UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT AND CHARACTERIZATION OF READOUT ELECTRONICS FOR NEUTRON SCATTERING INSTRUMENTATION

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DEVELOPMENT AND CHARACTERIZATION OF READOUT ELECTRONICS FOR NEUTRON SCATTERING INSTRUMENTATION

By

LOJIUS BIN LOMBIGIT

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for Degree of Master Science

May 2012

DEDICATIONS

Dedicated to my beloved wife & son

Rollyne Alip & Luke Ryan Lombigit

for their endless support

My parent,

Late Abel Lombigit Bolukis and Rubeca Ladom

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
In fulfilment of the requirement for the degree of Master of Science

DEVELOPMENT AND CHARACTERIZATION OF READOUT ELECTRONICS FOR NEUTRON SCATTERING INSTRUMENTATION

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LOJIUS BIN LOMBIGIT

May 2012

Chair: Associate Professor Mohd. Nizar Bin Hamidon, PhD

Faculty: Faculty of Engineering

In the field of material characterization, the neutron scattering technique is found to be useful in many applications. This technique requires a position sensitive neutron detector (PSND) and their readout electronics to detect the position of neutron interactions. Fast, high count rate and high positional resolution PSND such as the ^{3}He-filled Multi-Wire Proportional Counter (MWPC) is designed for specific applications and has unique technical specifications. Therefore, it requires customised readout electronics which capable of accepting a wide range input signal, good noise/ENC performance or fast signal processing to match their specifications. In order to optimize the detector' performance in terms of speed, count-rate, and positional resolution, the individual readout method is often employed as positional

encoding method to detect the neutron interactions. In this method, each wire are connected to an individual readout electronic and if the applications requires large active area detector, a large number of readout electronics are required thus, increased the development cost. This study presents the design and development of readout electronics comprise of an eight (8) channels low noise charge sensitive preamplifier-pulse shaping amplifier (CSP-PSA) chain capable of accepting a wide range input signal and fast signal processing which is ideal for high count rate and high position resolution neutron scattering instrumentations.

The readout electronic circuit is built entirely with low-noise FET-input operational amplifier (Op-amp) and passive components. The time constant for charge sensitive preamplifier (CSP) is around 250 ns and it is equipped with an additional T-network at output stage. The pulse-shaping amplifier (PSA) is designed based on a fifth-order complex-pole semi-Gaussian filter; comprising a cascade first-order high-pass filter (HPF) with pole-zero (PZ) cancellation networks and two second-order Sallen-Key low-pass filters (SK LPF). These circuits are designed using Laplace transform then verified with macro model component-based simulation. A series of testing had been carried out to measure how well the actual performance fulfilled the major objective. These procedures include measurements of direct-current (DC)

offset, dynamic range, gain, linearity, electronic noise and analysis of time over threshold (TOT).

The development cost of the readout electronics is around U.S $50/channel, which is suitable for low-cost applications. Results showed that the readout electronics has good electronic noise with measured Equivalent Noise Charge (ENC) average at 2108 e^- ± 10% and insensitive to input capacitance variation (25 e^-/pF). Charge calibration using the TOT method shows that it can separate small difference of charge and capable of accepting a wide dynamic range input charge (20-600 fC) with excellent linearity (nonlinearity < 1%). Fast peaking time around 300 ns and short pulse width around 1.2 - 1.6 us, shows that it can be used for fast detector with count rate capability below 50 kHz at 10% dead time.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN DAN PENCIRIAN LITAR PEMBACA-KELUAR ELEKTRONIK UNTUK INSTRUMENTASI PENYERAKAN NEUTRON

Oleh

LOJIUS BIN LOMBIGIT

Mei 2012

Pengerusi: Profesor Madya Mohd. Nizar Bin Hamidon, PhD

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Dalam bidang pencirian bahan, teknik penyerakan neutron didapati sangat berguna dalam pelbagai aplikasi. Teknik ini memerlukan pengesan neutron peka kedudukan (PSND) dan juga litar pembaca-keluar elektronik yang khusus untuk mengesan kedudukan tindakbalas neutron tersebut berlaku. Pengesan yang mampu mengesan tindakbalas neutron pada kadar yang pantas serta kadar bilang dan peleraian kedudukan yang tinggi seperti pembilang berkadaran berbilang dawai (MWPC) yang diisi dengan gas ^{3}He biasanya direkabentuk untuk aplikasi tertentu dan mempunyai spesifikasi teknikal yang unik. Oleh itu, ia memerlukan sebuah litar pembaca-keluar elektronik yang berupaya untuk menerima isyarat masukan pada julat yang besar, prestasi hingar elektronik/ENC yang baik atau mampu memproses

isyarat pada kadar yang pantas. Kaedah mengekod kedudukan dengan menggunakan teknik pembaca-keluar individu digunakan bagi mengoptimakan keupayaan pengesan jenis MWPC tersebut. Dalam kaedah ini, setiap dawai dalam pengesan MWPC perlu disambungkan kepada litar pembaca-keluar elektronik secara individu. Sekiranya aplikasi tersebut memerlukan pengesan dengan kawasan aktif yang luas maka litar pembaca-keluar elektronik dalam kuantiti yang banyak akan diperlukan dan ini akan meningkatkan kos untuk pembangunan peralatan tersebut. Kajian ini mengemukakan sebuah rekabentuk dan pembangunan lapan saluran (8-channels) litar pembaca-keluar elektronik berhinggar rendah yang dibina dengan rantaian pra-penguat jenis peka-cas dan penguat pembentuk denyut (CSA-PSA chain). Ia mampu menerima isyarat masukan pada julat dinamik yang luas serta berkeupayaan untuk memproses isyarat tersebut pada kadar yang pantas dan sesuai digunakan dalam peralatan serakan neutron yang memerlukan kadar bilang serta peleraian kedudukan yang tinggi.

Litar pembaca elektronik ini dibina sepenuhnya dengan menggunakan penguat kendalian (Op-Amp) jenis peranti masukan FET berhingar rendah sebagai komponen aktif utama dan komponen pasif seperti perintang dan pemuat. Litar pra-penguat jenis peka-cas (CSP) direkabentuk dengan pemalar masa sekitar 250 ns dan ia dilengkapi dengan rangkaian-T tambahan di peringkat keluaran. Manakala penguat pembentuk denyut

(PSA) adalah daripada penapis jenis separa-Gaussian kutub-kompleks tertib ke-5 yang dihasilkan daripada gandingan lata satu penapis laluan tinggi tertib pertama (HPF) yang dilengkapi dengan rangkaian pembatalan kutub-sifar (PZ) dan dua penapis laluan rendah tertib ke-2 jenis Sallen-Key (SK LPF). Litar ini telah direka dengan menggunakan Jelmaan Laplace kemudian disahkan dengan simulasi litar berasaskan komponen model-makro. Beberapa siri ujian telah dijalankan untuk mengukur sejauh mana prestasi sebenar litar pembaca-keluar tersebut dapat memenuhi objektif utama kajian ini. Pengujian ini termasuk pengukuran ofset arus terus (DC offset), julat dinamik isyarat masukan, gandaan serta kelurusan keluaran, magnitud hingar elektronik dan analisis masa atas ambang (TOT).

Kos pembangunan bagi litar pembaca-keluar elektronik tersebut adalah murah, sekitar USD50/saluran, oleh itu ia sesuai untuk aplikasi yang kos-sensitif. Keputusan pengujian menunjukkan bahawa ia mempunyai prestasi hingar elektronik yang baik dengan purata cas setara hinggar elektronik (ENC) sekitar 2108 e- ± 10% dan kurang sensitif terhadap perubahan kemuatan masukan (25e-/pF). Penentukuran cas dengan menggunakan kaedah analisa TOT menunjukkan bahawa litar pembaca-keluar elektronik tersebut dapat mengasingkan perbezaan kecil cas serta mampu menerima cas masukan pada julat dinamik yang luas (20-600 fC) pada kelurusan yang sangat baik (ketaklelurusan <1%). Denyut keluaran yang dihasilkan oleh litar

tersebut mencapai puncak sekitar 300 ns manakala lebar denyut isyarat keluaran adalah singkat sekitar 1.2 – 1.6 μs, ini menunjukkan bahawa ia boleh digunakan untuk pengesan PSND yang pantas dengan keupayaan kadar bilang di bawah 50 kHz pada masa mati sekitar 10%.

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I am grateful for being part of the UPM family. I truly thank UPM for providing all the necessary facilities to help me to complete this study.

APPROVAL

I certify that a Thesis Examination Committee has met on 18 May 2012 to conduct the final examination of Lojius bin Lombigit on his thesis entitled "Development and Characterization of Readout Electronics for Neutron Scattering Instrumentation" in accordance with Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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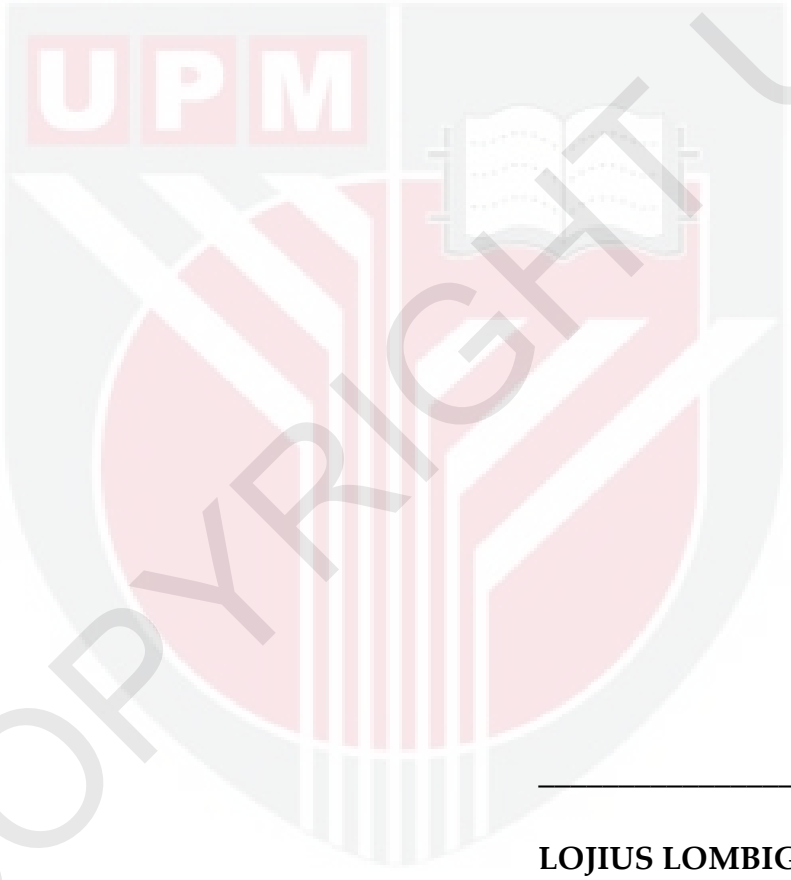
DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.



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Date: May 2012

TABLE OF CONTENTS