

21 bit resolution

52 μs full scale range

NIM Input Signals

5 ns Double Hit Resolution

Leading and Trailing Edge detection

Trigger Matching and Continuous Storage acquisition modes

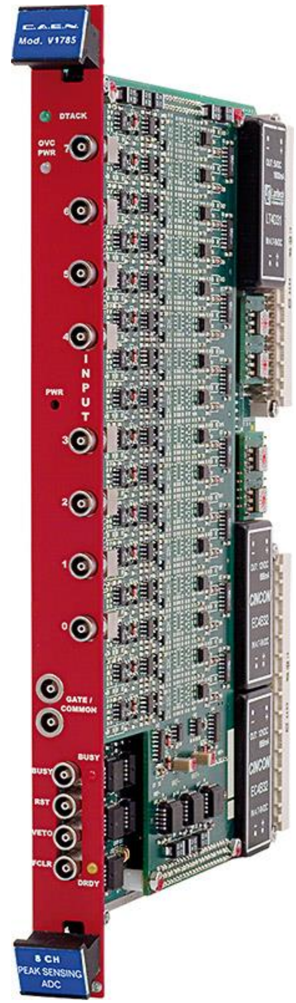
32 k x 32 bit output buffer

MBLT, CBLT and 2eSST data transfer

Multicast commands

Live Insertion

Libraries, Demos (C and LabView) and Software tools for Windows and Linux



CAEN V1785

8ch dual range multi-event peak sensing ADC

Two simultaneous ranges: 0~4 V / 0~500 mV

Resolution: 12 bit (4,096)
Dynamics range: 15 bit (32,768)

Least significant bit (LSB)
125 μV LSB on low range (500 mV)
1mV LSB on high range (4 V)

2.8 μs / 8 ch conversion time

600 ns fast clear time

Zero and overflow suppression for each channel

±0.1 % Integral non linearity

±1.5 % Differential non linearity

32 event buffer memory

BLT32/MBLT64/CBLT32/CBLT64 data transfer

Multicast commands

Live insertion

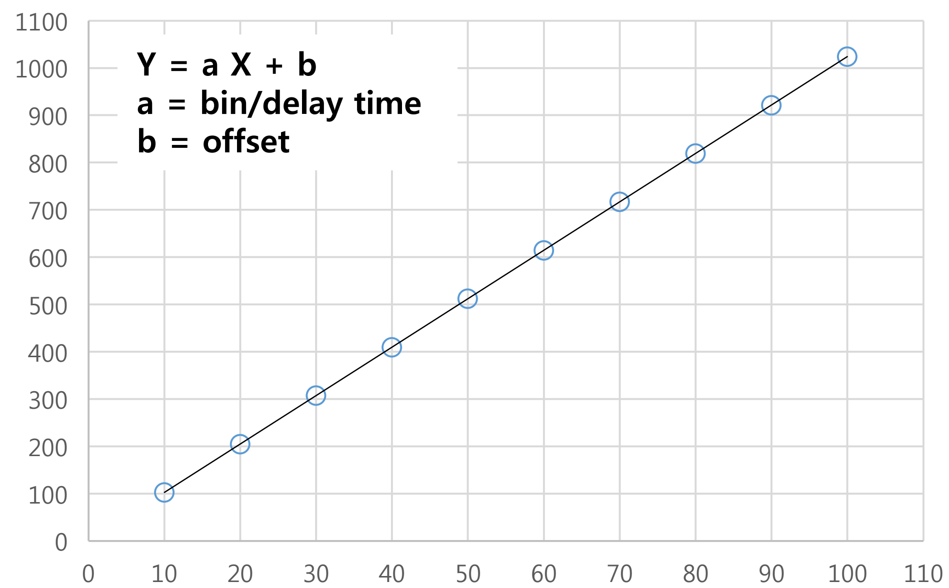
FAST ELECTRONICS: TDC calibration

T_full = 100 ns with 10 bit (1024) data set

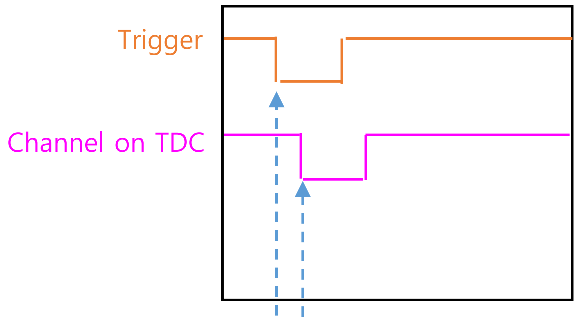
100	ns
1024	bin
0.09765625	ns/bin

delay (ns)	unit time (ns/bin)	TDC (bin)
10	0.09765625	102.4
20	0.09765625	204.8
30	0.09765625	307.2
40	0.09765625	409.6
50	0.09765625	512
60	0.09765625	614.4
70	0.09765625	716.8
80	0.09765625	819.2
90	0.09765625	921.6
100	0.09765625	1024

TDC (bin) vs Delay time (ns)

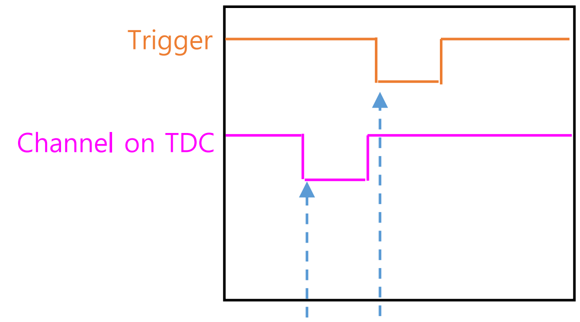


COMMON START MODE



10 ns delay

COMMON STOP MODE



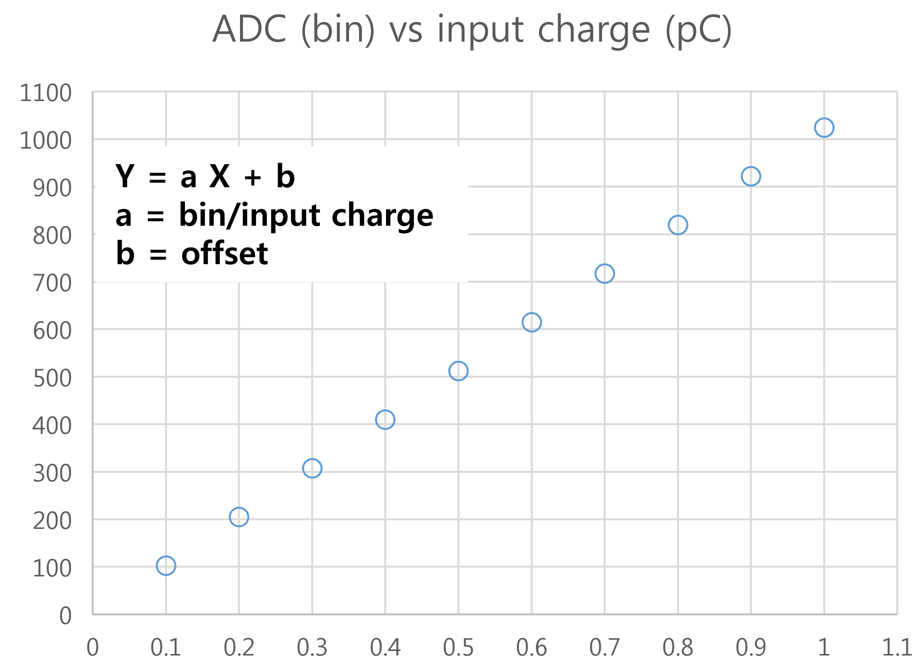
60 ns delay

FAST ELECTRONICS: ADC calibration

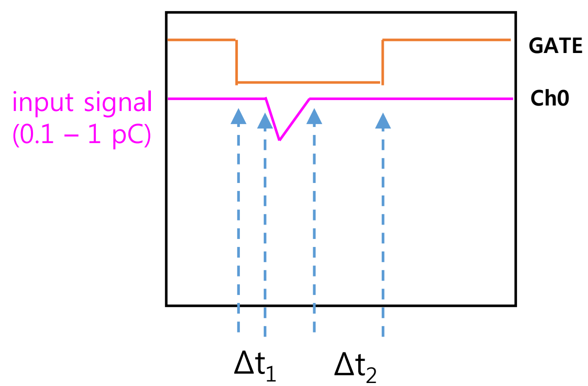
Q_full = 1 pC with 10 bit (1024) data set

1	pC
1024	bin
0.00097656	pC/bin

Q_in (pC)	unit time (pC/bin)	ADC (bin)
0.1	0.000976563	102.4
0.2	0.000976563	204.8
0.3	0.000976563	307.2
0.4	0.000976563	409.6
0.5	0.000976563	512
0.6	0.000976563	614.4
0.7	0.000976563	716.8
0.8	0.000976563	819.2
0.9	0.000976563	921.6
1	0.000976563	1024



Time domain of signals for ADC calibration



Δt_1 and Δt_2 depends on charge and shape of signal (ex, 10 ns or more).