REFERENCES

1. F.S. Goulding. Pulse-shaping in Low-noise Nuclear Amplifiers a physical approach to noise analysis. Nuclear Instruments and Methods vol.100 1972: 493-504.
2. F.S. Goulding, D.A. Landis. Signal processing for Semiconductors. IEEE Nuclear science Vol.29 1982: 1125-1141.
3. E.Fairstein. Linear Unipolar pulse-shaping networks :current technology. IEEE Nuclear science Vol.37 1990: 382-397.
4. Willy M.C. Sansen, Zhong Yuan Chang. Limits of Low Noise Performance of Detector Readout Front Ends in CMOS Technology. IEEE Nuclear science Vol.37 1990: 1375-1382.
5. Alberto Pullia, Angelo Geraci, Giancarlo Ripamonti. On-Field Determination of the Minimum-Noise Filter for Digital Radiation Spectrometers. IEEE Nuclear science 1998: 722-725.
6. A. Pullia, G.Ripamonti. Minimum-noise filter for baseline estimation in radiation detection systems. Nuclear Instruments and Methods A376 1996: 82-88.
7. A. Pullia, G. Ripamonti, D. Santo. Minimum-Noise filter for Baseline Estimation in Radiation Detection Systems. IEEE Nuclear science1996: 263-266.
8. A.Pullia , G.Gritti , G.Ripamonti. Design of high performance digital baseline restorers. IEEE Nuclear science Vol.44 1997: 331-337.
9. E. Gatti, A.Geraci, G. Ripamonti. Optimum filters from experimentally measured noise in high resolution nuclear spectroscopy. E.Fairstein. Linear Unipolar pulse-shaping networks :current technology. Nuclear Instruments and Methods A417 1998: 131-136.
10. E. Gatti, A.Geraci, G. Ripamonti. Optimum filter for 1/f current noise smoothed –to-white at low frequency. F.S. Goulding, D.A. Landis. Signal processing for Semiconductors. Nuclear Instruments and Methods A394 1997: 268-270.
11. Angelo Geraci, Emilio Gatti. Optimum filters for charge measurements in the presence of 1/f current noise. Nuclear Instruments and Methods A361 1995: 277-289.

12. A.geraci, G.Ripamonti, A.Pullia. An automatic initialization procedure for real-time digital radiation spectrometry. Nuclear Instruments and Methods A403 1998: 455-464.

13. Alberto Pullia. Impact of non-white noises in pulse amplitude measurements: a time-domain approach. Nuclear Instruments and Methods A405 1998: 121-125.

14. A.Geraci. Asymmetrical optimum filters for charge measurements in presence of 1/f current noise. . Nuclear Instruments and Methods A386 1997: 487-491.

15. A. Pullia, A. Geraci, G.Ripamonti. Quasi-optimum γ and X spectroscopy based on real-time digital techniques. Nuclear Instruments and Methods A439 2000: 378-384.

16. Alberto Pullia. How to derive the optimum filter in presence of arbitrary noises, time-domain constraints, and shaped input signals:A new method. . Nuclear Instruments and Methods A397 1997: 414-425.

17. Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon. Statiscal and Adaptive Signal Processing. : McGraw Hill, 2000.

18. P.W. Nicholson. Nuclear Electronics. :John Wiley & Sons,1974.

19. Ethan L. Hull, Richard H. Pehl, Craig Tindall, Paul N. Luke and James D. Kurfess. Radiation damage and charge collection effects in Si(Li) gamma-ray detectors. Nuclear Instruments and Methods A496 2003: 123-128.

20. P.F. Manfredi, M. Manghisoni, L.Ratti, V. Re, V. Speziali. Resolution limits achievable with CMOS front-end in X- and Gamma ray analysis with semiconductor detectors. Nuclear Instruments and Methods A512 2003: 167-187.

21. Werner Buttler, Bedrich J., Hosticka. A JFET-CMOS Radiation-Tolerant Charge-sensitive Preamplifier. IEEE journal of solid-state circuits Vol.25 1990: 1022-1024.

22. Angelo Geraci, Emilio Gatti. A new class of optimum filters with complete rejection of periodic noise disturbances. IEEE Nuclear science Vol.25 2002: 1009-1013.

23. G.P. Westphal, K. Jostl, P. Schroder, W. Winkelbauer. Adaptive Digital Filter for High-Rate High-Resolution Gamma Spectrometry. IEEE Nuclear science Vol.48 2001: 461-464.

24. P.J.M.B. Rachinhas, T.H.V.T. Dias, F.P. Santos, A.D. Stauffer, C.A.N. Conde. Monte Carlo Simulation of Xenon Filled Cylindrical Proportional Counter. IEEE Nuclear science Vol. 41 1994: 984-988

25. R.P. Gardner, S.H. Lee. Monte Carlo Simulation of Pulse Pile up. 2004 Denver X-ray Conference, USA, August 2-6, 2004

26. E. Karvelas , D. Loukas, A. Markou, A.H. Walenta. Calculation of pile-up effect in X-ray detection with large area circular silicon drift detectors. Nuclear Instruments and Methods A406 1998: 59-68.

27. . M. Brigida, C. Favuzzi, P. Fusco, F. Gargano, N. Giglietto, F. Giordano, F. Loparco, B. Marangelli, M.N. Mazziotta, N. Mirizzi, S. Raino, P. Spinelli. A new Monte Carlo code for full simulation of silicon strip detectors. Nuclear Instruments and Methods A533 2004: 322-343.

28. M.Kuwata,R.Isobe. Noise Analysis of a Pulse Processor Using SPICE. IEEE Nuclear science Vol.46 1999: 1876-1879.

29. Tae-Hoon Lee, Gyuseong Cho. Monte Carlo based time-domain Hspice noise simulation for CSA-CRRC circuit. Nuclear Instruments and Methods A505 2003: 328-333.

30. Alberto Pullia, Stefano Riboldi. Time-Domain Simulation of Electronic Noises. IEEE Nuclear science Vol. 51 2004: 1817-1823.

31. REUVEN Y.,RUBINSTEIN. SIMULATION AND THE MONTE CARLO METHOD. : John Wiley & Sons, 1981.

32. Averill M.Law,W.David Kelton. SIMULATION MODELING AND ANALYSIS. :McGraw-Hill, 1982.

33. C.D. MOTCHENBACHER. LOW-NOISE ELECTRONIC SYSTEM DESIGN. :John Wiley & Sons, 1993.

34. Craig S. Petrie, J. Alvin Connelly. THE SAMPLING OF NOISE FOR RANDOM NUMBER GENERATION. IEEE Circuits and Systems Vol.6 1999: 26-29

35. R.W.Harris. INTRODUCTION TO NOISE ANALYSIS. :Pion limited, 1974.

36. P.Silva Girao. Characterization of Noise Generators: Automated Measuring System for the Determination of the Probability Distribution and Autocorrelation Function. IEEE 1994.

37. Patrick Bilingsley. Probability and Measure. : John Wiley & Sons, 1979.

38. Steven W. Smith. The scientist and engineer's Guide to Digital Signal Processing. Second edition. :California Technical Publishing. 1997

Appendices

APPENDIX A. The summary of all applied MATLAB function

This section provides a quick review of all MATLAB function applied in this research work. For more detail type *help command* at Command Window.

Function	Description
abs	Compute the absolute value.
butter	Butterworth digital and analog filter design.
conv	Convolution sum computation.
ecdf	Calculate the cumulative distribution function of data values.
fclose	Close file.
fft	Computes the discrete Fourier transform coefficients.
filter	Create the filtered data from the input data and the filter coefficients.
fix	Rounds towards zero.
fopen	Open file.
fprintf	Write formatted data to file.
fscanf	Read formatted data from file
ifft	Computes the inverse discrete Fourier transforms coefficients.
imag	Determine the imaginary part of complex number.
max	Determine the largest element of a vector.
mean	Determine average or mean data values.
min	Determine the smallest element of a vector.
plot	Generate linear 2-dimension plot.
psd	Power spectral estimation via Welch's method.
rand	Generated pseudorandom number that is uniformly distribution over 0,1.
real	Determines the real part of complex number.
serial	Construct serial port object.
set	Set object properties.
std	Determine the standard deviation of data values.
tfe	Transfer function estimation from input and output of system.
zeros	Create array of zero.

APPENDIX B. The summary of an applied script files

This section provides a description and detail of MATLAB script files applied in this research work.

Function	Description
comm	Establish communication between TDS 360 and computer.
tdstmp	Setup the controlled parameters of TDS 360.
tdsver	Get amplitude multiplies and offset parameter.
tdsdaq	Acquire data from TDS 360.
tdsacc	Acquire a set of data from TDS 360.
commclose	Close communication between TDS 360 and computer.
noise	Generate random number from arbitrary cumulative distribution function
events	Generate time interval.
signal_sim	Generate preamplifier output signal.
cfilter	Calculate digital filter from an arbitrary frequency response.

1. **[out,tds_comm]=comm**

```
tds_comm = serial('COM1');
set(tds_comm,'BaudRate',9600);
set(tds_comm,'InputBufferSize',2014);
set(tds_comm,'Timeout',2);
set(tds_comm,'Terminator','CR');
fopen(tds_comm);
fprintf(tds_comm,'*IDN?')
out= fscanf(tds_comm);
```

2. **tdstmp(tds_comm)**

```
%Turn off the header from query responses.
cmd=['HEADER OFF' char(13)]
fprintf(tds_comm,cmd)
%Set up the data source to be channel 1.
cmd=['DATA:SOURCE CH1' char(13)]
```

```
fprintf(tds_comm,cmd)
%Set up the data encodeing to be ribinary and data width to 1.
cmd=['DATA:ENCDG RIBINARY;WIDTH 1' char(13)]
fprintf(tds_comm,cmd)
%Set up the record length, which start from 1 stop at 1000
cmd=['HORIZONTAL:RECORDLENGTH 1000' char(13)]
fprintf(tds_comm,cmd)
%Start at 1
cmd=['DATA:START 1' char(13)]
fprintf(tds_comm,char(13))
%Stop at 1000
cmd=['DATA:STOP 1000' char(13)]
fprintf(tds_comm,cmd)
cmd=['HEADER OFF' char(13)]
fprintf(tds_comm,cmd)
```

3. **[yoff,ymult]=tdsver(tds_comm)**

```
%fprintf(tds_comm,'HEADER OFF')
cmd=['WFMPRE:CH1:YOFF?' char(13)];
fprintf(tds_comm,cmd)
yoff=fscanf(tds_comm);
fprintf(tds_comm,'HEADER OFF')
%for i=1:200000
%end
cmd=['WFMPRE:CH1:YMULT?' char(13)];
fprintf(tds_comm,cmd)
ymult=fscanf(tds_comm);
```

4. **[sample]=tdsdaq(tds_comm,ymult,yoff)**

```
[yoff,ymult]=ptdsver(tds_comm)
sample=[];
for i=1:10
[volt,wave]=ptdsacc(tds_comm,ymult,yoff);
```

```
sample=[sample;wave];
i
end
```

5. [volt,wave]=tdsacc(tds_comm,ymult,yoff)

```
fprintf(tds_comm,'ACQUIRE:STATE RUN')
%Wait for the scopr to acquire data
for i=1:40000
end
%Send scope curve query to get waveform data
fprintf(tds_comm,'CURVE?')
%Read data waveform
%Wait for the scopr to acquire data
%for i=1:100000
%end
%volt = fscanf(tds_comm);
volt=fread(tds_comm,2014,'uint8');
%Turn off the header from query responses.
fprintf(tds_comm,'HEADER OFF')
volt=volt(7:1007);
%volt=volt(2:1000);
for i=1:1000
   %if volt(1+i*2)>127
    if volt(1)>127
      volt(i)=volt(i)-256;
   end
end
for i=1:1000
   %wave(1+i)=volt(1+i*2)*256+volt(2+i*2)-sscanf(yoff,'%f');
   wave(i)=volt(i)-sscanf(yoff,'%f');
end
wave=wave*sscanf(ymult,'%f');
```

6. commclose(tds_comm)

```
fclose(tds_comm)
delete(tds_comm)
clear tds_comm
```

7. [sim]=noise(f,x)

```
%Generate random number
rnd=rand(1,1);
id=1;
while f(id) < rnd
   id=id+1;
end
id=id-1;
%id=16
if id==24
   sim=x(24);
else
   dsim=(rnd-f(id))*(x(id+1)-x(id))/(f(id+1)-f(id));
   %dsim=0;
   sim=x(id)+dsim;
end
```

8. [event,count]=events(lambda,preset_time)

```
% This function returns time series of disintegration.
% 'event' is time series.
% 'count' is number of photons
% 't' is time distribution
a=0;
c=1;
while a<preset_time
   t(c)=photon_gen(lambda);
   % loop unitl reach preset_time
   a=a+t(c);
```

```
   % counting
   c=c+1;
end
v=size(t);
count=v(2);
N=ones(1,count+1);
% stem(t,N)
% t=t';
event(1)=0;
for i=1:count
   event(i+1)=event(i)+t(i);
end
count=count+1;
```

9. [v,t_sim,event,count]=signal_sim(a,lambda,preset_time,resol)

```
% event is time serie driven from events.m
% a is amplitude
[event,count]=events(lambda,preset_time);
% Time digitizer resolution is 1e-8
% resol=1e-8;
b=1;
s=size(event);
v=zeros(fix(preset_time/resol)+1,1);
t_sim=zeros(fix(preset_time/resol)+1,1);
for t=0:resol:preset_time
     for i=1:1:s(2)
   if t>event(i)
      v(b)=v(b)+a*exp((t-event(i))/-50e-6);
   end
end
 t_sim(b)=t;
 b=b+1;
```

```
end
```

10. [ht]=cfilter(h)

```
% h is frequency response
a=size(h);
na=a(1);
t=zeros(na,1);
% Kernel length
% old value 26/4/2004 M=100;
%M=5000;
M=1000
% Shift filter kernel length
%for i=1:a
%   j=i+M/2;
%   if j>a
%       j=j-a-1
%   end
%   t(j)=h(i);
%end
%TEMPLATE
%b(1:M/2)=a(na-M/2+1:na)
%b(1+M/2:na)=a(1:na-M/2)
t(1:M/2)=h(na-M/2+1:na);
t(1+M/2:na)=h(1:na-M/2);
% Truncate and window the signal
for i=1:a
   if i<= M
      % Hamming windows
      %t(i)=t(i)*(0.54-00.46*cos(2*pi*i/M));
      % Blackman
      t(i)=t(i)*(0.42-0.5*cos(2*pi*i/M)+0.08*cos(4*pi*i/M));
   end
```

APPENDIX C.1 CANBERRA 2022 Spectroscopy amplifier specification

Specifications

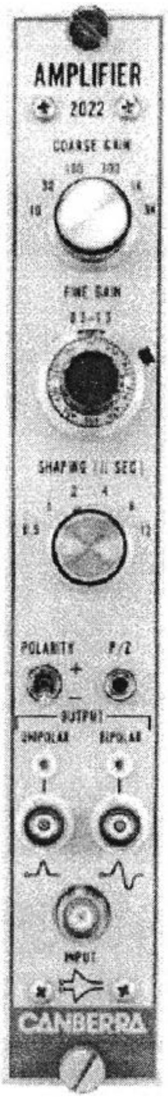
INPUTS

INPUT – Accepts positive or negative pulses from an associated preamplifier; amplitude: ±10 V divided by the selected gain for linear response; ±12 V maximum; rise time: less than SHAPING time constant; decay time constant: 40 µs to ∞ for 0.5, 1, 2, 4 and 8 µs shaping time constants, 100 µs to ∞ for 12 µs shaping time constant; $Z_{in} \approx 1\ k\Omega$; front and rear panel BNC connectors.

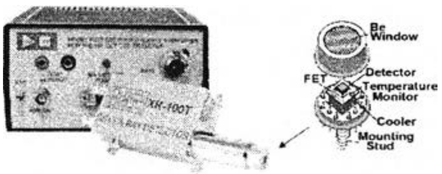
OUTPUTS

UNIPOLAR OUTPUT – Provides positive linear active-filtered near-Gaussian shaped pulses; amplitude linear to +10 V, 12 V max.; dc restored; output dc level factory calibrated to 0±5 mV; front panel $Z_{out} < 1\ \Omega$ or ≈ 93 Ω, internally selectable; rear panel $Z_{out} \approx 93\ \Omega$; short circuit protected; prompt or delayed 2 µs with option 2022-2 or 4 µs with option 2022-4; front and rear panel BNC connectors.

BIPOLAR OUTPUT – Provides prompt positive lobe leading linear active-filtered bipolar-shaped pulses; amplitude linear to −10 V, 12 V max., negative lobe is approximately 70% of positive lobe; dc coupled; output dc level ≈25 mV; front panel



APPENDIX C.2 XR-100T-CdTe radiation detector specification



SPECIFICATIONS

MODEL XR-100T-CdTe
X-RAY and GAMMA RAY DETECTOR

GENERAL

Detector Type:	CdTe-Diode
Detector Size:	3 x 3 mm (9 mm^2)
Detector Thickness:	1 mm
Energy Resolution @ 122 keV, ^{57}Co:	<1.2 keV FWHM, typical
Dark Counts:	<5 x 10^{-3} counts/sec @ 10 keV < E < 1 MeV
Detector Window:	Be, 10 mil thick (250 µm)
Preamplifier:	Amptek Model A250, with Current Divider Feedback
Case Size:	3.75 x 1.75 x 1.13 in (9.5 x 4.4 x 2.9 cm)
Case Weight:	4.4 ounces (125 g)
Total Power:	Less than 1 Watt

INPUTS

Test Input:	20 mV test pulse ~ 30 keV
Preamp Power:	± 8 Volts @ 25 mA
Detector Power:	+ 400 Volts @ 1 µA
Cooler Power:	Current = 0.7 A maximum Voltage = 2.1 Volt maximum

OUTPUTS

1) Preamplifier	
Sensitivity:	0.82 mV/keV
Polarity:	Negative Signal Out (1 kΩ max. load)
2) Temperature Monitor	
Sensitivity:	1 µA corresponds to 1 °K

CONNECTIONS

Preamp Output:	BNC coaxial connector
Test Input:	BNC coaxial connector
Other connections:	6-Pin, LEMO connector with 5 ft cable

OPTIONS

- Other detector sizes (5 x 5 x 1 mm^3) are available on special orders.
- Other Be window thicknesses are available.
- Components for vacuum applications.
- Collimator kit for high flux applications.
- See also XR-100CR specifications using Si-PIN for detection of low energy X-Rays with high resolution (186 eV FWHM @ 5.9 keV, ^{55}Fe).

6-PIN LEMO CONNECTOR ON THE XR-100T-CdTe

Pin 1: +8 Volt temperature monitor power
Pin 2: + H.V. detector bias, +400 Volt max
Pin 3: -8 Volt preamp power
Pin 4: +8 Volt preamp power
Pin 5: Cooler power return
Pin 6: Cooler power (0 to +2.1 Volt @ 0.7 A max.)
CASE: Ground and shield

MODEL PX2T
POWER SUPPLY + SHAPING AMPLIFIER

GENERAL

Size:	6 X 6 X 3.5 inches (15.3 X 15.3 X 8.9 cm)
Weight:	2.5 lbs (1.15 kg)

Input AC power to the PX2T is provided through a Standard IEC 320 plug (110/250 VAC, 50/60 Hz). See Figure 3.

The four (4) DC Voltages needed to operate the XR-100T-CdTe are supplied through a female 9-Pin D-Connector on the PX2T. The Pin list to this connector is given below. The multiconductor cable which connects the PX2T to the XR-100T-CdTe is provided with the system.

9-PIN D-CONNECTOR ON THE PX2T-CZT

Pin 1: +8 Volt preamp power
Pin 2: -8 Volt preamp power
Pin 3: 0 to +3 Volt cooler power @ 0.7 A max.
Pin 4: +8 Volt temperature monitor power
Pin 5: + H.V. detector bias, +400 Volt max.
Pin 6: Ground and case
Pin 7: Cooler power return
Pin 8: Ground and case
Pin 9: Ground and case

PX2T SHAPING AMPLIFIER

Polarity:	Positive Unipolar
Shaping Time:	3 µs
Pulse Width:	7.2 µs FWHM. See Figure 4
Shaping Type:	7 pole "Triangular" with Base Line Restoration, Pileup Rejection, and Rise Time Discrimination (RTD).
Sensitivity with XR-100T-CdTe:	6 to 60 mV/keV
Output Range:	+6.0 Volts into 500 Ω load
Output Impedance:	50 Ω

The output pulse produced by the PX2T Shaping Amplifier is optimum for most applications using cooled CdTe detectors, and can be connected directly to the input of a Multichannel Analyzer (MCA). If different shaping time constants or gains are needed, an external NIM type shaping amplifier with base line restoration can be used.

PX2T SIGNAL CONNECTIONS

Input from XR-100T-CdTe:	Front panel BNC
Output to MCA:	Front panel BNC
Pileup Rejection (PU):	Rear panel BNC, Positive TTL For the duration of this output gate, any detected pulse must be rejected by the MCA.
Input Count Rate (ICR):	Rear panel BNC, Positive TTL <2 µs When connected to a counter, the ICR countrate corresponds to the total number of X-Rays events that strike the detector.

Biography

Mr.Hudsaleark Neamintara was born on January 20,1966 in Bangkok, Thailand. He got his Bachelor Degree from the Department of Radiological Technology, Faculty of Associated Medical Sciences, Chiangmai university in 1988 and Master degree from Department of Nuclear Technology, Faculty of engineering, Chulalongkorn university in 1993. At present he serves as Lecturer in the field of X-ray Diagnostic Apparatus, Department of Radiological Technology, Faculty of Associated Medical Sciences, Chiangmai University. In May 2000, he was awarded a grant from Chiangmai University to further his study for the Doctoral Degree at the Department of Nuclear Technology, Faculty of Engineering, Chulalongkorn University.