APD-ACE

Pulse Processing Unit

Operating & Service Manual

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2. Introduction

This manual details the specification and operating requirements for the IC-ACE electronics module

ATTENTION

- Before operation fully read and understand the manuals. If there is anything you do not understand contact FMB Oxford / third party supplier before use.
- This product should only be used by those persons legally permitted to do so

2.1.1 Important Health and Safety Notice

When returning components for service or repair, it is essential that the item is shipped together with a signed declaration that the product has not been exposed to any hazardous contamination, or that appropriate decontamination procedures have been carried out so that the product is safe to handle.

2.1.2 Feedback

Care has been taken to ensure the information in this manual is accurate and at an appropriate level. Please inform FMB Oxford if you have any suggestions for corrections or improvements to this manual.

2.1.3 Trademarks

FMB Oxford acknowledges all trademarks and registrations.

2.1.4 Copyright

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3. Warranty

2.1 FMB OXFORD warrants that the Equipment shall be free from defects by reason of faulty design, workmanship or materials and that if within the guarantee period set out in sub-clause 3 the Equipment proves defective for such reason FMB OXFORD shall adjust, repair or replace it as it sees fit free of charge, provided that:

2.1.1 The Equipment has been used solely for the purpose for which FMB OXFORD understands it is to be used and in accordance with the operating instructions;

2.1.2 The defect has not been caused by fire, accident, misuse, neglect, incorrect installation by the customer, its customers, agents or servants or unauthorised repair or maintenance or by use of sub-standard consumables;

2.1.3 The defect has not arisen from any design, specification, component or material supplied by the customer;

2.1.4 No part of the Equipment has been replaced with a part not supplied by FMB OXFORD or approved as suitable by it;

2.1.5 Payment in full of all sums due in respect of the Equipment has been made;

2.1.6 The customer shall be liable for any costs incurred by FMB OXFORD in responding to claims made in respect of erroneous results caused by operator error or incorrect application;

2.1.7 Upon the customer making a claim under sub-clause 1 it shall accord sufficient access to the Equipment to enable FMB OXFORD staff to inspect and adjust, repair, remove or replace the Equipment;

2.1.8 FMB OXFORD will co-operate with the customer in the assessment of reported defects but the final decision regarding the applicability of this guarantee shall rest with FMB OXFORD.

2.2 FMB OXFORD shall decide if the Equipment should be repaired pursuant to sub-clause 1 at its site or returned.

2.3 The applicable guarantee period shall be 12 months after delivery save where the Equipment is installed and/or commissioned by or under the supervision of FMB OXFORD in which case it shall be 12 months from the date of the installation certificate or 18 months after the date of delivery, whichever is the earlier.

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4. Health and Safety Information

4.1 General

In normal operation, the system is designed to operate safely. The user should, however, be aware of potential hazards which exist in and around equipment of this type and of the ways of avoiding possible injury and equipment damage which may result from inappropriate ways of working. A description of such potential hazards and how to avoid them is given in this section.

If the equipment is used in a manner not specified in the User Manual, the protection provided by the equipment may be impaired.

This manual adopts the following convention:

ATTENTION

- Indicates important information that must be adhered to

WARNING

- Indicates a potential hazard which may result in injury or death

CAUTION

- Indicates a potential hazard, which may result in damage/injury to equipment or user

Do not take risks. You have a responsibility to ensure the safe condition and safe operation of equipment.

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4.2 Potential Electrical Hazards

The following list is not intended as a complete guide to all the electrical hazards on the system, but illustrates the range of potential hazards that exist:

WARNING

- Electrical shock
- Electrical burn
- Fire of electrical origin
- Electrical arcing particularly at partial vacuum

4.3 Electrical Precautions

WARNING

- Ensure that all electrical equipment is properly grounded.
- Conform to all local and national electrical regulations.
- Ensure that the mains supply is properly fused and can be isolated locally via a clearly labeled, visible and easily accessible isolating switch.
- Isolate the supply before carrying out any maintenance work.
- Do not defeat interlocks, remove connectors, disconnect equipment, open safety covers, dismantle or modify equipment unless qualified and authorized to do so.

CAUTION

- Only personnel who are qualified and authorized to work with the voltages and currents used by this equipment and are fully conversant with its operation and potential hazards may disconnect, open, dismantle, service or modify the equipment.

4.4 Moving Parts

CAUTION

- Keep clothing and body parts away from moving mechanisms

4.5 X-Ray Radiation

This equipment is intended for use on an X-ray beamline of a synchrotron.

CAUTION

- Ensure that all facility safe working practice and procedures are followed

The manufacturer does not accept and liability for personnel injury or damage resulting from ionising radiation

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4.6 Modifications and service

The safety, reliability or performance of the equipment may be impaired if assembly operations, extensions, re-adjustments, modifications or repairs are not carried out in accordance with the instructions provided in this manual and with any other instructions issued by the manufacturer. If you wish to modify the equipment please contact FMB Oxford for further advice

ATTENTION

It should be stressed that those parts of the equipment which are interchangeable, and which are subject to deterioration during operation, may significantly affect the safety of the equipment

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5. ACE Overview

The ACE pulse processing unit provides all signal and power for an Avalanche photo-diode detector for use in direct X-ray counting

This module includes both local and remote user interfaces and is based on a 16MHz micro controller and a programmable counter implemented in a Complex Programmable Logic Device that can run up to 100MHz

Computer control will communicate to the module through a serial line port (RS232 and RS422) or a parallel GPIB port. The local user interface is provided by a graphic LCD display with a touch panel facility.

The firmware controls all calculation and synchronisation, timing specifications are guaranteed by the internal timers of the micro controller. However the module can also receive synchronisation and gate signals from an external source.

TTL and NIM output signals are available and can be synchronised to an external counter and data acquisition system.

The unit is housed in a two-units wide NIM enclosure, with most of the signal connectors placed on the front panel. Communication and detector head connectors are located on the rear panel.

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6. External Signals

6.1 Front panel

All the signals on the front panel are available in Lemo 00 coaxial connectors.

Signal	Type	Description
Alarm	Lemo, TTL output	Software instruction error and Over count
Trigger Input	Lemo, TTL / Fast NIM	When validated by software, every rising edge of this signal generates an internal line trigger event (see TRIG software command). The rising edge is the active edge. The necessary 50-ohm impedance use in NIM standard, as to be set manual by an internal switch. ACE can be used as a single channel 32-bits counter up to 50 MHz. This input can be used for this propose.
Gate Input	Lemo, TTL / Fast	When validated by software, the internal counter is enabled during active signal. (See GATE software command). The necessary 50-ohm impedance use in NIM standard, as to be set manual by an internal switch.
SCA Out TTL	Lemo, TTL	When validated by software, every low-level threshold in integral mode and every level between low-level and high-level threshold in window mode, a pulse is generated. The pulse width is adjustable by software with the following value: 5, 10,20, 30ns. Additional dead time will be generating in case of using 20 and 30ns width. This TTL can be use with a 50 ohms termination. In this case the high level will be limited to 2.5V. This output is not recommended for time resolve experiment.
SCA Out NIM	Lemo, Fast NIM	When validated by software, every low-level threshold in integral mode and every level between low-level and high-level threshold in window mode, a pulse is generated. The pulse width is adjustable by software with the following value: 5, 10,20, 30ns. Additional dead time will be generating in case of using 20 and 30ns width. This NIM output as to be used with a 50 ohms termination. Nevertheless a signal is observable with -1.6V amplitude without correct termination. This output is not recommended for time resolve experiment.
Gate/Trig Out TTL	Lemo, TTL	When validated by software, a pulse is generated during the counting time or a short pulse is generate at the begin and at the end of the counting time. The short pulse width is fixed at 1us.This TTL can be use with a 50 ohms termination. In this case the high level will be limited to 2.5V.
Gate/Trig Out NIM	Lemo, Fast NIM	When validated by software, a pulse is generated during the counting time or a short pulse is generate at the begin and at the end of the counting time. The short pulse width is fixed at 1us . This NIM output as to be used with a 50 ohms termination. Nevertheless a signal is observable with -1.6V amplitude without correct termination.

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SCA LLD Out NIM	Lemo, Fast NIM	Direct Fast NIM output. The signal as to be observes with 50 Ohms load. This output generates a pulse of 6ns each time than the low threshold is reach the total dead time is 12 ns. This signal contain time resolution information with a jitter < 100ps
SCA HLD Out NIM	Lemo, Fast NIM	Direct Fast NIM output. The signal as to be observes with 50 Ohms load. This output generates a pulse of 6ns each time than the high threshold is reach the total dead time is 12 ns. This signal contain time resolution information with a jitter < 100ps
ANALOG OUT	Lemo Analog Signal 50 Ohms Output	Observation of the analog signal after the amplification G=-8 and the base line restoration. The signal as an offset of +200mv due the base line restoration.

LED	Colour	Description
Error	Red	Software instruction error and Over count

6.2 Rear panel

Signal	Type	Description
SERIAL	DB9	RS232 and RS422 ports
GPIB	Centronics 24/IEEE-488	GPIB Port
Head Signal	SMA F	Signal input from Head Amplitude +25mv to -44mv
Head Power +HV	Lemo ERN1S306CLL	6V -43mA Power supply600V High voltage bias, temperature sensor readout

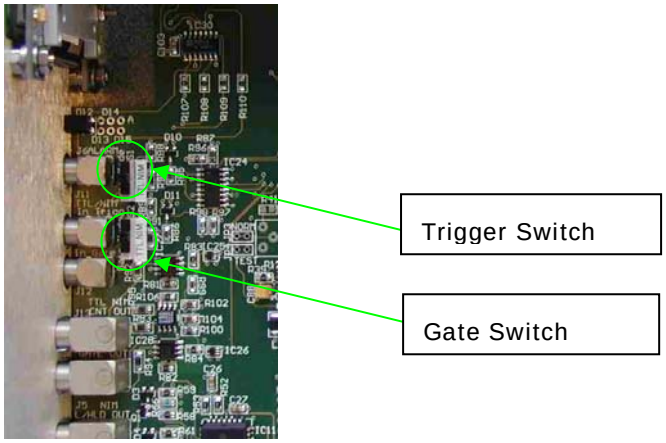
6.3 Trigger and Gate input configuration

If synchronisation of the ACE counter is necessary the Trigger and Gate input must be configured. These inputs are compatible with a NIM or TTL signal. For fast NIM signal compatibility an internal switch must be set for each input. These switches have two positions NIM or TTL. For the NIM mode a 50 ohms termination is required and for the TTL mode the 50 ohms termination should be removed and a1K ohms pull up resistor to 5V introduced. Software configurations are necessary: see command TLVL and GLVL.

It is possible to use the NIM position (50 termination to GND) with TTL signal if The TTL driver is able to provide 1.5V in 50 ohms.

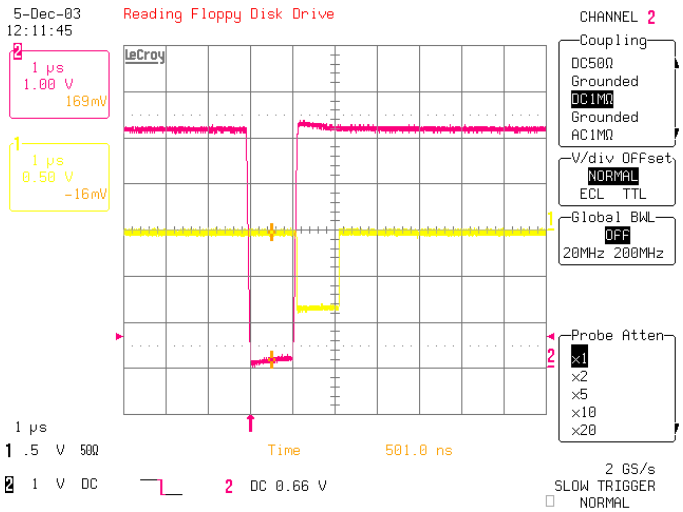
IMPORTANT: If the gate input is not used and the Gate switch configured on NIM and the software configuration is in TTL (GLVL = TTL), the counter is in disabled state and the count rate will remain at 0.

Localisation of switches

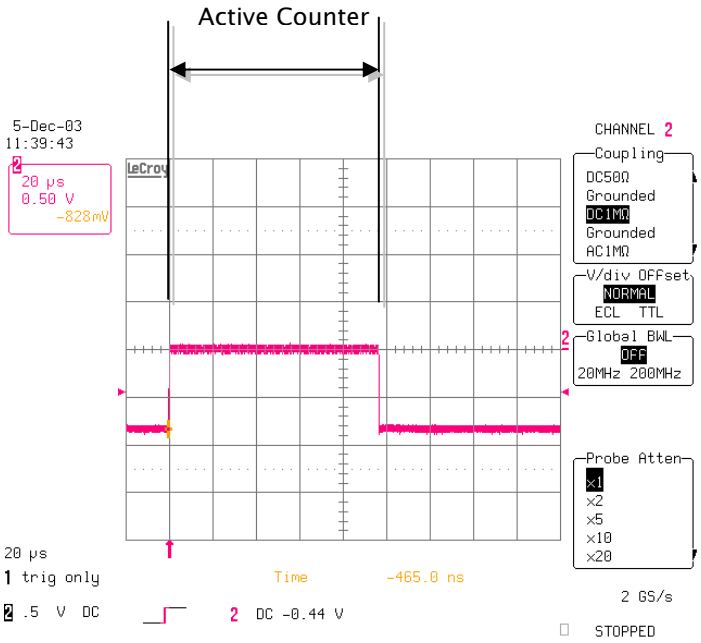


6.4 Typical Trigger and Gate signal

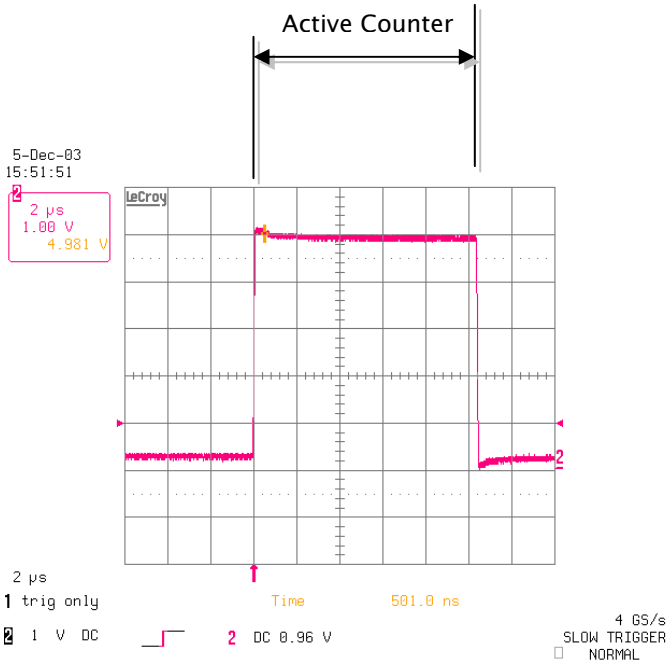
Trace 2 (red) below is the trigger input signal, TTL compatible. The rising edge is the active edge. Trace 1 is the NIM Gate/Trig out configured as trigger out and negative signal.



Below is a typical NIM input gate signal. In this case the counter is active during 100us.



Below is a typical TTL input gate signal. In this case the counter is active during 10us.



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6.5 Specifications

Parameter	Conditions	Min	Typical	Max	Units
Timing					
Time base resolution			1		µs
Internal counter Freq. Max. RMS			100		MHz
Internal counter Freq. Max. Peak	10 pulses		180		MHz
Pulse pair resolution	10 pulses		5.6		ns
SCA dead time	DL .5ns	5	5.2	6	ns
SCA Jitter LLD/HLD peak to peak	@1MHz			<100	ps
SCA Jitter LLD/HLD RMS	@1MHz			<30	ps
Head Input					
Amplitude			+25 to -440		mV
Integrated Amplifier Band pass	G= -8@-3db		2 to 270		MHz
Base Line Restoration short pulse	DC-90MHz		-5		%
(Hamamatsu diode 5*3mm)	DC-40MHz		-1%		%
Base Line Restoration long pulse	DC-40MHz		-5		%
(EGG 5*5mm)	DC-10MHz		-1%		%
Head Power					
6V adjustable precision power supply 50mA		4.3	6	6.8	V
Internal adjustable High voltage power supply 600V 3mA				600	V
High voltage linearity between set point and real output.			0 to +0.5		%
Head measurement					
High voltage current measurement range.			0 to 10		uA
High voltage current measurement resolution.			24.4		nA
Head integrated thermal sensor range		0		50	ºC
Head integrated thermal sensor resolution			.05		ºC

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Module Power Requirement		*6.5*	*W*
+6V		*300*	*mA*
-6V		*450*	*mA*
-12V		*30*	*mA*
+12V		*130*	*mA*

7. Remote control

7.1 Remote control command summary

COMMAND	DESCRIPTION
RESET [DEFAULT]	Program reset
?HSTATE	Returns the state of the head
?HTEMP	Returns the temperature of the head in degrees
?HCURR	Returns the current the head in uAmps
HLIM, ?HLIM	Set/returns head limits
HVOLT, ?HVOLT	Set/returns the bias voltage
?HVMON	Returns the HV monitor voltage

CSRC, ?CSRC	Selects/Returns the current counting source
SCA, ?SCA	Sets/returns the SCA mode and levels
?RATE	Returns the current values of the rate meters

ALMODE, ?ALMODE	Sets/returns the alarm mode
ALSET	Adds an alarm mode
ALCLEAR	Clears an alarm mode
ALRATE, ?ALRATE	Sets/returns the rate meter alarm threshold
ALCURR, ?ALCURR	Sets/returns the current alarm threshold
?ALARM	Returns the current alarm status

GLVL, ?GLVL	Sets/returns the input level of GATE_IN

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TLVL, ?TLVL	Sets/returns the input level of TRIGGER_IN
OUT, ?OUT	Sets/returns the mode for the external counter
SOUT, ?SOUT	Sets/returns the mode for the external gate and trig.

TCT	Starts the counter using the internal time base
ECT	Starts the counter using the external time base
STCT	Stops the counter
?CT	Returns the status of the counter

?MEMSIZE	Returns the size of the data memory
BUFFER, ?BUFFER	Sets/returns buffer options
?BUFSIZE	Returns the maximum number of records in the buffer
?BUFPOS	Returns the current position in the buffer
DFORMAT, ?DFORMAT	Sets/returns the data format
?DAT, ?*DAT	Returns data in the current buffer
?ADAT,?*ADAT	Returns data in the previous buffer
?INFO	Return the module configuration

ECHO		Select echo mode
NOECHO		cancel echo mode
	?ERR	Query last error message
ADDR	?ADDR	Set/query serial line address
	?CHAIN	Query secondary serial port status
NAME	?NAME	Set/query module name
	?VER	Query firmware version
	?HELP	Query list of available commands

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7.2 Commands reference

ADDR <slAddress>

Sets serial line address to <slAddress>
The address may be any alphanumerical character string. The maximum length is 9 characters. Any leading zeroes in the address are discarded.
When different modules are daisy-chained for communication, a particular module can be accessed by preceding any command with a prefix formed by the module address followed by a colon character (:). If the first character of the address is non-numeric, an initial zero must be added. The reserved character (>) can be use instead of the address and colon character. The first module in the chain will interpret that he is not the addressee of the command. He will remove the first (>) character of the chain and send the chain to the next module. Example:
COMMAND; the chain "COMMAND" will be interpreted by the first module
>COMMAND; the chain "COMMAND" will be interpreted by the second module
>>COMMAND; the chain "COMMAND" will be interpreted by the third module

?ADDR

Queries the serial line address
Returns the serial line address of the module.
Answer: <slAddress>

?ALARM

Returns the current alarm status:
OFF indicates no alarm defined.
ON indicates that one or a few alarms are defined. If the ON message is followed by an alarm mode message it indicates that a mode has passed a threshold.
Answer: {OFF | ON [HEAD] [RATE] [CURR]}

ALCLEAR {[HEAD] [RATE] [CURR]}

Clears an alarm mode:
One/multiple parameters can be transmitting to the command to suppress one/multiple alarm modes.

ALCURR <currvalue>

Sets the threshold of the bias current alarm.
Answer: <currvalue> should be in a range of 0 to 25 mA.

?ALCURR

Queries the threshold of the bias current alarm.
Answer: <ratevalue>
<ratevalue> is in a range of 0 to 25 mA.

ALMODE {OFF | [HEAD] [RATE] [CURR]}

Sets the alarm mode:
One/multiple parameters can be transmitting to the command to set the appropriate alarm mode.
For the adjustment of thresholds, dedicated commands need to be used.
Thresholds of HEAD parameters are set by the HLIM command.
Thresholds of RATE are set by the ALRATE command.
Thresholds of CURR is set by the ALCURR command.

?ALMODE

Queries the actual alarm mode
Returns the actual alarms modes set. If no alarms are set the answer is OFF.
Answer: {OFF | [HEAD] [RATE] [CURR]}

ALRATE <ratevalue>

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Sets the threshold of the rate meter alarm.
This should be in a range of 0 to 1e8
Answer: <ratevalue>.

?ALRATE

Queries the threshold of the rate meter alarm.
This should be in a range of 0 to 1e8.
Answer: <ratevalue>

ALSET {[HEAD] [RATE] [CURR]}

Sets an alarm mode.
One/multiple parameters can be transmitting to the command to suppress one or more alarm mode.

?CHAIN

Queries the secondary serial port status
This returns whether or not ("YES" or "NO") there is another instrument connected to the secondary serial port and its electrical specification ("RS232" or "RS422").
The secondary serial port is the port that is not used for communications with the host computer and that can be eventually used for daisy-chaining of modules.
Answer: {YES | NO} {RS232 | RS422 | NONE}

CSRC {SCA | TRG}

Selects the current counting source {SCA | TRG}
When TRG is selected, the trigger input is used as source of the counter. In this mode the ACE unit is used as a one channel 50 MHz counter. In this mode the input signal should be TTL or NIM. When SCA is selected the Rear input Head signal is used as source. The SCA mode is the standard mode to use APD Head.

?CSRC

Queries the current counting source
This returns the current counting source Trigger input of the front panel when TRG is set or Head input from rear panel when SCA is set.
Answer: {SCA | TRG}

?CT [DATA]

Returns the status of the counter [and the data]
Answer: S <nremain> <ntotal> [<time> <counts>]
The first letter S give the actual state of the counter: D for state "down" and data are ready to be read. R for state "running", data can be read but integration time is not completed. W for "wait" state (wait for a trigger). A for state "abort" when the command STCT is send before end of a repetitive count or when the counter is in wait state. <nremain> is the remain count before end of repetitive count. For single count this value is 0 or 1. <ntotal> is the number of count request in case of repetitive count. In case of single count this value is 1. If the optional parameter [DATA] is set, the answer <time> give the integration time already done in us for the count running, and <counts> the actual value of the count running.

ECHO

Sets the serial line echo to 'on'
Use for direct communication with a terminal.

NOECHO

Sets the serial line echo to 'off'
This is the default mode after a power on or RESET command, use with remote control with SPEC macro or National Instrument's VI.

ECT [<nrep>] [EXT]

Starts the counter using the external timebase

This parameter can be use to make repetitive counts and store values in a table. When the optional parameter [EXT] is set, the counter starts when a trigger signal is sent to the Trigger input. Without this parameter, the counter starts when the command is recognised by the modules firmware. The counter will run until it receives the next trigger level.

?ERR

This returns the error message generated by the previous command. If there was no error the string "OK" is returned.
Answer: OK | <error message>

GLVL [NIM | TTL]

This sets/returns the input level mode (NIM or TTL) of the Gate input
The level must be linked with a modification to a physical switch setting on the board.

?GLVL

Queries the input Gate level mode
Answer: {NIM | TTL}

?HELP

Queries the list of available commands.

?HCURR

Queries the current of the detector heads bias voltage.
The range of measurement is from 0 to 11uA with a resolution of 24nA.
Answer: Returns the current of bias voltage of the head in uA.

HLIM <maxhcurr> [<maxhtemp>]

This sets the head limits
Where <maxhcurr> is the maximum bias current in the range of 0 to 25 mA and <maxhtemp> is in the range of 0 to 50 ^{o}C.
The parameter <maxhcurr> is redundant if the alarm mode ALCURR is set to a higher level. Set <currvalue> to 11 for normal use of alarms.

?HLIM

This queries the head limits.
Answer: <maxhcurr> <tempvalue>
The heads current limits are returned, where <maxhcurr> is in the range of 0 to 25 mA and <maxhtemp> is in the range of 0 to 50 ^{o}C.

?HSTATE

Returns the state of the head
Answer: {OK | NOHEAD | OVCURR | OVTEMP | HVERR}
It returns {NOHEAD} when the head's power cable is disconnected.
It returns {OVCURR | OVTEMP | HVERR} when one of theses parameters is out of range (ranges are set by the HLIM command).

?HTEMP

Queries the detector head current.
The range of measurement is from 0 to 50 ^{o}C with a resolution of 0.05 ^{o}C. If no head is connected to the module the temperatura will show 0 ^{o}C.
Answer: Returns the temperature of the head in ^{o}C.

HVOLT <biasvalue> [ON | OFF]

This sets a bias to the head

The bias value range is 0 to 600V with a resolution of .01V.

?HVOLT

This queries the bias setpoint of the detector head and the state of the detector head.
The range of measurement is from 0 to 600V with a resolution of 0.01mV, the states are ON or OFF.
Answer: Returns the bias setpoint of the head in Volts and the state [ON | OFF].

?HVMON

This queries the bias voltage of the head.
The range of measurement is from 0 to 655 V with a resolution of 0.6V. The difference between the set point HVOLT and the measurement of the high voltage (using ?HVMON) is due to the linearity and resolution of the readout system. In addition the High voltage bias compensation increases the bias with 1V per uA to compensate for the protection filter in the head (1Mohm serial resistor in high voltage bias).

?INFO

Returns the module configuration

NAME <name>

This sets the name of the device
The name of the device is the string name

?NAME

Query name of the device
Answer: <name>

OUT < 5 | 10 | 20 | 30 >

This sets the SCA out parameter
Defines the pulse shaping of the SCA output where the number 5,10,20 or 30 is the time shaping in ns. This shaping is necessary for an output counter with limited maximum frequency.
The setting of this parameter influences the dead time law for the output counter. For example, to respect compatibility of the VCT6 input the setting of 20 or 30 is necessary. The dead time law is 40 or 60 ns (two time the shaping time).

?OUT

This queries the pulse shaping of the SCA output
Answer: <5 | 10 | 20 | 30 >
Returns the current pulse shaping of the SCA output, where 5,10,20 or 30 are shaping times in ns.

?VER

This queries the firmware version
Answer: <ACE 1.00>

?RATE

This queries the rate meter value - the range of measurement is from 0 to 1e8.
Answer: <intratevalue> <winratevalue>.

RESET [DEFAULT]

This resets the unit
Resets the internal hardware, resets the current settings to the default values and saves them in the internal non-volatile memory.
In the current version of the firmware (01.02) the default settings are:
ECHO OFF, GPIBX1, HVOLT = 200, LLTH = 1, WIN = 1V, GPIB_ADDR = 9.

SCA [{ INT | WIN }] [<llth> [<winth>]]

This sets the mode of the SCA and the discriminator levels.
Level <llth> is in range from –0.2 to 5 (v)
Level <winth> is in range from 0 to 5 (v).

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?SCA

This queries the mode and levels of the SCA.
Answer: { INT | WIN } <llth> [<winth>]
In INT mode only <llth> level is given.

SOUT [GATE | TRIG] [POS | NEG]

This sets the Gate/Trigger out parameters.
Defines the use of SOUT (synchronisation output). The output can be assigned with Gate output or Trigger output. Using POS or NEG parameters the user can modify the active edge. When Gate mode is set the active integration time is assigned to the output. When Trigger mode is set, a 1us wide pulse is sent at the beginning of the integration time and a second pulse is sent at the end of the integration time.

?SOUT [GATE | TRIG] [POS | NEG]

This queries the Gate/Trigger out parameters
Answer: {GATE | TRIG} {POS | NEG}

STCT

Aborts a count or a repetitive count.

TCT <ctime> [<nrep>] [EXT]

This starts the counter using the internal time-base
The parameter <ctime> is the time in us and must to be provided. The minimum integration time is 1 us and the maximum is 2^{31} = 2 147 483 648 us or 35’ 47”. The parameter [<nrep>] can be use to make repetitive Count and store values in a table. When the optional parameter [EXT] is set, the counter is start when a trigger signal is send to the Trigger input. Without this parameter, the counter is started when the command is recognise by the firmware in the ACE module.

TLVL [NIM | TTL]

This sets/returns the input level mode (NIM or TTL) of the Trigger input
The level mode of the input also needs a modification of the physical switch on the main board.

?TLVL

Queries the input Trigger level mode (NIM or TTL)

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7.3 Remote control configuration for SPEC

ACE.MAC is the macros set for operating the module ACE.

7.3.1 Device server

ACE.MAC will communicate properly with the module ace through a serial line and a device server installed on VME/OS9-LINUX or on PC using LINUX. The database associated with the device server as to be update to set the serial link in the following mode:

Parity =none stop=1 baud=9600 data length=8 (no handshake control)

7.3.2 Special Macros request

To operate properly ACE.MAC as to be installed in ~specadm/jmacros/, and need 2 Standard ISG macros in this directory called isgdevice.mac and isg.mac. The code of ACE.MAC will run automatically these 2 macros. And ACE.MAC needs also the standard STLIST.MAC present und running.

7.3.3 Additional declaration in SPEC session

For each module, a number of pseudo motor and counter as to be define.

4 counters: Pulse counter, head temperature (optional), High voltage current (optional but very useful), High voltage monitor (optional).

3 pseudo motors: Low-level threshold of discriminator, window width (high-low) level threshold, and high voltage set point.

In setup file of the spec session, the following line is necessary:

acesetup ACEdet idxx/idxxx/y timebase llth=llth win=win hv=hvol hvmon=hvmon htemp=htemp hcurr=hcurr.

Where ACEdet is the pulse counter. The mnemonic use as to be in accordance with mnemonic use in SPEC session.

Idxx/idxxx/y is the serial line device server.

timebase is the special mnemonic to set ACE as main time base (if a time base already exist, the main time base remain the same).

For the 6 following parameters, left mnemonic as to have this exact name and the right mnemonic as to be in accordance with mnemonic use in SPEC session

llth=llth. This is the common mnemonic to define low level threshold discriminator pseudo motor.

win=win. This is the common mnemonic to define the window of discriminator pseudo motor (high level – low level).

hv=hvol. This is the common mnemonic to define the high voltage pseudo motor set point apply to APD the mnemonic hvol is use in spec session to avoid conflict with the common use “hv”.

hvmon=hvmon. This is the common mnemonic to define the high voltage counter use to verify the high voltage parameter set to APD. This parameter is optional and is use commonly for diagnostic.

htemp=htemp. This is the common mnemonic to define the temperature counter use to verify temperature of the head. If the APD head is not connected, the temperature = 0.
hcurr=hcurr. This is the common mnemonic to define the high voltage current counter use to verify breakdown and even occur in APD.

7.3.4 Config file in SPEC session

This is an example of config file with pseudo motors and counter ready to run one ACE module. For pseudo motors, it is important to use the correct dial (value = 1) and to remove backlash (value = 0) Low an high limits as to be set at 0 and 5 for llth and win, 0 and 600 for hvol.

Number: <>Controller	1:NONE	2:NONE	3:NONE
Unit/Channel Name	LLD Th	Window	HV
Mnemonic	llth	win	hvol
Steps per degree/mm	300	500	2000
Sign of user * dial	1	1	1
Backlash [steps]	0	0	0
Steady-state rate [Hz]	300	500	2000
Base rate [Hz]	200	200	200
Acceleration time [msec]	125	125	125
Motor accumulator	660	5	0
Restrictions	NONE	NONE	NONE

Dial = accumulator / steps

High limit	5.0000	5.0000	600.0000
Current	2.2000	0.0100	0.0000
Low limit	-0.200	0.0000	0.0000

User = sign * dial + offset

Offset	0.0000	0.0000	0.0000
`High' limit	5.0000	5.0000	600.0000
Current	2.2000	0.0100	0.0000
`Low' limit	-0.200	0.0000	0.0000

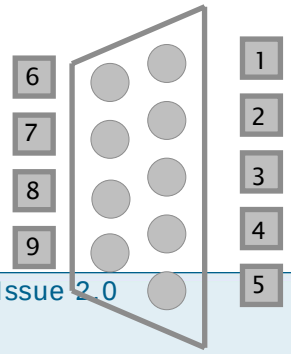
Scaler (Counter) Configuration

Number	Name	Mnemonic	<>Device	Unit	Chan	<>Use As	Scale Factor
0	Seconds	sec	NONE	0	0	timebase	1000
1	Detector	ACEdet	NONE	0	1	monitor	1
2	htemp	htemp	NONE	0	2	counter	1
3	hvmon	hvmon	NONE	0	3	counter	1
4	hcurr	hcurr	NONE	0	4	counter	1

8. Connection guide

8.1 Remote control by serial link

The rear panel is equipping with a female DB-9 connector for RS-232 and RS-422 operation. Use a crossed DB-9 shielded cable for RS-232 operation without hardware flow control.

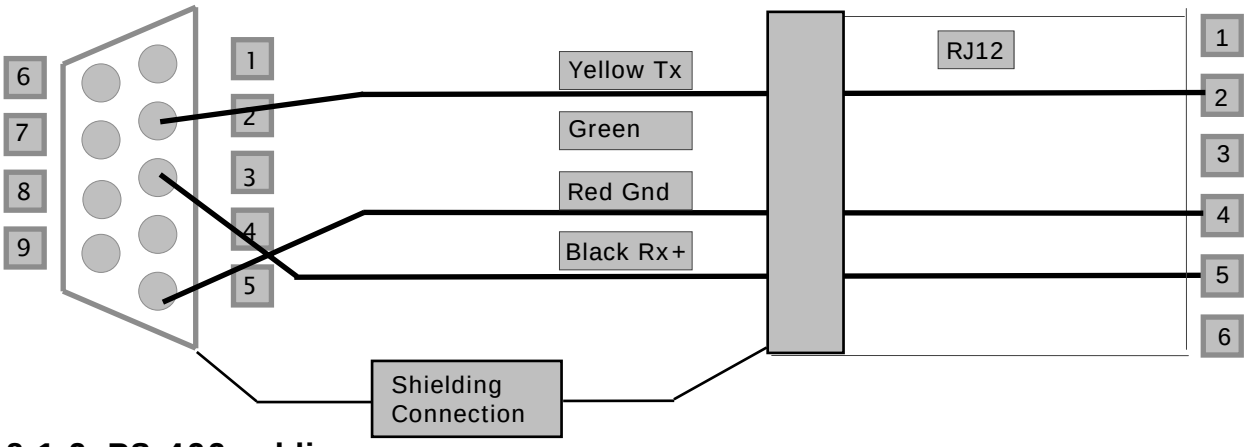


1=NC
2 RS-232 RX
3= RS-232 TX
4 =NC
5=GND
6=RS-422 RX+
7=RS-422 RX-
8=RS-422 TX+

9=RS-422 TX-

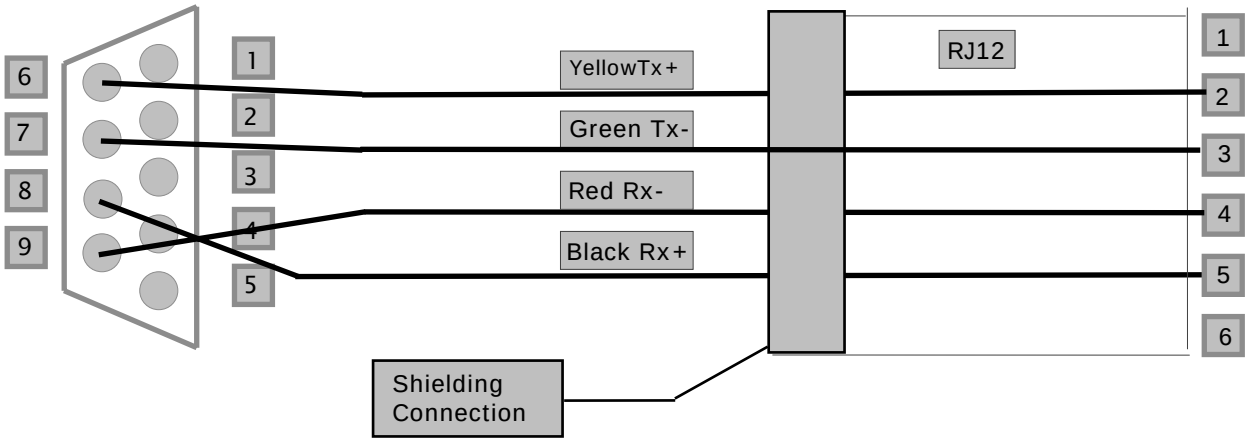
8.1.1 RS-232 cabling

If the RS-232 standard is used the following cabling, between the ACE module and the IBAM board of a VME, can be used. The cable use is a standard 3 m RJ12 / Lead connection Ref: 293-7960 with an optional additional extension 5m Ref: 293-7932 adapted to a standard male sub D 9 connector with the following cabling:



8.1.2 RS-422 cabling

If the RS-422 standard is used, the following cabling between ACE and IBAM board of a VME can be used. The cable use is a standard 3 m RJ12 / Lead connection Ref: 293-7960 with an optional additional extension 5m Ref: 293-7932 adapted to a standard male sub D 9 connector with the following cabling:



The test procedure for remote command test is the following (port /i6 use):

```
deiniz /i6
xmode /i6 par=none stop=1 baud=9600 cs=8
iniz /i6
talk /i6
```

8.2 Using ACE with terminal connected to serial link.

The rear panel is equipped with a female DB-9 connector for RS-232 and RS-422 operation. A PC with windows 9.x or NT can be use as a terminal – one serial link must be configured for direct communication with the following setting:

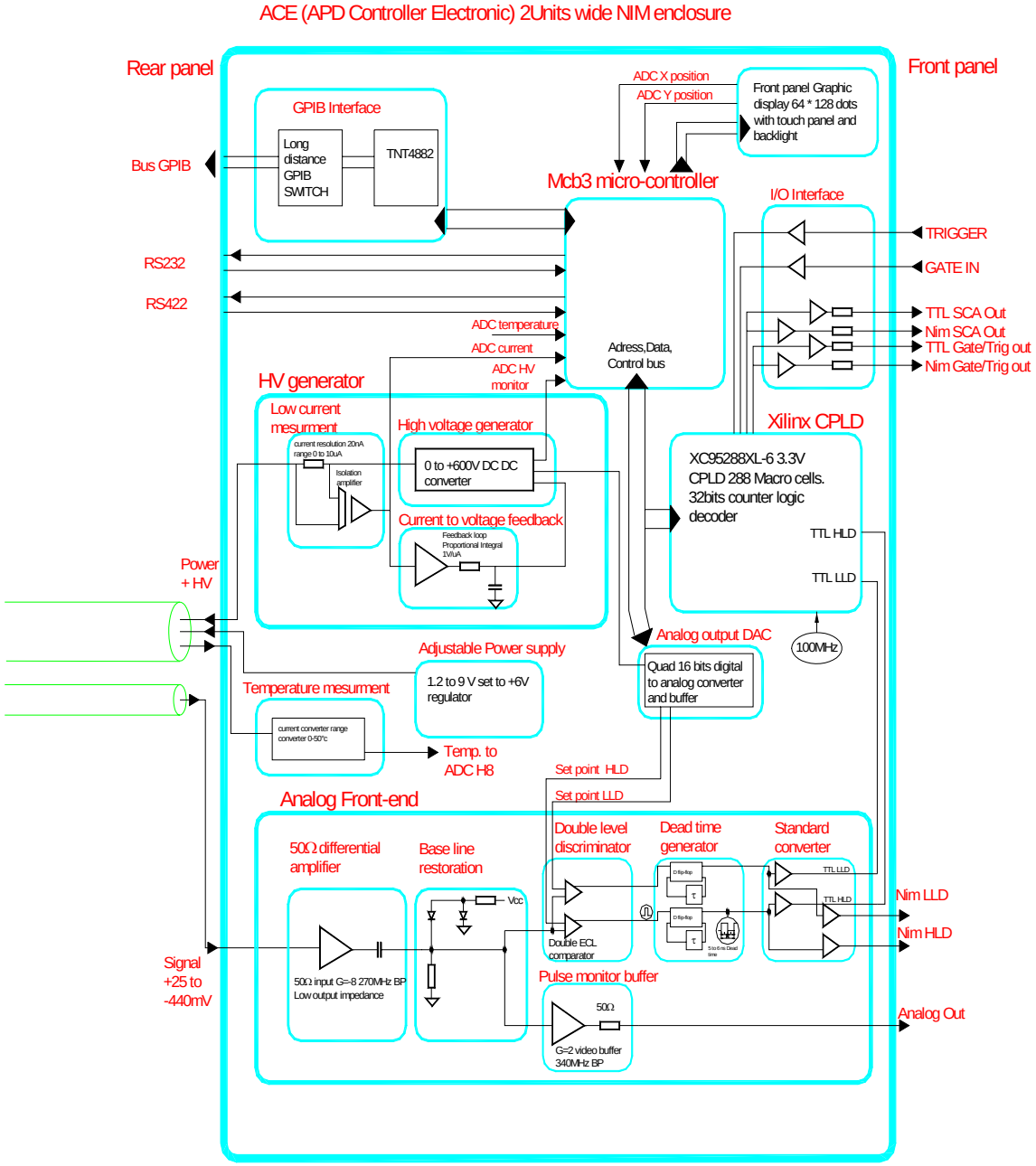
Bits per second: 9600 Baud
Data bits: 8
Parity: none
Stop bits: 1
Flow control: none

Type ECHO on the terminal connected to have echo typed characters locally.

Type ?INFO to get miscellaneous information about ACE and about the head.

9. Instrument overview

9.1 Block diagram



9.2 Signal input and discriminator

The analog signal input labelled head input on the rear panel is terminated into 50 ohms. This input accepts amplitudes from +25 to –440 mV. The typical signal amplitude from the head is pulses form -50 to -400 mV. An AC coupled amplifier with a gain of -8 follows the input. The bandwidth of this amplifier is 270MHz. Pulses form the head are inverted (gain of –8). The typical amplitude of the signal becomes +400mV to +3.2V internally (before the level discriminator circuit). A base line restoration circuit is introduced before a double level discriminator. This circuit removes any base line shift at high-count rate. This circuit creates a general offset of 200mV. The ACE firmware removes this offset and converts the discriminator range of to –0.2 to 5.0 V. For this reason, units

used for discriminator have 10 times the amplitude of the input signal. A monitor of the analog signal before discriminators is ready to be used with 50-ohms load. This output is labelled Analog Out on the front panel. A double level discriminator with threshold programmable from 0 to 5V can scan pulses from +25 to –440mv (referenced to the input). The threshold of the High level discriminator is set by a windows value from 0 to 5V for user easiness use and to avoid High level discriminator set under low level discriminator. A dead time generator is set at 5ns for pulse shaping. A direct NIM output is available on the front panel Labelled NIM LLD and NIM HLD. These two outputs are dedicated for time resolved experiments.

9.3 Counting

Discriminator outputs (LLD and HLD) are sent to a 32 bit counter. The counter can be set to count LLD only (integral mode) or LLD-HLD (window mode). The window mode is used to count an energy range. If the window is very small, a sliding window is used to resolve the pulse height distribution (energy resolution). All inputs and outputs, other than Analog out, NIM LLD, and NIM HLD are synchronic to a 100MHz clock and cannot be used for time resolve experiment. The module can be used as a simple 50MHz counter for TTL or NIM signal. The Trigger input can be use as an input, a remote command to switch the counter from SCA to Trigger input. See CSRC command for detail.

10. Example instrument setup

In this typical experiment the unit is required to count all photon from low to high energy. Remote commands are used in this example – the commands can be used by typing then manually into a simple terminal or with other specific programs.

Note - better results are achieved if a warm-up settling period of 1 hour is observed.

10.1 Instrument configuration

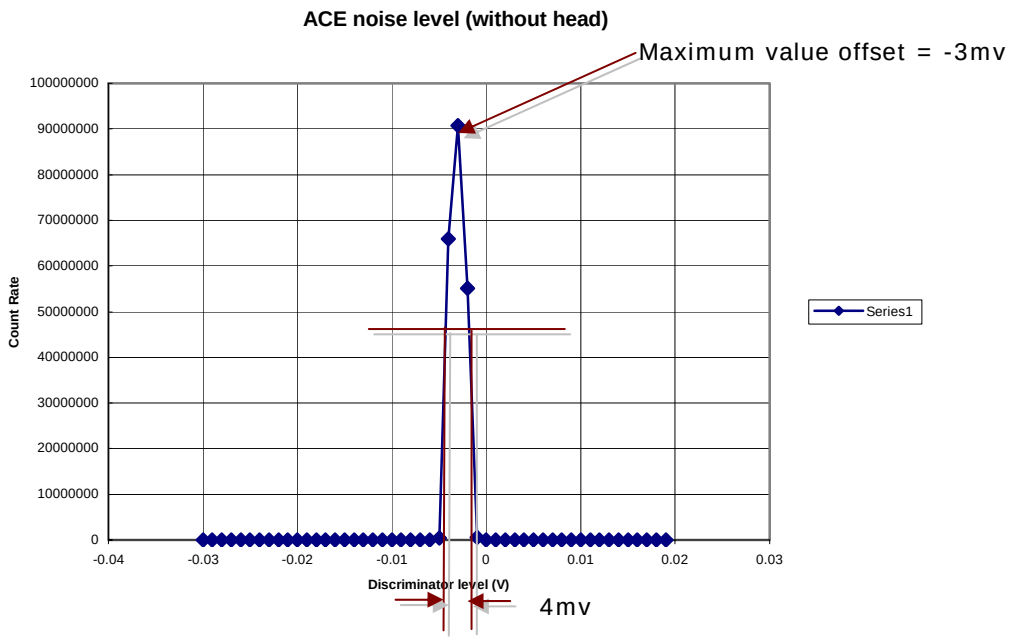
Before connecting the detector head the high voltage must be set to 0 using the following remote command: HVOLT 0. The command: ?HTEMP returns the temperature value of the head. If no head is connected to the module the temperature of the head should return as 0°C.

For this experiment we will use the internal counter and the internal time-base. To set this mode the command: CSRC SCA should be used.

We want to count all photons from low energy, at the limit of noise, to high energy. The integral mode of SCA must be set by the command: SCA INT .

10.2 Determination of offset value and noise due to ACE

As describe previously, the input signal to the ACE module is followed by an RF amplifier with a gain of -8. Without attaching a detector head, scan the discriminator threshold, LLTH, near 0mV, to determine the noise level of the module. The maximum count and the FWHM value give the noise level due to the RF amplifier integrated in the ACE module. Without a detector head the ACE FWHM should be about 4mv, and is equivalent to .5mv at the input.



In this scan, the integration time was 0.1s, if an integration time of 1s is used the count rate can reach 90MHz. This curve is made with a scan by remote control. Manually you need to send the following command for each point.

- Set discriminator level at -30mv, for example: SCA -.03

- Count 1s (1000000us) using internal counter and internal Time-base: TCT 1000000

- Read status of counter and value: ?CT DATA

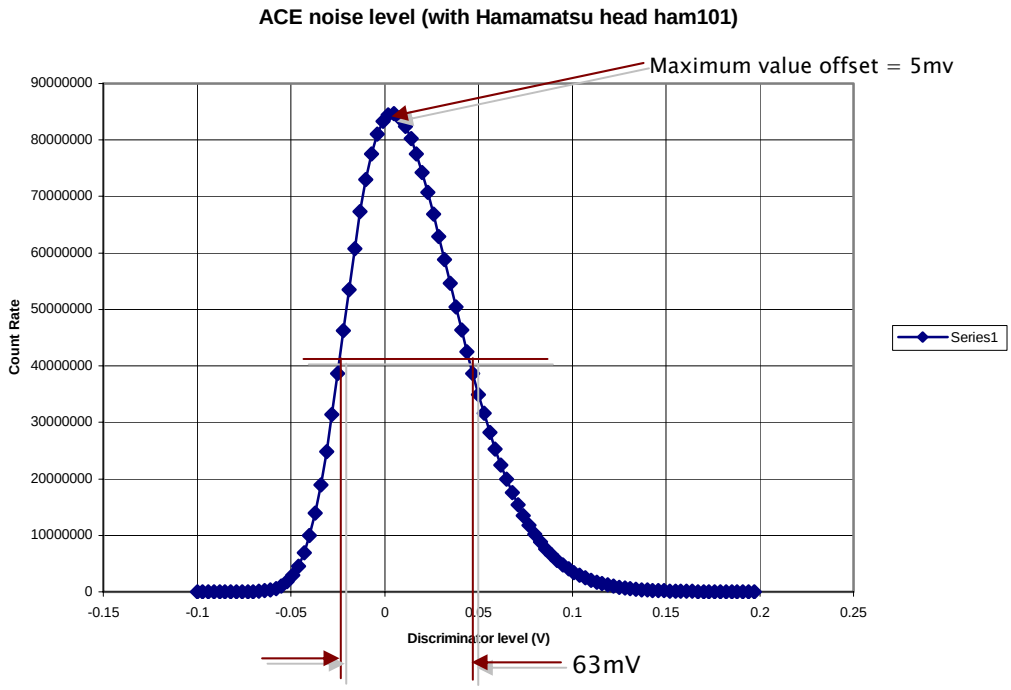
Response: D 0 1 1000000 80778615

Where D is for Down, 1000000 for the real integration time in us and 80778615 the counter value.

If the first character is not D repeat the read status command.

10.3 Determination of Noise Due to Head Preamplifier

At this stage the detector head should be connected to the ACE module. Without bias **(HVOLT 0),** the scan of the discriminator threshold LLTH near 200mV gives the following curve:



With the detector head attached the ACE FWHM is about 60mv and is equivalent to 6mv bring back to the input.

10.4 Measurement of X-ray in integral mode

When an experiment provides X-ray photons of 3 to 30 KeV the typical amplitude of pulses from the head are in the range of –50 to –400mV. After amplification the amplitude range is .4 to 3.2V , plus the 200mV offset due to the base line restorer circuit.

For most applications and general use, the bias voltage of the APD should be set at 80% of the Break down voltage (except time resolve experiments).

For the EG&G diode used in this head, with a 5mm x 5mm active area, the useful Bias voltage is in the range 300 – 360 V.

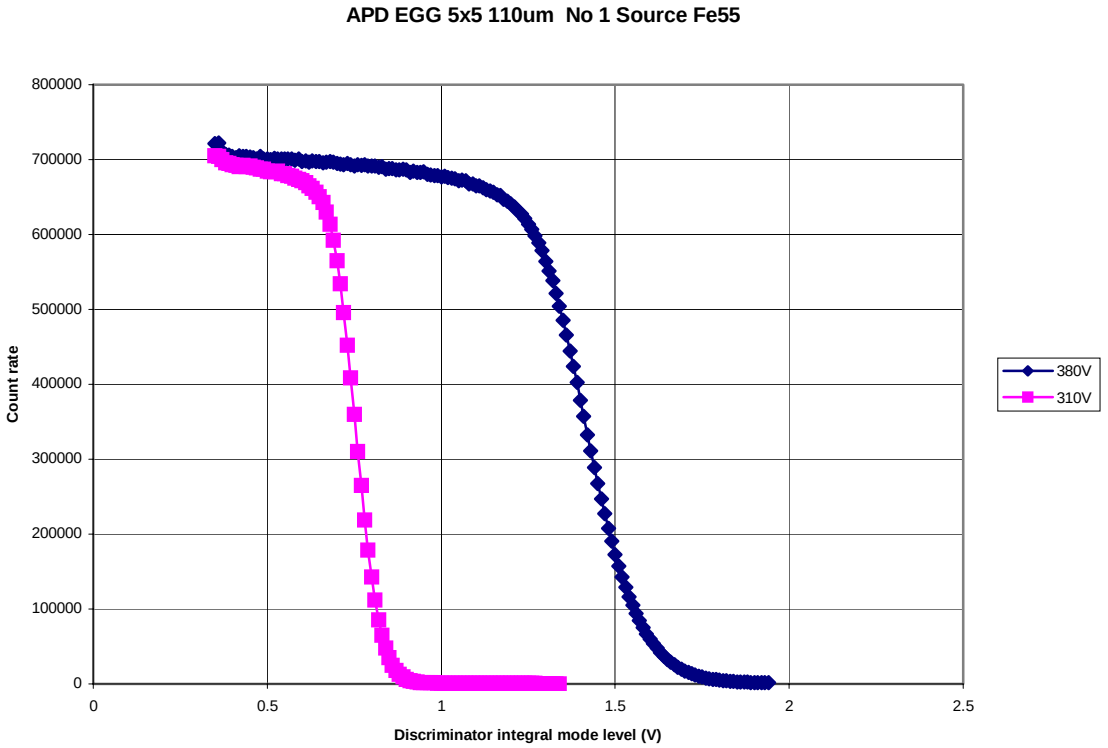
To set the High voltage bias, say to 310V, you have to type the following command: HVOLT310.

To verify the high voltage value you can type: ?HVMON The response should be, 311.44.

The value read can be a little bit different from the set point due to current compensation circuitry and the precision of A/D converters.

The EG&G 5x5 mm active area and 110um of thickness diode in this head has a breakdown voltage of 388V @ 27°C.

With a bias set to 80% of breakdown (310V) a scan of the discriminator threshold LLTH from .15 mV (end of noise) to 2V, gives the following curve:



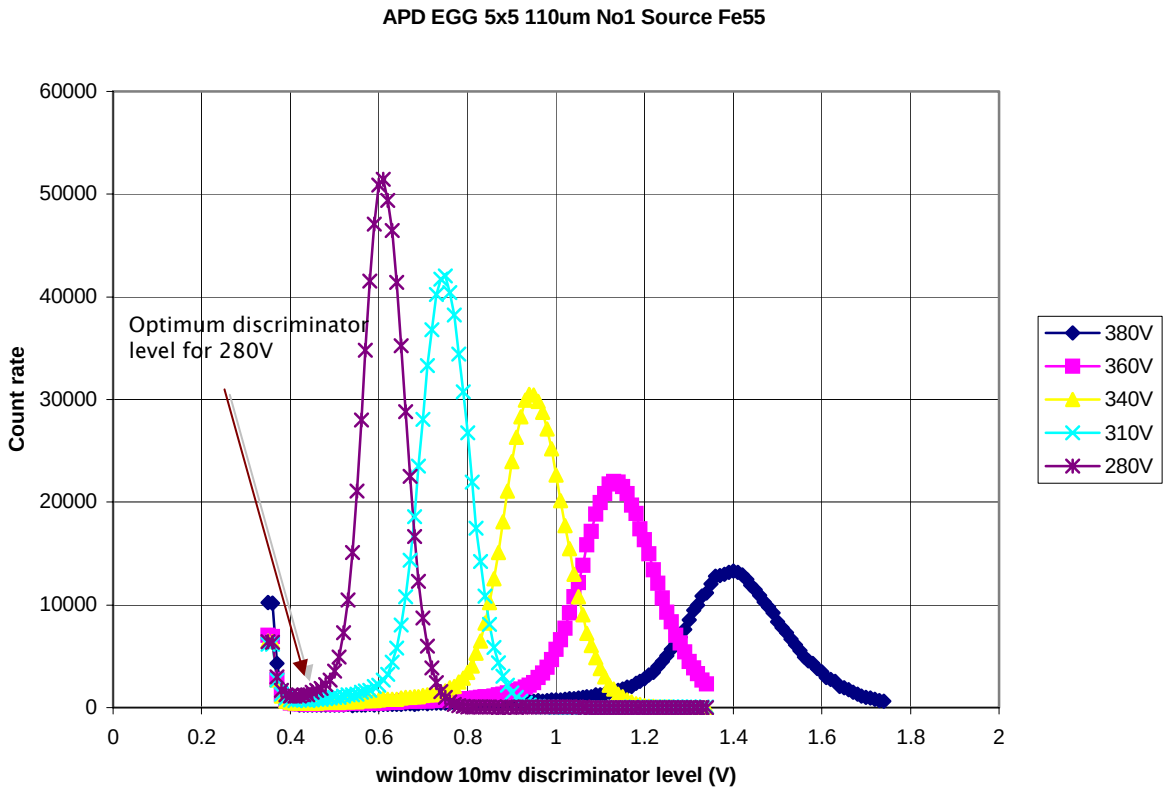
The integration time used was 1s for this test.

10.5 Measurement of X-ray in window mode

The window mode is an easy way to resolve the pulse height distribution. This information can be useful to optimise the gain of APD or to select energy from incoming X-ray photons.

In window mode the counter outputs the difference between the Low-level discriminator count and the High-level discriminator count. Users do not have access to the high-level discriminator threshold, only the difference between low level and high level; this difference is the window size. To resolve a pulse height distribution a window of 10 to 30mv is a good compromise between count rate and resolution.

The following examples were produced with a detector, utilising the APD EGG 5x5 mm diode, and an iron Fe55 radioactive source (≈6Kev). Different bias voltages were applied to find the optimum gain of APD.



The energy resolution (FWHM) versus bias voltage is:
Bias = 380V Energy resolution = 21% (optimal value for 6Kev)

Bias = 360V Energy resolution = 21.5%

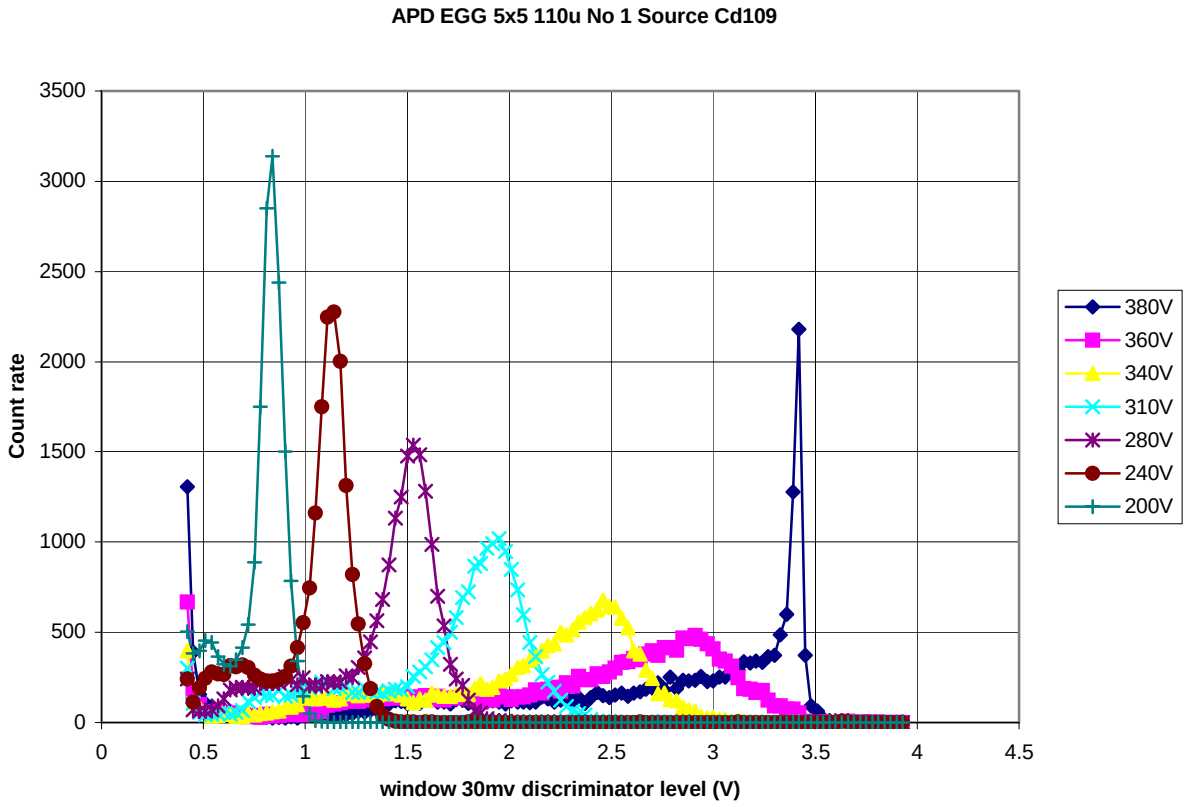
Bias = 340V Energy resolution = 21.6%

Bias = 310V Energy resolution = 22.7%

Bias = 280V Energy resolution = 27%

For the curve at 380V of bias, near breakdown value (this DUT as breakdown value of 388V) the noise level starts to increase.

The following curves utilised a cadmium Cd109 radioactive source (≈22Kev). Different bias voltages are applied to find the optimum gain of APD for this photon energy.



The energy resolution (FWHM) versus bias voltage is:

Bias = 380V Energy resolution = no measurement (saturation of input)

Bias = 360V Energy resolution = 26.6%

Bias = 340V Energy resolution = 24%

Bias = 310V Energy resolution = 22%

Bias = 280V Energy resolution = 18.5%

Bias = 240V Energy resolution = 17% (optimal value for 22Kev)

Bias = 200V Energy resolution = 20%

For the curve at 380V of bias, near breakdown value (this DUT as breakdown value of 388V) the noise level starts to increase. The saturation effects in window mode do not affect the integral mode and all photons over the low-level threshold discriminator value will be counted.

10.6 Conclusion

For simple counter use, the setting of bias voltage at 80% of the Breakdown voltage is a good compromise for a large scale of X-ray energy. The integral mode with the low level threshold

discriminator set at .15 to .2V (out of preamplifier noise) is a good working setting for most applications. For APDs larger than 5 x 5 mm of active area the user voltage will be close to Breakdown voltage (Vb-10V) due to an unfavourable signal to noise ratio.

11. Dead time

In all detector systems, there will be a minimum time between two events in order to be recorded as two separate pulses. This limitation is due to the detector or due to associated electronic.

11.1 ACE internal counter dead time

Due to the limited maximum count frequency of the internal counter of the ACE module a pulse shaper creates a dead time for external events. The same pulse shaper is used to generate SCA LLD and HLD NIM output. The fixed dead time value is 5.2ns. For a random radioactive source such as a sealed radioactive source or an X-ray generator, the simple nonparalyzable or paralyzable model can be use to find the true events rate.

Depending on the low-level discriminator threshold, the real model of the ACE unit will be close to the non-paralyable or paralysable model. For this reason compensation of dead time over 30% is not reliable.

For simple and first order compensation the non-paralyzable model can be use with the following expression:

$$n = m / (1-m \quad)$$

With n = true interaction rate

m = recorded count rate

= system dead time.

More detail about dead time corrections can be found in G.F. Knoll, Radiation Detection and Measurement, 1989 p120 to p128.

11.2 Dead time case study - ESRF temporal structure of X-ray beam

Due to the radio-frequency accelerating cavities, used in the ESRF storage ring to compensate for synchrotron radiation loss, the beam has a temporal structure directly link with the frequency used to supply the cavities. The 352.2 MHz Radio Frequency used at the ESRF generates 992 buckets in the electron beam travelling close to the speed of light along the 844.39m circumference.

The stable accelerator phase in the radio frequency cavities is narrow so 1 bunch will have a time size from 20 to 80 ps RMS (depending on the current density per bench) inside the 2.84ns bucket size.

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- In uniform filling mode, all the 992 buckets are filled. As describef above a temporal structure of 2.84ns is generated. Due to the dead time of the ACE electronics, adjacent bunches cannot be recorded. Only bunches separated by a minimum of 2 Radio Frequency periods can be recorded. The final dead time viewed by the internal counter of ACE will be 2x 2.84ns = 5.68ns.

- In 2 x 1/3 filling mode, two groups of 1/3 consecutive buckets are filled (about 331consecutive buckets) separate by a hole of 1/6 consecutive buckets unfilled (about 165 consecutive buckets). If the integration time is larger than the superstructure created in the storage ring, due to this specific filling mode (minimum of 300us of integration time to minimise stroboscopic effect of the superstructure), the final dead time will be 5.68ns x 3 / 2 = 8.52ns. The transition between a group of filled buckets and a group of unfilled buckets is a decay and is not well defined, the final dead time must be adjust to take account of this difference.

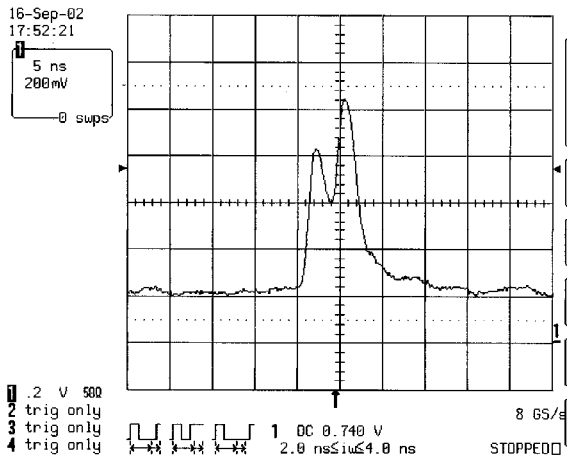
- In 16 bunches mode, 16 highly populated and equally spaced bunches (176ns of period) limit the count rate to 5.68MHz.

- In single mode, only one of the 992 buckets is filled (2.8us of period), which limits the count rate at 355KHz.

- In hybrid mode the pattern must be identified to determine the final dead time.

Without dead time correction, in uniform filling mode, the APD ACE system will be linear at 1% if the count rate is not over 2 MHz.

The following data was recorded with a digital oscilloscope (1GHz of band pass) using the Analog from the ACE unit. The detector used contained a 5 x 3 mm APD and the source was the ESRF port ID02 @ 12.5KeV in uniform filling mode.



With a low level threshold adjust near the noise level only one event can be recorded. In these picture 2.84 ns is the distance between pulses (1 Radio Frequency period).

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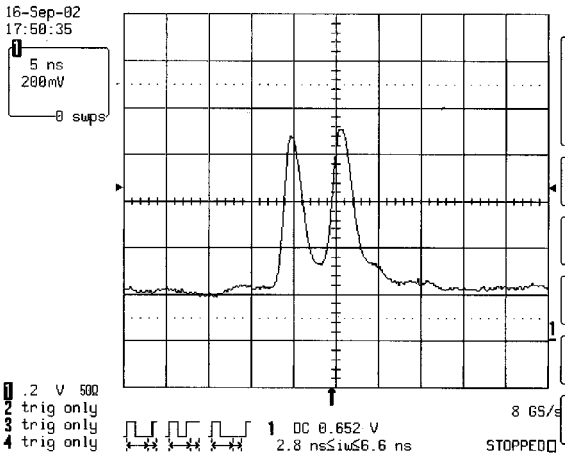
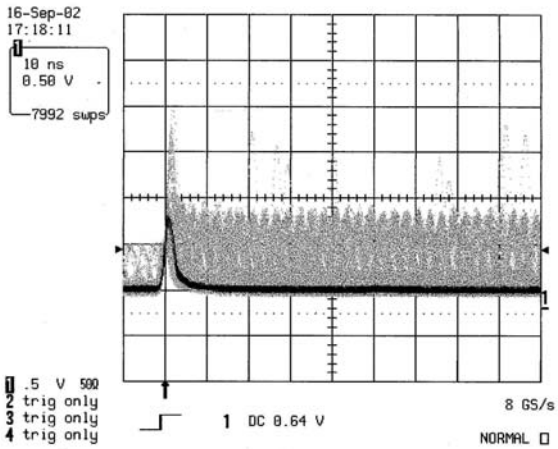


In these picture 5.6 ns is the distance between pulses (2 Radio Frequency periods). Internal counter of ACE recorded two events.



Using pseudo persistence mode of the oscilloscope, the structure @352MHz is visible. Pileup events are visible too: 2 X-ray photons recorded at the same time give a double high pulse.

11.3 Example of Dead time correction

For this test the mode of the machine was 2/3 filling. A linear detector is used as a reference for the X axis. The non-paralysable model with τ = 8.2ns is use to make dead-time corrections.

Dark blue curve = APD count rate before dead time correction (maximum dead-time = 32%)

Magenta curve = non-paralysable model τ = 8.2ns

Light blue curve = APD count rate after dead-time correction (linearity is inside ±1%)

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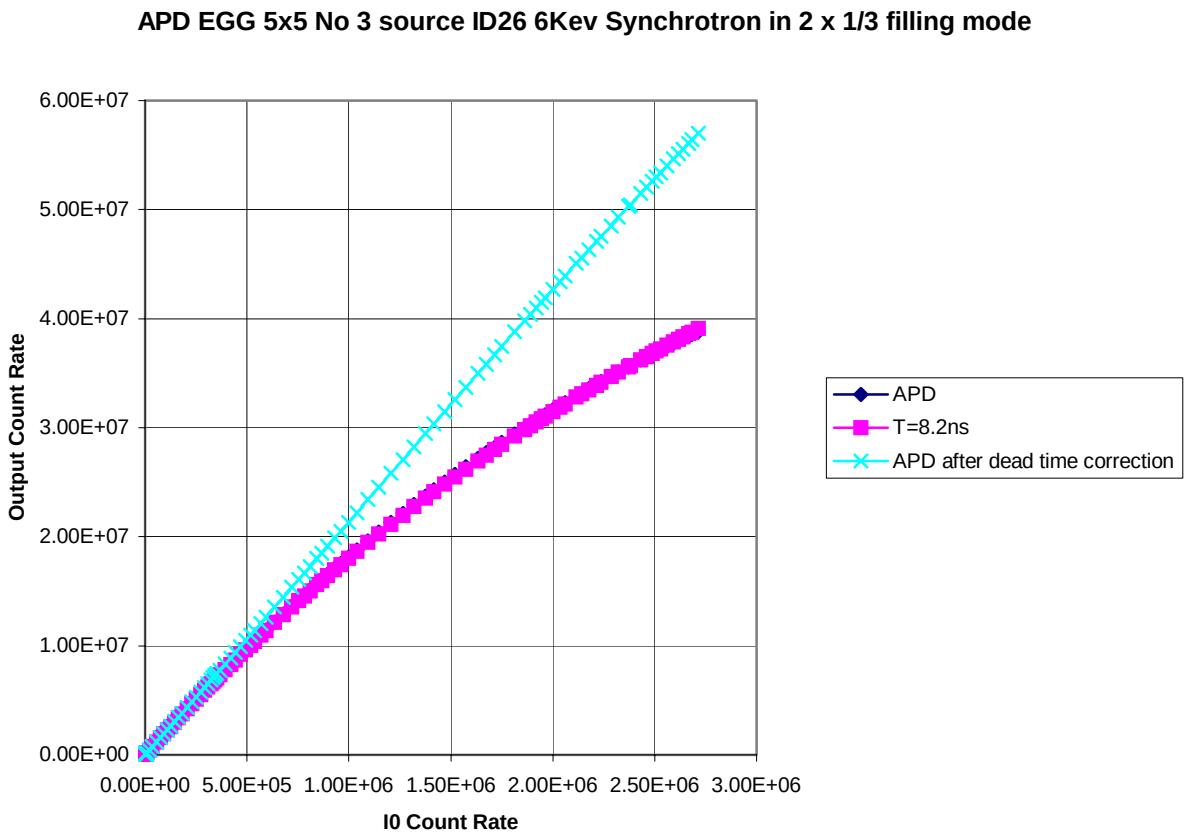
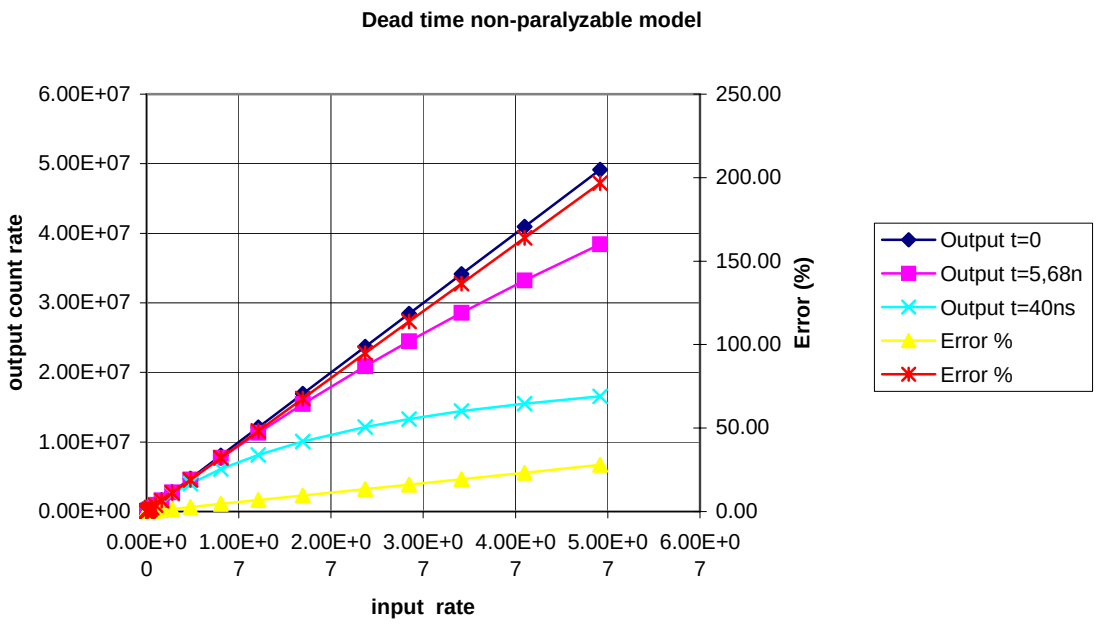


11.4 Degradation of dead time when using an external counter

Using an external counter will always deteriorate maximum count rate and dead time. As far as possible it is preferable to use the internal counter.

When using an external counter the pulse shaping has to be adjusted for compatibility with the performance of the external counter. In case of a VCT6 counter, the pulse shaping is adjusted to 20ns (best case) or 30ns. The final dead time for the external counter will be 40 or 60 ns.

The graph below shows some comparisons. The dark blue curve is an ideal counter without dead time. The magenta curve is the internal counter (τ = 5.68ns). The cyan curve is the external counter with 20ns of shaping time (τ = 40ns). The Yellow curve is the error in % of the internal counter (28% @ 50MHz). The Red curve is the error in % of an external counter with 20ns of shaping time (32%@8MHz).


Dead time non-paralyzable model
output count rate
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
250.00
200.00
150.00
100.00
50.00
0.00
Error (%)
0.00E+0 0
1.00E+0 7
2.00E+0 7
3.00E+0 7
4.00E+0 7
5.00E+0 7
6.00E+0 7
input rate
Output t=0
Output t=5,68n
Output t=40ns
Error %
Error %