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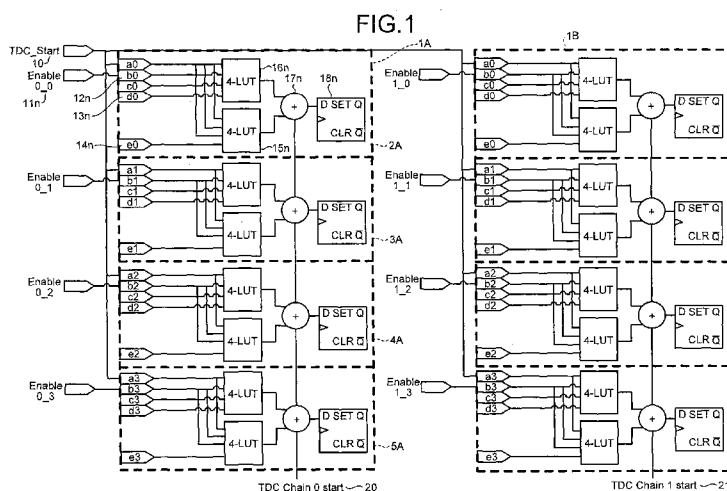
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- with international search report (Art. 21(3))
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claims and to be republished in the event of receipt of
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(88) Date of publication of the international search report:
4 December 2014(54) Title: DELAY APPARATUS, NUCLEAR MEDICINE IMAGING DEVICE, DELAY METHOD, AND CALIBRATION
METHOD

(57) Abstract: A delay apparatus of an embodiment is an apparatus for delaying a signal to a plurality of chain-based time-to-digital circuits (TDCs) and includes a plurality of propagation path devices each connected to a respective one of the plurality of TDCs. Each propagation path device is configured to delay a common start signal sent to each propagation path device by a selectable amount based on a delay selection signal received by the propagation path device, and to transmit the delayed start signal to the respective one of the TDCs.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/020263

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H03M 1/00 (2014.01)

USPC - 341/155

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - H03M 1/00; H03M 1/10; G01T 1/00; G01T 1/161 (2014.01)

USPC - 341/120, 155; 250/208.1, 363.03, 363.04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G04F 10/005; G01T 1/2985 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, Google Scholar,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/137109 A2 (ZWAANS et al.) 11 October 2012 (11.10.2012) entire document	11
Y		1-10, 12-17
Y	US 2012/0104259 A1 (MANN) 03 May 2012 (03.05.2012) entire document	1-10, 12-17
Y	US 2008/0069292 A1 (STRAAYER et al.) 20 March 2008 (20.03.2008) entire document	5, 15
Y	US 2010/0295590 A1 (YOSHIHARA et al.) 25 November 2010 (25.12.2010) entire document	17
A	US 2008/0238652 A1 (HENZLER et al.) 02 October 2008 (02.10.2008) entire document	1-17

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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04 September 2014

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/020263

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Extra Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/020263

Continuation of Box No. III:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-10, 12-16, drawn to an apparatus for delaying a signal to a plurality of time-to-digital circuits

Group II, claims 11, drawn to a nuclear medicine imaging device using emitted radiation for reconstructing an image

Group III, claims 17, drawn to a method of calibrating a system including a plurality of time-to-digital circuits using delay signals to evaluate performance of the time-to-digital circuits

The inventions listed as Groups I, II and III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: an apparatus for delaying a signal to a plurality of time-to-digital circuits as claimed therein is not present in the invention of Groups II and III. The special technical feature of the Group II invention: a nuclear medicine imaging device that uses emitted radiation to reconstruct an image of a subject as claimed therein is not present in the invention of Groups I or III. The special technical feature of the Group III invention: using a propagated delay signal to evaluate the performance of time-to-digital circuits for implementing calibration of the time-to-digital circuits as claimed therein is not present in the invention of Groups I or II.

Groups I, II and III lack unity of invention because even though the inventions of these groups require the technical feature of time-to-digital circuits which include delay elements configured to delay a trigger signal and propagate the delayed signal along a propagation path, this technical feature is not a special technical feature as it does not make a contribution over the prior art. Specifically, US 2012/0104259 A1 (MANN) 03 May 2012 (03.05.2012) teaches an apparatus for delaying a signal to a plurality of chain-based time-to-digital circuits (para [0019]), comprising: a plurality of propagation path devices each connected to a respective one of TDCs (para [0020], a time-to-digital converter includes a plurality of delay elements (claimed propagation path devices)), each propagation path device configured to delay a common start signal sent to each propagation path device by a selectable amount (para [0026], each delay element delays the start signal by t_{sup.u} [claimed selectable amount]). Also see para [0019] as well as para [0035]) based on a delay selection signal received by the propagation path device (para [0035], the start signal is delayed, or offset, in delay chain 43 by a delay of delay element 40 [therefore, delay elements on delay chain 43 will include a delay based on a selected delay of delay element 40, thus the delay selection signal is received by the propagation path and is used to delay a start signal]). Mann does not teach a plurality of TDCs and to transmit the delayed start signal to the respective one of the TDCs. However, WO 2012/137109 A2 (FRACH et al.) 11 October 2012 (11.10.2012), in analogous art, a plurality of TDCs (page 3, lines 4-20, first and second TDCs) and transmitting the delayed start signal to the respective one of the TDCs (page 10, lines 21-32 discloses each TDC is configured to receive a trigger signal, where, as further disclosed in page 18, lines 28-32 as well as fig. 9, delay elements 160 are configured to delay the trigger signal in the trigger circuitry). Therefore it would have been obvious to one of ordinary skill in the art at the time of the invention to use the teachings of Frach to incorporate a plurality of TDC's configured to receive a delayed trigger signal in the invention of Mann in order to enhance resolution for gamma ray detection (Col. 10, lines 11-20).

Since none of the special technical features of the Group I, II or III inventions are found in more than one of the inventions, unity of invention is lacking.