

US006801868B1

(12) United States Patent

Medelius et al.

(54) **REAL TIME CALIBRATION METHOD FOR** SIGNAL CONDITIONING AMPLIFIERS

- (75) Inventors: Pedro J. Medelius, Merritt Island, FL (US); Carlos T. Mata, Rockledge, FL (US); Anthony Eckhoff, Cocca, FL (US); Jose Perotti, Merritt Island, FL (US); Angel Lucena, Orlando, FL (US)
- (73) Assignce: The United States of America as represented by the Administrator of the National Aeronautics and Space Administration, Washington, DC (US)
- (*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
- Appl. No.: 10/283,353 (21)
- Filed: Oct. 15, 2002 (22)
- (51)
- (52)
- Field of Search 702/107, 64; 710/16, (58) 710/100, 310, 113, 36, 240, 301, 69; 375/359; 11/107; 711/152

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,800,513	Α		1/1989	Deutsch	
4,847,569	Α		7/1989	Dudziak et al.	
5,065,351	Α		11/1991	Johnson et al.	
5,089,979	Α		2/1992	McEachern et al.	
5,327,539	Α	*	7/1994	Sudo et al	710/107

5,361,218	Α		11/1994	Tripp et al.		
5,444,644	Α	*	8/1995	Divjak	702/64	
5,485,120	Α		1/1996	Anvari		
5,734,596	Α		3/1998	Medelius et al.		
5,742,200	Α		4/1998	He		
6,249,753	B1		6/2001	Mason et al.		
6,470,399	В1	*	10/2002	laster	710/16	

OTHER PUBLICATIONS

Heinz-Peter Beckemeyer, Interfacing the TLV1544 and TLV1548 A/D conveters to Digital processors, Dec. 1997.*

* cited by examiner

Primary Examiner-John Barlow Assistant Examiner-Tung S Lau (74) Attorney, Agent, or Firm-Randall M. Heald; Gary Borda; Harry Lupuloff

(57)ABSTRACT

A signal conditioning amplifier receives an input signal from an input such as a transducer. The signal is amplified and processed through an analog to digital converter and sent to a processor. The processor estimates the input signal provided by the transducer to the amplifier via a multiplexer. The estimated input signal is provided as a calibration voltage to the amplifier immediately following the receipt of the amplified input signal. The calibration voltage is amplified by the amplifier and provided to the processor as an amplified calibration voltage. The amplified calibration voltage is compared to the amplified input signal, and if a significant error exists, the gain and/or offset of the amplifier may be adjusted as necessary.

20 Claims, 2 Drawing Sheets



US 6,801,868 B1 (10) Patent No.: (45) Date of Patent:

Oct. 5, 2004

I



ţ

.



15

45

55

from the spirit of the invention are intended to be included within the scope of the appended claims.

Having thus set forth the nature of the invention, what is claimed herein is:

1. A method of calibrating a signal conditioner amplifier 5 comprising the steps of:

receiving an input signal;

- providing the input signal at a first input to a multiplexer, said multiplexer also configured to receive a calibration signal at a second input;
- providing the input signal to an amplifier having a programmable gain initially set at a present channel gain, said amplifier receiving the input signal from an output of the multiplexer, said amplifier providing an amplified output of the input signal;
- an analog-to-digital converter receiving the amplified output of the amplifier and providing a digitized signal;
- a processor receiving the digitized signal and outputting digital data; following the receipt of the digitized 20 signal, the processor calculating an estimated input signal based on the received digitized signal and the present channel gain of the amplifier,
- providing said estimated input signal as the calibration signal to the multiplexer at the second input which is ²⁵ then transmitted to and amplified by the amplifier to provide an amplified calibration signal; and
- the amplified calibration signal is then processed by the analog-to-digital converter and received by the processor with said processor comparing the amplified cali-³⁰ bration signal to the digitized signal.

2. The method of claim 1 wherein the input signal is received as a voltage.

3. The method of claim 1 wherein the calibration signal is provided as a voltage. 35

4. The method of claim 1 wherein the amplifier is provided with a programmable gain and a channel offset.

5. The method of claim 1 further comprising a filter which receives the input signal and provides a filtered signal to the input of the multiplexer.

6. The method of claim 2 wherein the voltage is provided by a transducer.

7. The method of claim 3 wherein the calibration voltage is provided to the multiplexer by a programmable reference voltage generator.

8. The method of claim 7 wherein the programmable reference voltage generator receives an input from an ultrastable voltage reference.

9. A method of calibrating a signal conditioner amplifier comprising the steps of: 50

receiving an input signal;

- providing the input signal at a first input to a multiplexer, said multiplexer also configured to receive a calibration signal at a second input;
- providing the input signal to an amplifier having a programmable gain initially set at a present channel gain, said amplifier receiving the input signal from an output of the multiplexer, said amplifier providing an amplified output;
- an analog-to-digital converter receiving the amplified output of the amplifier and providing a digitized signal;
- a processor receiving the digitized signal and outputting digital data; following the receipt of the digitized signal, the processor calculating an estimated input 65 signal based on the received digitized signal and the present channel gain of the amplifier,

- providing said estimated input signal as the calibration signal to the multiplexer at the second input which is then transmitted to the amplifier to provide an amplified calibration signal; and
- the amplified calibration signal is then processed by the analog-to-digital converter and received by the processor with said processor comparing the amplified calibration signal to the digitized transducer signal;
- The method of claim 1 wherein the estimated input signal is generated by subtracting a present channel offset from the digitized signal and then dividing by a system present channel gain.
- **10**. A method of calibrating a signal conditioner amplifier comprising the steps of:

receiving an input signal;

- providing the input signal at a fit input to a multiplexer, said multiplexer also configured to receive a calibration signal at a second input;
- providing the input signal to an amplifier having a programmable gain initially set at a present channel gain, said amplifier receiving the input signal from an output of the multiplexer, said amplifier providing an amplified output;
- an analog-to-digital converter receiving the amplified output of the amplifier and providing a digitized signal;
- a processor receiving the digitized signal and outputting digital data; following the receipt of the digitized signal, the processor calculating an estimated input signal based on the received digitized signal and the present channel gain of the amplifier,
- providing said estimated input signal as the calibration signal to the multiplexer at the second input which is then transmitted to the amplifier to provide an amplified calibration signal; and
- the amplified calibration signal is then processed by the analog-to-digital converter and received by the processor with said processor comparing the amplified calibration signal to the digitized transducer signal;
- The method of claim 1 wherein a difference between the digitized signal and the amplified calibration signal is calculated as an error, and the error is utilized to determine whether adjustment at least one of the present channel gain and an offset is necessary.
- 11. The method of claim 10 wherein if the error is within a preset limit, no adjustment is made to the present channel gain and offset of the signal conditioning amplifier.

12. A method of calibrating a signal conditioner amplifier comprising the steps of: receiving an input signal;

- providing the input signal at a first input to a multiplexer, said multiplexer also configured to receive a calibration signal at a second input;
- providing the input signal to an amplifier having a programmable gain initially set at a present channel gain, said amplifier receiving the input signal from an output of the multiplexer, said amplifier providing an amplified output;
- an analog-to-digital converter receiving the amplified output of the amplifier and providing a digitized signal;
- a processor receiving the digitized signal and outputting digital data; following the receipt of the digitized signal, the processor calculating an estimated input signal based on the received digitized signal and the present channel gain of the amplifier,
- providing said estimated input signal as the calibration signal to the multiplexer at the second input which is

then transmitted to the amplifier to provide an amplified calibration signal; and

- the amplified calibration signal is then processed be the analog-to-digital converter and received by the processor with said processor comparing the amplified cali-⁵ bration signal to the digitized transducer signal;
- The method of claim 10 wherein if the error is outside of a preset limit, the processor provides a signal to the amplifier to adjust at least one of the present channel gain and the channel offset.

13. The method of claim 12 wherein the output of the amplifier is linear according to a formula: output voltage equals channel offset plus the product of input voltage multiplied by channel gain.

14. The method of claim 12 wherein the preset limit is ¹⁵ zero.

15. The method of claim 13 wherein at least two amplified calibration signals and their respective amplified input signals arc compared by the processor to adjust at least one of the channel gain and channel offset. 20

16. A method of calibrating a signal conditioner amplifier comprising the steps of:

receiving an input signal;

- providing the input signal at a first input to a multiplexer, 25 said multiplexer also configured to receive a calibration signal at a second input;
- providing the input signal to an amplifier having a programmable gain initially set at a present channel gain, said amplifier receiving the input signal from an output 30 of the multiplexer, said amplifier providing an amplified output;
- an analog-to-digital converter receiving the amplified output of the amplifier and providing a digitized signal;
- a processor receiving the digitized signal and outputting ³⁵ digital data; following the receipt of the digitized signal, the processor calculating an estimated input signal based on the received digitized signal and the present channel gain of the amplifier,
- providing said estimated input signal as the calibration signal to the multiplexer at the second input which is then transmitted to the amplifier to provide an amplified calibration signal; and
- the amplified calibration signal is then processed by the ⁴⁵ analog-to-digital converter and received by the processor with said processor comparing the amplified calibration signal to the digitized transducer signal;
- The amplifier of claim 1 wherein the estimated input signal is calculated at a sampling frequency greater 50 than the Nyquist frequency.

17. A method of calibrating a signal conditioning amplifier comprising the steps of:

a transducer providing an input voltage to a multiplexer; a multiplexer receiving the input voltage;

55

a programmable gain amplifier receiving an input from an output of the multiplexer, said amplifier providing an output by amplifying the output received from the new signals; an analog-to-digital converter receiving the output of the amplifier and providing a digitized signal;

- a processor receiving the digitized signal and outputting digital data, said processor also at intervals estimating the value of the input voltage from the transducer as an estimated input signal;
- providing the estimated input signal as a calibration signal to the multiplexer;
- said multiplexer providing the calibration signal to the amplifier which is amplified as an amplified calibration signal;
- said amplified calibration signal then provided to the analog-to digital converter which is then received by the processor, and then comparing said amplified calibration signal to the digitized signal.

18. The method of claim 17 wherein the intervals are periodic.

19. A method of calibrating a signal conditioning amplifier comprising the steps of:

- a transducer providing an input voltage to a multiplexer; a multiplexer receiving the input voltage;
- a programmable gain amplifier receiving an input from an output of the multiplexer, said amplifier providing an output;
- an analog-to-digital converter receiving the output of the amplifier and providing a digitized signal;
- a processor receiving the digitized signal and outputting digital data, said processor also at intervals estimating the value of the input voltage from the transducer as an estimated input signal;
- providing the estimated input signal as a calibration signal to the multiplexer;
- said multiplexer providing the calibration signal to the amplifier which is amplified as an amplified calibration signal;
- said amplified calibration signal then provided to the analog-to-digital converter which is then received by the processor, and then comparing said amplified calibration signal to the digitized signal; and
- the programmable gain amplifier has a present channel offset and a present channel gain and substantially operates under the equation voltage out equals channel offset plus the product of channel gain multiplied by voltage in, and said processor utilizes present channel gain and present channel offset to estimate the estimated input signal.

20. The amplifier of claim 19 wherein a difference between the amplified calibration signal and the digitized signal is an error, and when comparing the amplified calibration signal to the digitized signal, if said error exceeds a predetermined limit, said processor provides a signal to adjust at least one of the present channel gain and present channel offset of the amplifier.

* * * * *