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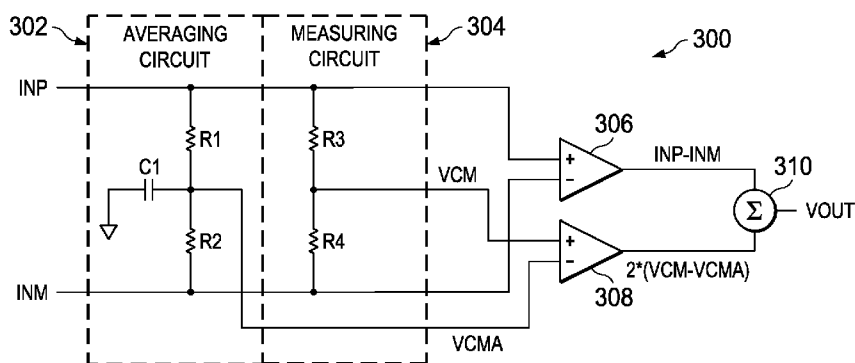
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(54) **Title:** INTRA-PAIR SKEW CANCELLATION FOR DIFFERENTIAL SIGNALING**FIG. 4**

(57) **Abstract:** A method for deskewing a differential signal is provided. A common-mode voltage (VCM) of a differential signal (INP, INM) from a measuring circuit (304) and an average for the common-mode voltage of the differential signal (VCMA) from an averaging circuit (302) are measured. A difference between first and second portions of the differential signal (INP-INM) is determined at amplifier (306) and skew information ($2 \cdot (VCM - VCMA)$) is derived from the common-mode voltage and the average at amplifier (308). The skew information can then be combined with the difference at summer (310) to deskew the differential signal.

INTRA-PAIR SKEW CANCELLATION FOR DIFFERENTIAL SIGNALING

[0001] The invention relates generally to deskewing circuitry and, more particularly, to intra-pair deskewing circuitry.

BACKGROUND

[0002] FIG. 1 illustrates an example of a conventional communication system 100 generally including a transmitter 102, a transmission medium 104, and a receiver 106. Typically, the transmission medium 104 is comprised of a pair of transmission lines that are configured to carry a differential signal from the transmitter 102 to the receiver 106. This type of system 100 is used in a wide variety of applications ranging from transmitting information over long distance (through cables) to on-chip communications. One issue with system 100 is that there is usually a length mismatch between the transmission lines in medium 104 that can lead to skew between the portions of the differential signal carried by the medium 104 (known as “intra-pair skew”), and an example of intra-pair skew can be seen in FIG 2, where the transmission medium 104 for this example introduces 1 unit interval (UI) of skew. For low frequency signals, intra-pair skew can be largely ignored, but, for high frequency signals (i.e. >1Gb/s), intra-pair skew can significantly impair communications.

[0003] To address intra-pair skew, several solutions have been proposed. These proposed solutions approach intra-pair skew as being a propagation delay issue, and an example of such a proposed solution can be seen in FIG. 3. As shown, skew compensator 200 (which is included within receiver 106) uses several delay elements 202-1 to 202-N coupled in series with one another to delay each portion of the differential signal accordingly to compensate for the intra-pair skew. Adjustments to the delay elements 202-1 to 202-N are made through adjustment of the control voltage VCNTL, but it can often be difficult to adequately adjust the relative delays to compensate for the intra-pair skew. Therefore, there is a need for an improved skew compensator.

[0004] Some other conventional circuits are described in: U.S. Patent Appl. Serial No. 12/948,757; U.S. Patent No. 6,335,647; U.S. Patent No. 6,909,980; U.S. Patent No. 7,729,874;

U.S. Patent Pre-Grant Publ. No. 2005/0099216; U.S. Patent Pre-Grant Publ. No. 2006/0244505; U.S. Patent Pre-Grant Publ. No. 2009/0174448.pdf; Zheng et al., "A 5Gb/s Automatic Sub-Bit Between-Pair Skew Compensator for Parallel Data Communications in 0.13 μ m CMOS," 2010 Symposium on VLSI Circuits/Technical Digest of Technical Papers, June 16-18, 2010; Olisar, Robert, "Unbalanced Twisted Pairs Can Give You the Jitters!," Maxim Engineering Journal, Vol. 64, Sept. 2008, pp. 5-12.

SUMMARY

[0005] An example embodiment provides an apparatus. The apparatus comprises a measuring circuit that is configured to receive a differential signal and that is configured to determine a common-mode voltage; an averaging circuit that is configured to receive the differential signal and that is configured to determine an average for the common-mode voltage; and an output circuit having that is coupled to the measuring circuit and the averaging circuit and that is configured to receive the differential signal, wherein the output circuit determines a difference between first and second portions of the differential signal, and wherein the output circuit determines deskew information from the common-mode voltage and the average, and wherein the output circuit generates a deskewed differential signal from the deskew information and the difference.

[0006] In an example embodiment, the output circuit further comprises: a first differential amplifier that is configured to receive the differential signal; a second differential amplifier that is coupled to the measuring circuit and the averaging circuit; and an adder that is coupled to the first and second differential amplifiers.

[0007] In an example embodiment, the first and second amplifiers have first and second gains, respectively, wherein the second gain is twice the first gain.

[0008] In an example embodiment, the measuring circuit further comprises a voltage divider.

[0009] In an example embodiment, the averaging circuit further comprises: a first resistor that is configured to receive the first portion of the differential signal and that is coupled to the output circuit; a second resistor that is coupled to the first resistor and that is configured to receive the second portion of the differential signal; and a capacitor that is coupled to the first and second resistors.

[0010] In an example embodiment, a method is provided. The method comprises measuring a common-mode voltage of a differential signal; measuring an average for the common-mode voltage of the differential signal; determining a difference between first and second portions of the differential signal; determining deskew information from the common-mode voltage and the average; and combining the deskew information with the difference to deskew the differential signal.

[0011] In an example embodiment, the step of determining the deskew information further comprises determining a difference between the common-mode voltage and the average.

[0012] In an example embodiment, the step of determining the difference between the first and second portions of the differential signal further comprises applying a gain to the difference between the first and second portions of the differential signal.

[0013] In an example embodiment, the gain further comprises a first gain, and wherein the step of determining the deskew information further comprises applying a second gain to the difference between the common-mode voltage and the average.

[0014] In an example embodiment, the second gain is at least twice the first gain.

[0015] In an example embodiment, an apparatus is provided. The apparatus comprises a first terminal that is configured to receive a first portion of a differential signal; a second terminal is configured to receive a second portion of the differential signal; a measuring circuit that is coupled to the first and second terminals and that is configured to determine a common-mode voltage; an averaging circuit that is coupled to the first and second terminals and that is configured to determine an average for the common-mode voltage; a first difference circuit that is coupled to the first and second terminals and that is configured to determine a difference between the first and second portions of the differential signal; a second difference circuit that is coupled to the measuring circuit and the averaging circuit and that is configured to determine deskew information from the common-mode voltage and the average; and a combiner that is coupled to the first and second output circuits.

[0016] In an example embodiment, the first difference circuit further comprises a differential amplifier having a gain.

[0017] In an example embodiment, the differential amplifier further comprises a first differential amplifier, and wherein the gain further comprises a first gain, and wherein the second difference circuit further comprises a second differential amplifier having a second gain.

[0018] In an example embodiment, the combiner further comprises a node.

[0019] In an example embodiment, the second gain is at least twice the first gain.

[0020] In an example embodiment, the measuring circuit further comprises: a first resistor that is coupled to the first terminal and the second differential amplifier; and a second resistor that is coupled between the second terminal and the first resistor.

[0021] In an example embodiment, the averaging circuit further comprises: a node that is coupled to second differential amplifier; a third resistor that is coupled between the first terminal and the node; a fourth resistor that is coupled between the second terminal and the node; and a capacitor that is coupled to the node.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Example embodiments are described with reference to accompanying drawings, wherein:

[0023] FIG. 1 illustrates an example of a conventional communication system;

[0024] FIG. 2 illustrates intra-pair skew for the system of FIG. 1;

[0025] FIG. 3 shows an example of a conventional skew compensator;

[0026] FIG. 4 shows an example of a skew compensator in accordance with an embodiment; and

[0027] FIGS. 5A-8 depict the operation of the skew compensator of FIG. 4.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0028] FIG. 4 depicts an example of a skew compensator 300 in accordance with an embodiment. This skew compensator 300 is generally included in a receiver (i.e., receiver 106) so as to perform intra-pair skew compensation, and it generally comprises an averaging circuit 302, a measuring circuit 304, and an output circuit. The output circuit generally uses two difference circuits (which are typically differential amplifiers 306 and 308) that generate differential signal information and deskew information on a main signal path and a deskew path, respectively. This differential signal information and deskew information can then be combined by combiner 310 to generate an output signal VOUT that should generally match the desired, deskewed differential signal. Typically, differential amplifier 306 (which is in the main signal path) is coupled to the input terminals of the skew compensator 300 (which carry the portions INM and INP of the differential signal), while the differential amplifier 308 (which is in the

deskew path) is coupled to the averaging circuit 302 and measuring circuit 304 so as to receive a common-mode voltage VCM and an average of the common-mode voltage VCMA. The common-mode voltage VCM is usually generated by the measuring circuit 304 through the use of a voltage divider (i.e., resistors R3 and R4), while the average VCMA is generated by using a voltage divider (i.e., resistors R1 and R2) to continuously measure the common-mode voltage VCM and a memory device (i.e., capacitor C1) to average it over a long period of time.

[0029] To illustrate the function of skew compensator 300, signals propagating through system 100 (which includes skew compensator 300) are shown in FIGS. 5A and 5B. In this example, transmitter 102 outputs a differential signal, where the portions INM and INP can have a value of +1 or -1 (assuming differential amplifier 306 has unity gain). As the differential signal propagates across medium 104, 1 UI of intra-pair skew is introduced, which significantly distorts the differential signal. It can, however, be recognized that the intra-pair skew converts the differential signal to common-mode, since there is a difference between the common-mode voltage VCM and the average VCMA (which for this example is 0). When the difference between portions INM and INP (i.e., INP-INM) is taken by differential amplifier 308, this difference can have values of +2, 0, and -2, and the difference does not match the desired (deskewed) output from transmitter 102. Because the difference between the common-mode voltage VCM and the average VCMA can have values of -1, 0, or +1, differential amplifier 308 (for this example) applies again of 2 so as to generate the deskew information (i.e., $2 \cdot (VCM - VCMA)$). This deskew information can then be combined with the difference between the portions INM and INP by combiner 310 (which can, for example, be an adder or node) to generate the output signal VOUT, which generally matches the output of the transmitter 102. It should also be noted that the gains of differential amplifiers 306 and 308 are typically different, and that the gain of differential amplifier 308 will typically be at least twice or double the gain of differential amplifier 306.

[0030] FIG. 6-8 show other examples of the operation of the skew compensator 300. In FIG. 6, there is no intra-pair skew, so the skewed and deskewed signals generally match (but are shown with different scales). In FIG. 7, $\frac{1}{2}$ UI (which is about 50ps for this example) of skew is introduced, and the skew compensator 300 is able to fully recover the eye. In FIG. 8, there is 1 UI (i.e., about 100ps for this example) of skew (which significantly distorts the differential signal), and the skew compensator 300 is able to recover the differential signal.

[0031] Those skilled in the relevant art will appreciate that modifications may be made to the example embodiments, and also that many other embodiments are possible, without departing from the scope of the claimed invention.

CLAIMS

What is claimed is:

1. An apparatus comprising:
 - a measuring circuit that is configured to receive a differential signal and that is configured to determine a common-mode voltage;
 - an averaging circuit that is configured to receive the differential signal and that is configured to determine an average for the common-mode voltage; and
 - an output circuit having that is coupled to the measuring circuit and the averaging circuit and that is configured to receive the differential signal, wherein the output circuit determines a difference between first and second portions of the differential signal, and wherein the output circuit determines deskew information from the common-mode voltage and the average, and wherein the output circuit generates a deskewed differential signal from the deskew information and the difference.
2. The apparatus of Claim 1, wherein the output circuit further comprises:
 - a first differential amplifier that is configured to receive the differential signal;
 - a second differential amplifier that is coupled to the measuring circuit and the averaging circuit; and
 - an adder that is coupled to the first and second differential amplifiers.
3. The apparatus of Claim 2, wherein the first and second amplifiers have first and second gains, respectively, wherein the second gain is twice the first gain.
4. The apparatus of Claim 1, wherein the measuring circuit further comprises a voltage divider.
5. The apparatus of Claim 1, wherein the averaging circuit further comprises:
 - a first resistor that is configured to receive the first portion of the differential signal and that is coupled to the output circuit;

a second resistor that is coupled to the first resistor and that is configured to receive the second portion of the differential signal; and
a capacitor that is coupled to the first and second resistors.

6. A method comprising:

measuring a common-mode voltage of a differential signal;
measuring an average for the common-mode voltage of the differential signal;
determining a difference between first and second portions of the differential signal;
determining deskew information from the common-mode voltage and the average; and
combining the deskew information with the difference to deskew the differential signal.

7. The method of Claim 6, wherein the step of determining the deskew information further comprises determining a difference between the common-mode voltage and the average.

8. The method of Claim 7, wherein the step of determining the difference between the first and second portions of the differential signal further comprises applying a gain to the difference between the first and second portions of the differential signal.

9. The method of Claim 8, wherein the gain further comprises a first gain, and wherein the step of determining the deskew information further comprises applying a second gain to the difference between the common-mode voltage and the average.

10. The method of Claim 9, wherein the second gain is at least twice the first gain.

11. An apparatus comprising:

a first terminal that is configured to receive a first portion of a differential signal;
a second terminal is configured to receive a second portion of the differential signal;
a measuring circuit that is coupled to the first and second terminals and that is configured to determine a common-mode voltage;
an averaging circuit that is coupled to the first and second terminals and that is configured to determine an average for the common-mode voltage;

a first difference circuit that is coupled to the first and second terminals and that is configured to determine a difference between the first and second portions of the differential signal;

a second difference circuit that is coupled to the measuring circuit and the averaging circuit and that is configured to determine deskew information from the common-mode voltage and the average; and

a combiner that is coupled to the first and second output circuits.

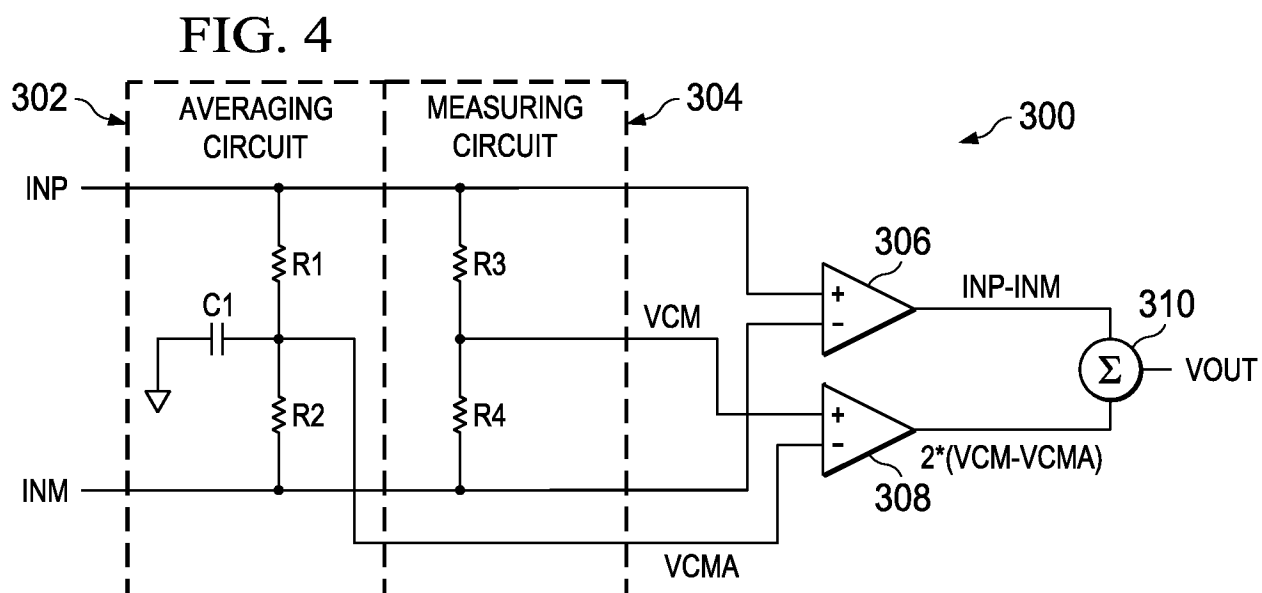
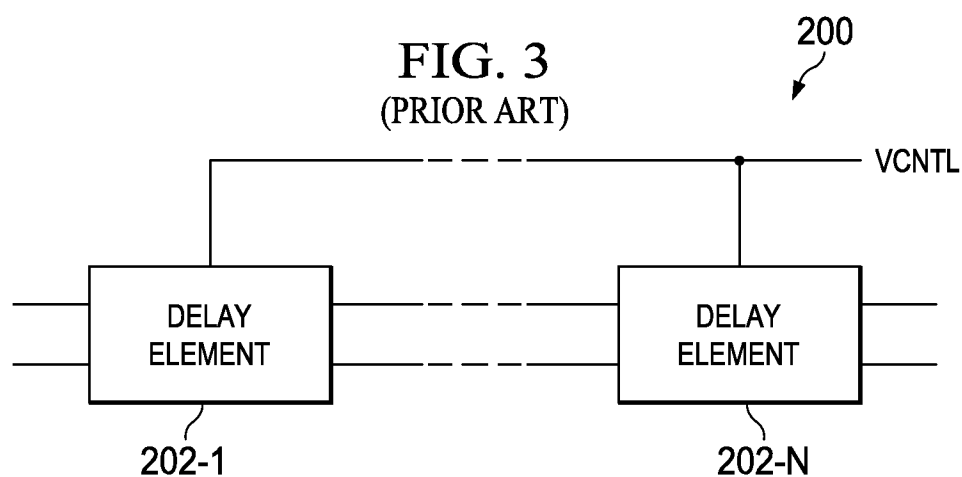
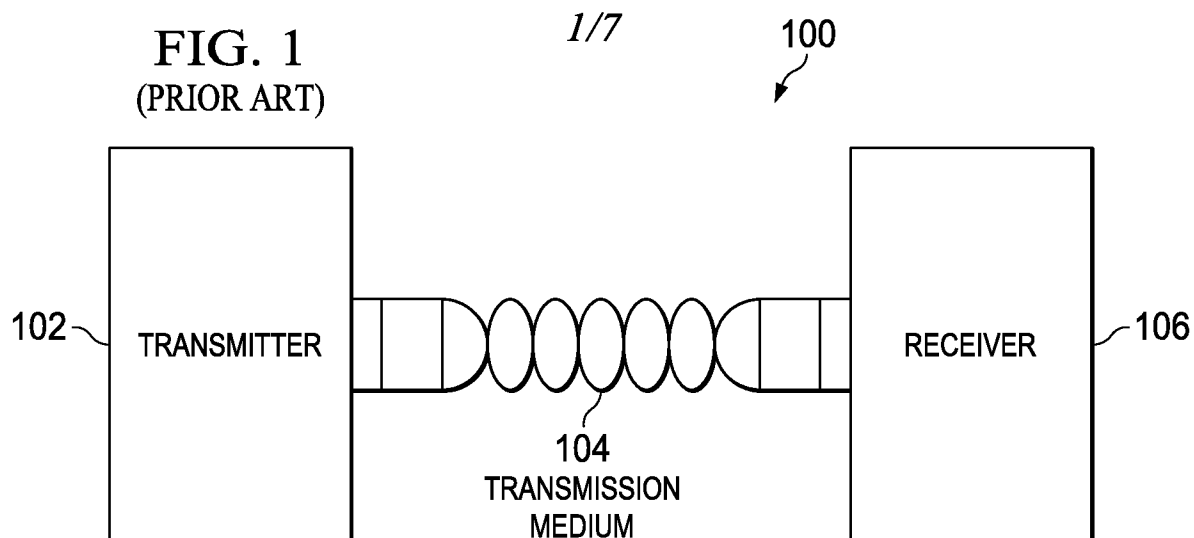
12. The apparatus of Claim 11, wherein the first difference circuit further comprises a differential amplifier having a gain.

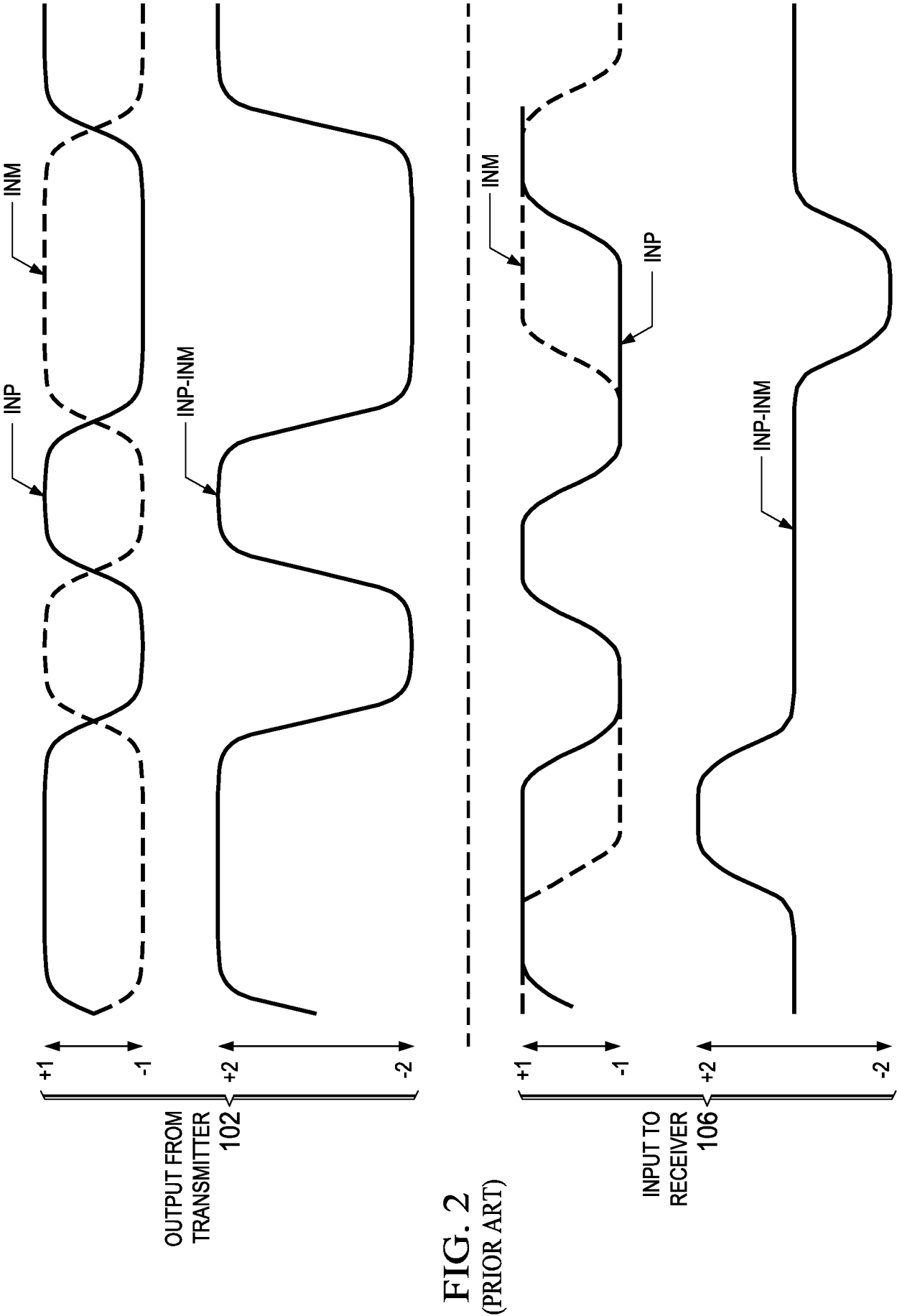
13. The apparatus of Claim 12, wherein the differential amplifier further comprises a first differential amplifier, and wherein the gain further comprises a first gain, and wherein the second difference circuit further comprises a second differential amplifier having a second gain.

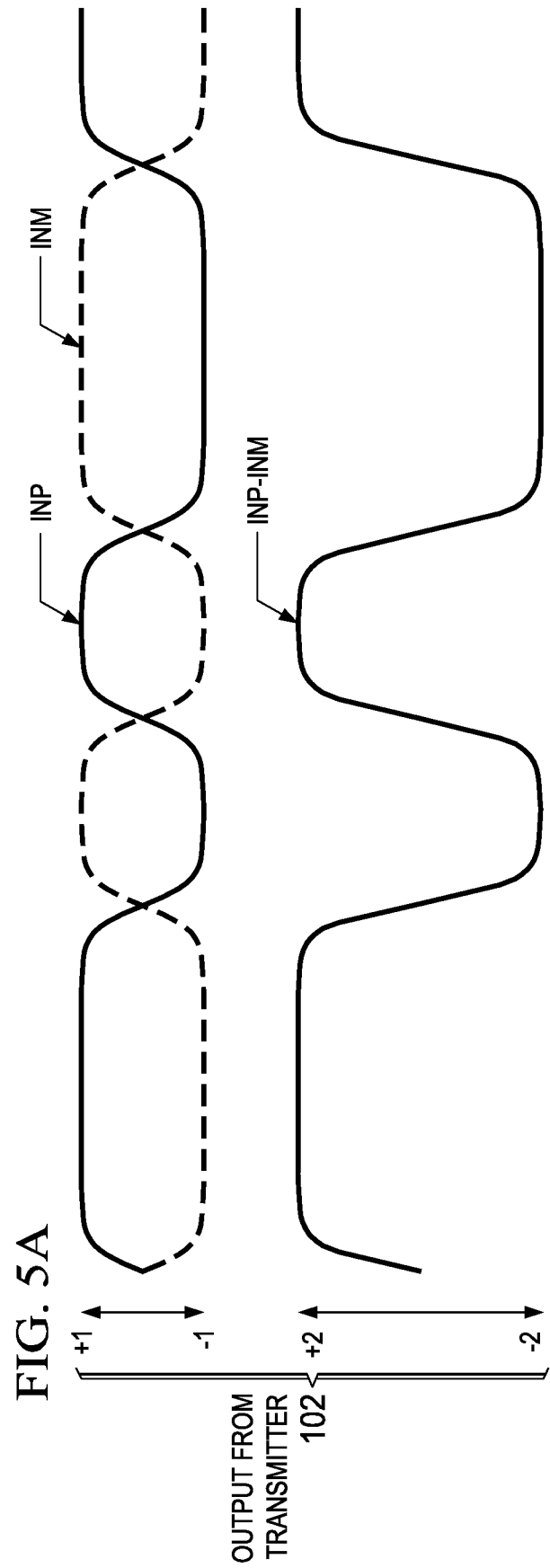
14. The apparatus of Claim 13, wherein the second gain is at least twice the first gain.

15. The apparatus of Claim 14, wherein the measuring circuit further comprises:
a first resistor that is coupled to the first terminal and the second differential amplifier;
and
a second resistor that is coupled between the second terminal and the first resistor.

16. The apparatus of Claim 15, wherein the averaging circuit further comprises:
a node that is coupled to second differential amplifier;
a third resistor that is coupled between the first terminal and the node;
a fourth resistor that is coupled between the second terminal and the node; and
a capacitor that is coupled to the node.







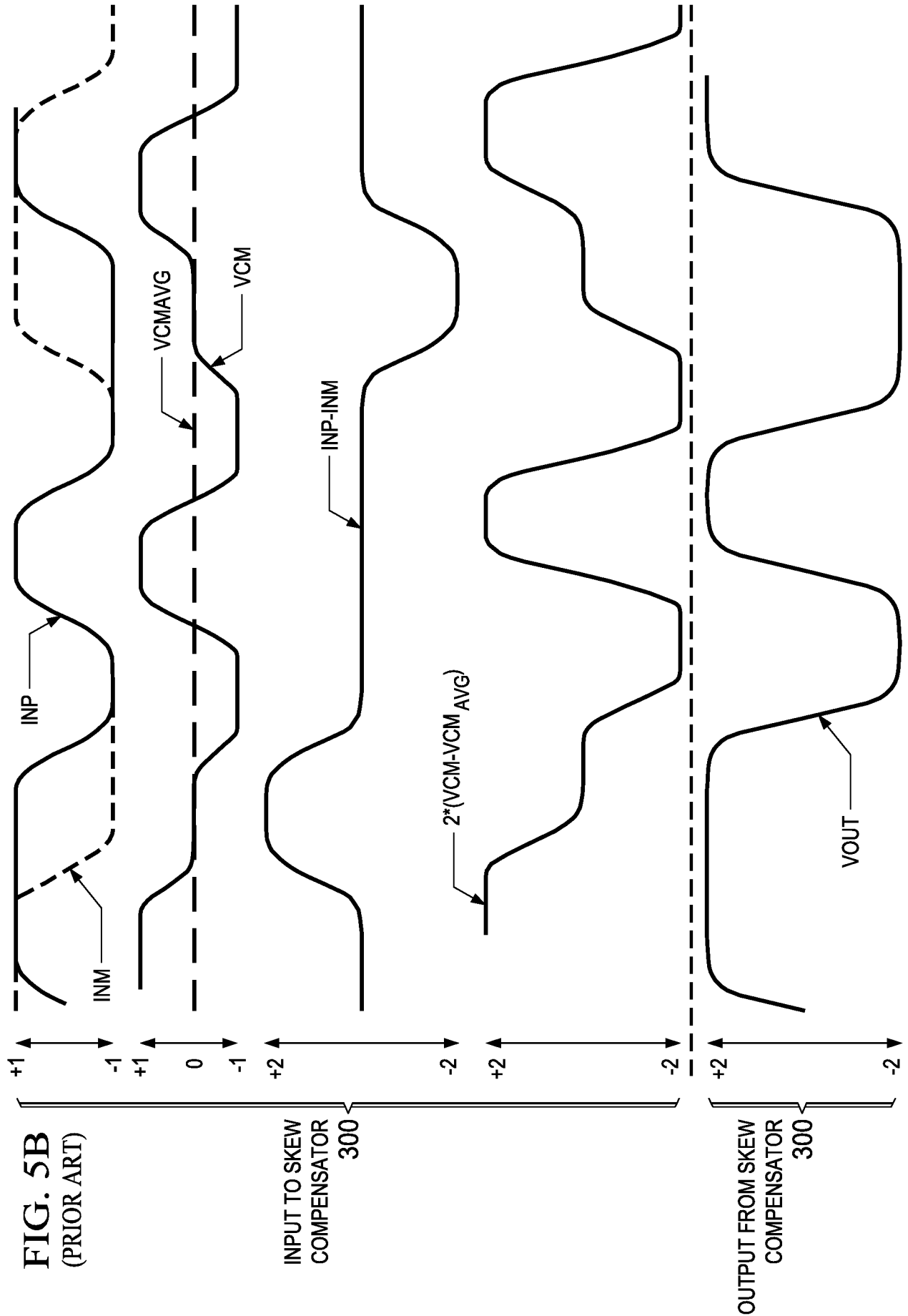


FIG. 6

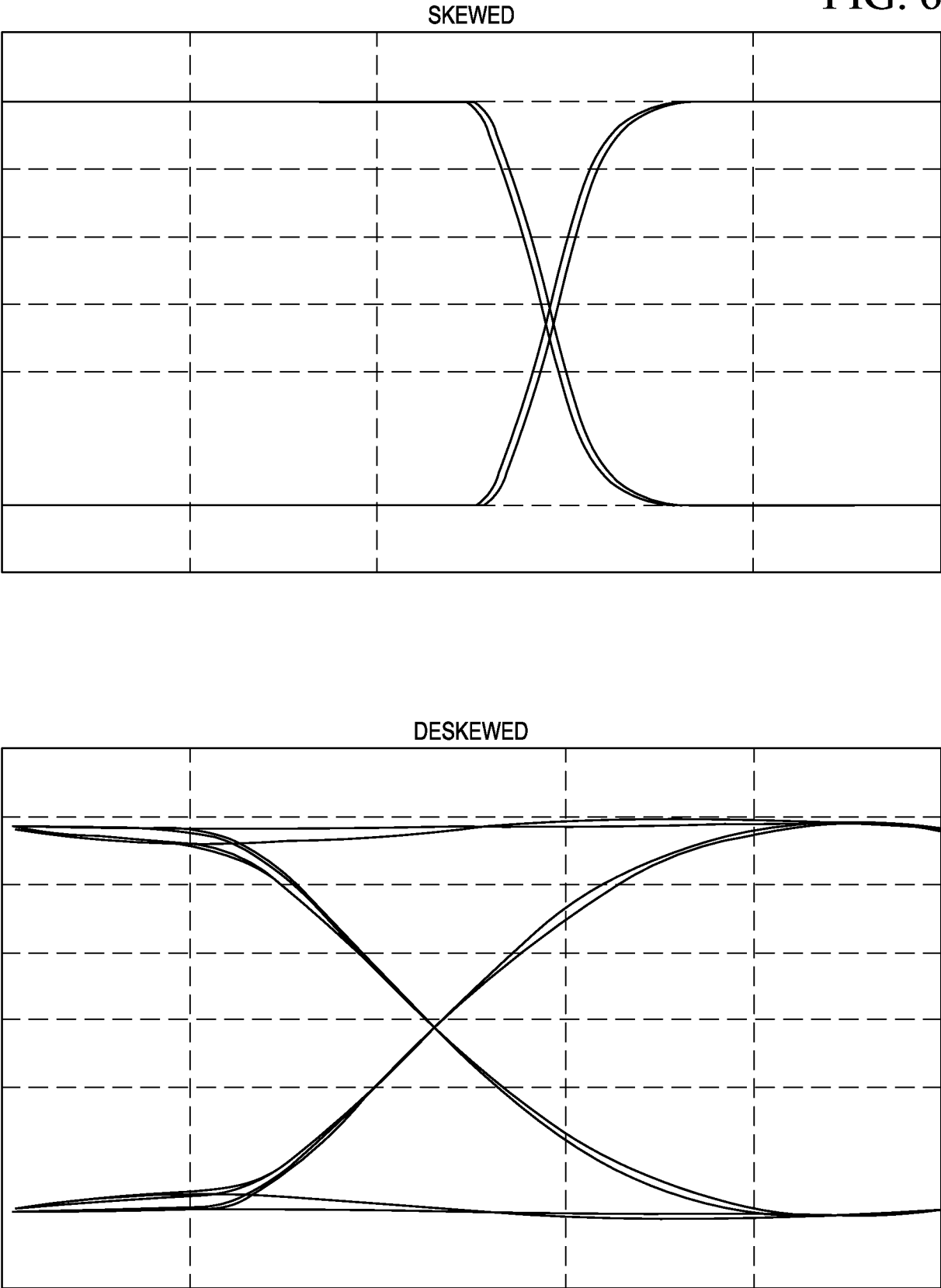


FIG. 7

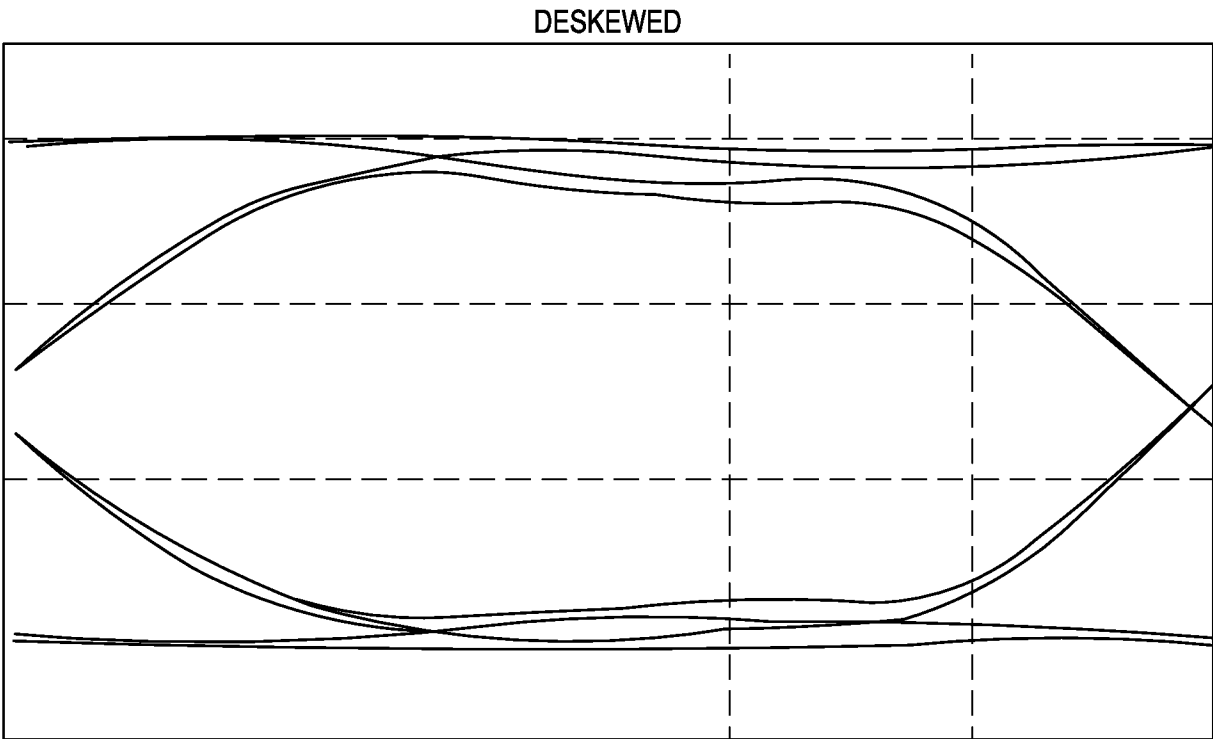
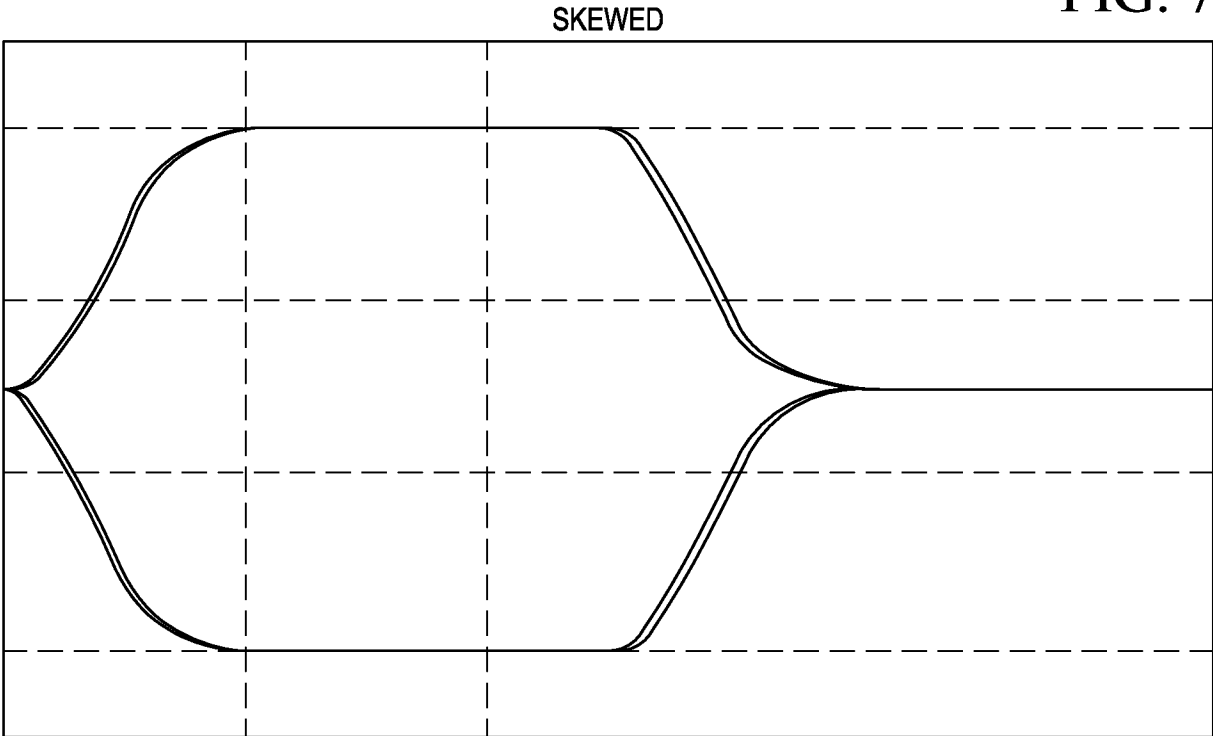


FIG. 8

