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(54) **ANALOG SWITCH FOR TRANSMITTING HIGH VOLTAGE SIGNALS WITHOUT UTILIZING HIGH VOLTAGE POWER SUPPLIES**

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(57) **ABSTRACT**

Described herein are multiple designs for an improved analog switch for use in transmitting high voltage signals without using high voltage power supplies for the switch. The analog switches are able to pass and block input signals in the approximate range of -100V to +100V. The use of translinear loops and a bootstrap configuration results in a constant on-resistance of the symmetrical switches and matches the conductance of each analog switch to the transconductance of an NMOS transistor, which can be easily stabilized with a constant g_m biasing scheme. In certain embodiments, a shunt termination (T-switch) configuration is used for better off-isolation, and each of the symmetrical switches has its own translinear loop and thus flexibility of on-resistance and termination voltage.

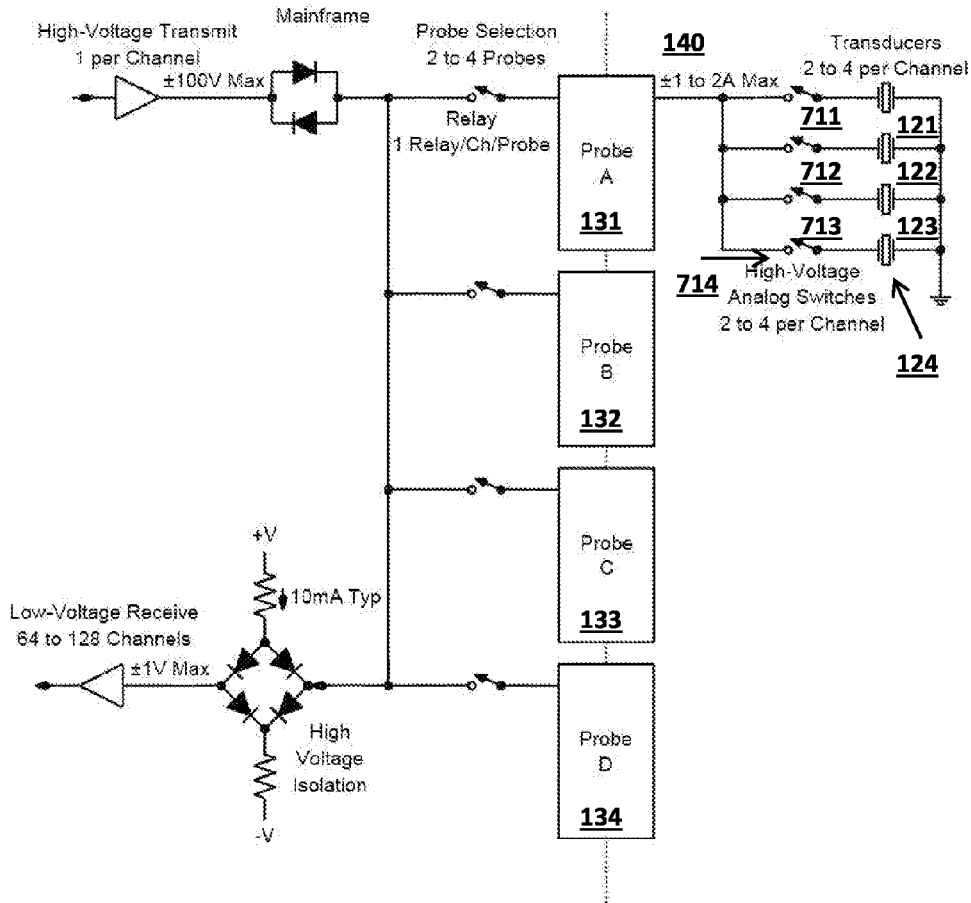
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700



100

FIGURE 1 (PRIOR ART)

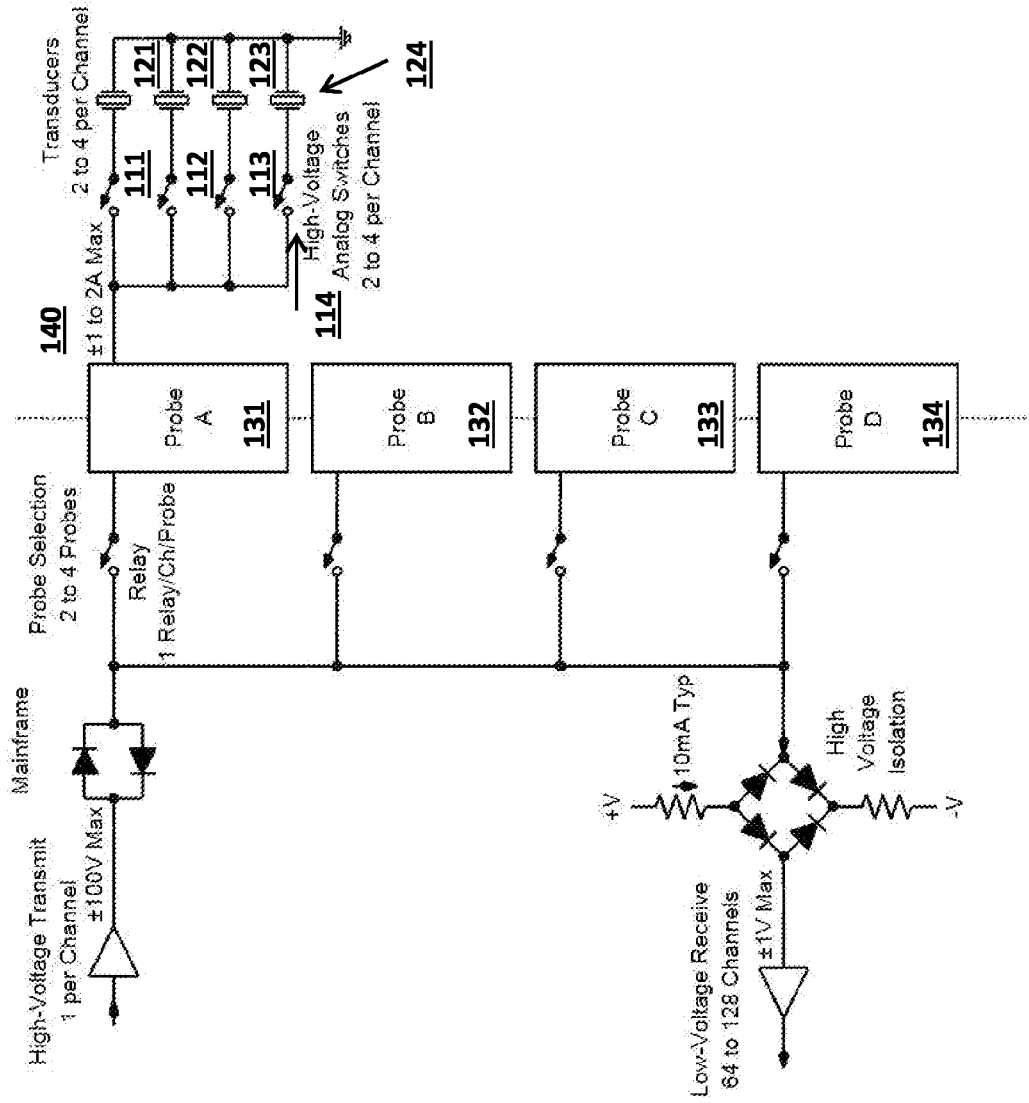


FIGURE 2 (PRIOR ART)

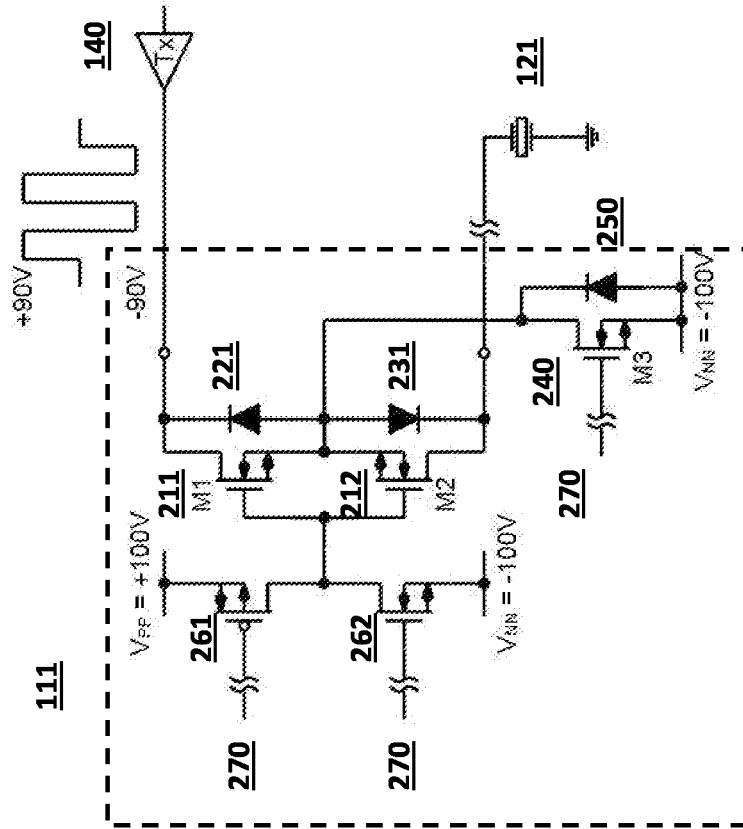


FIGURE 3 (PRIOR ART)

300

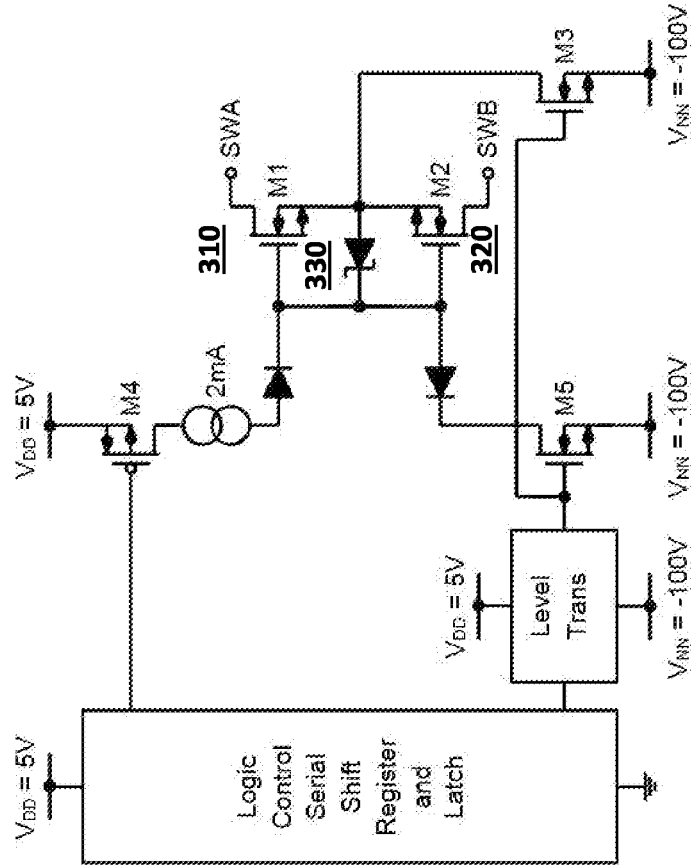


FIGURE 4

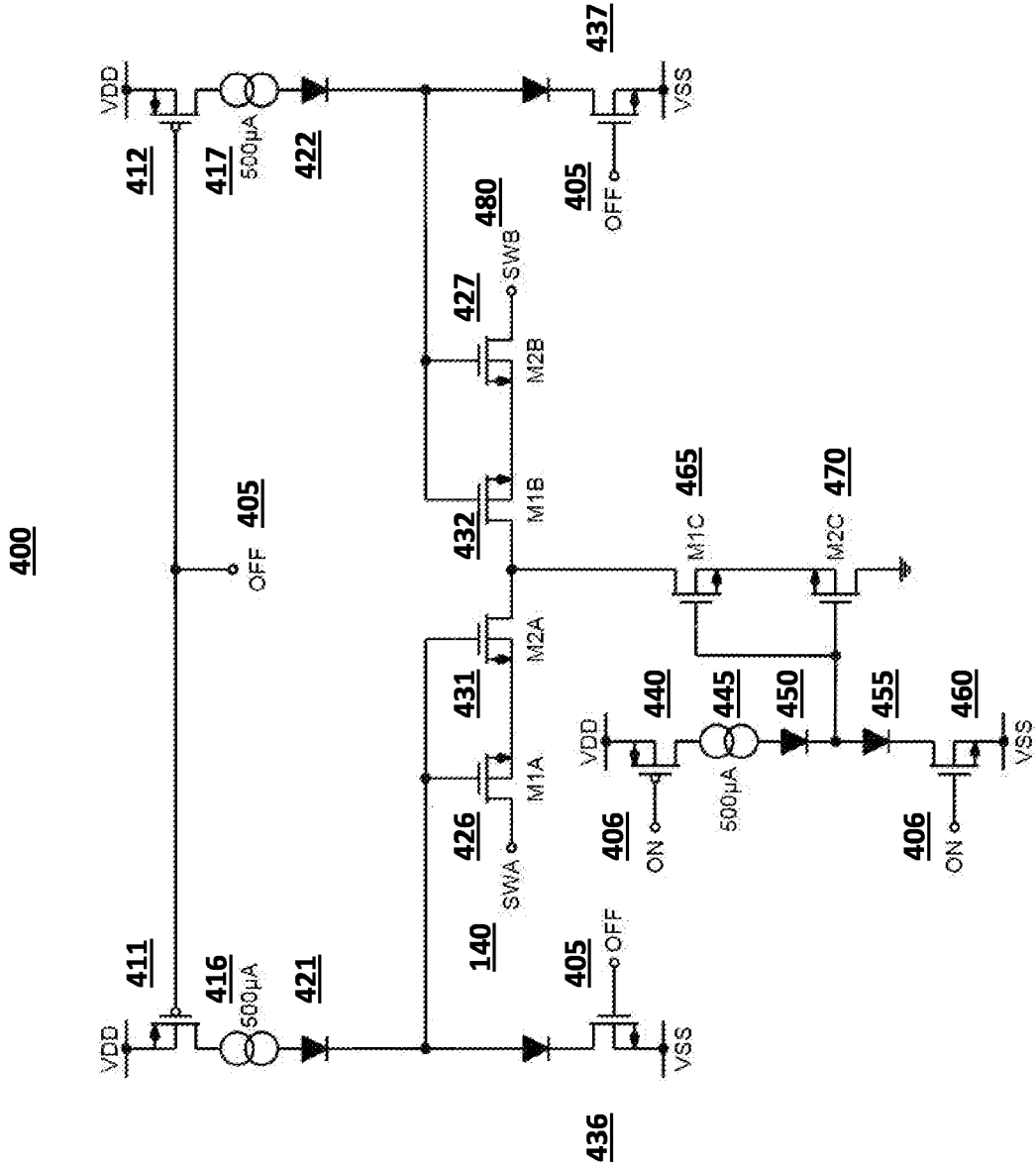


FIGURE 5

500

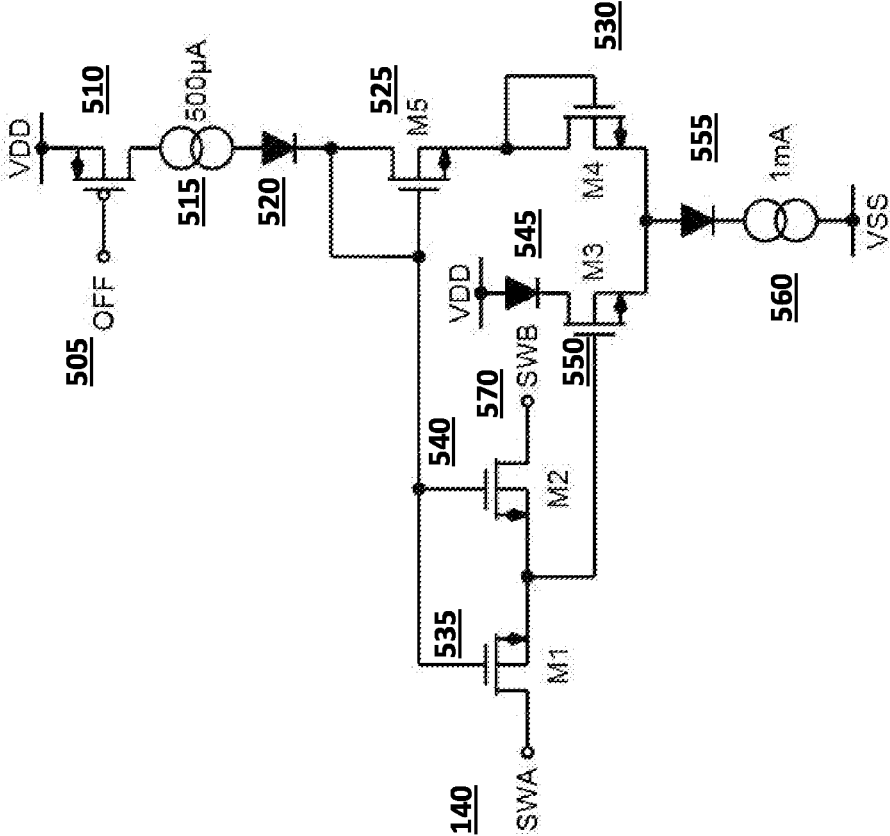
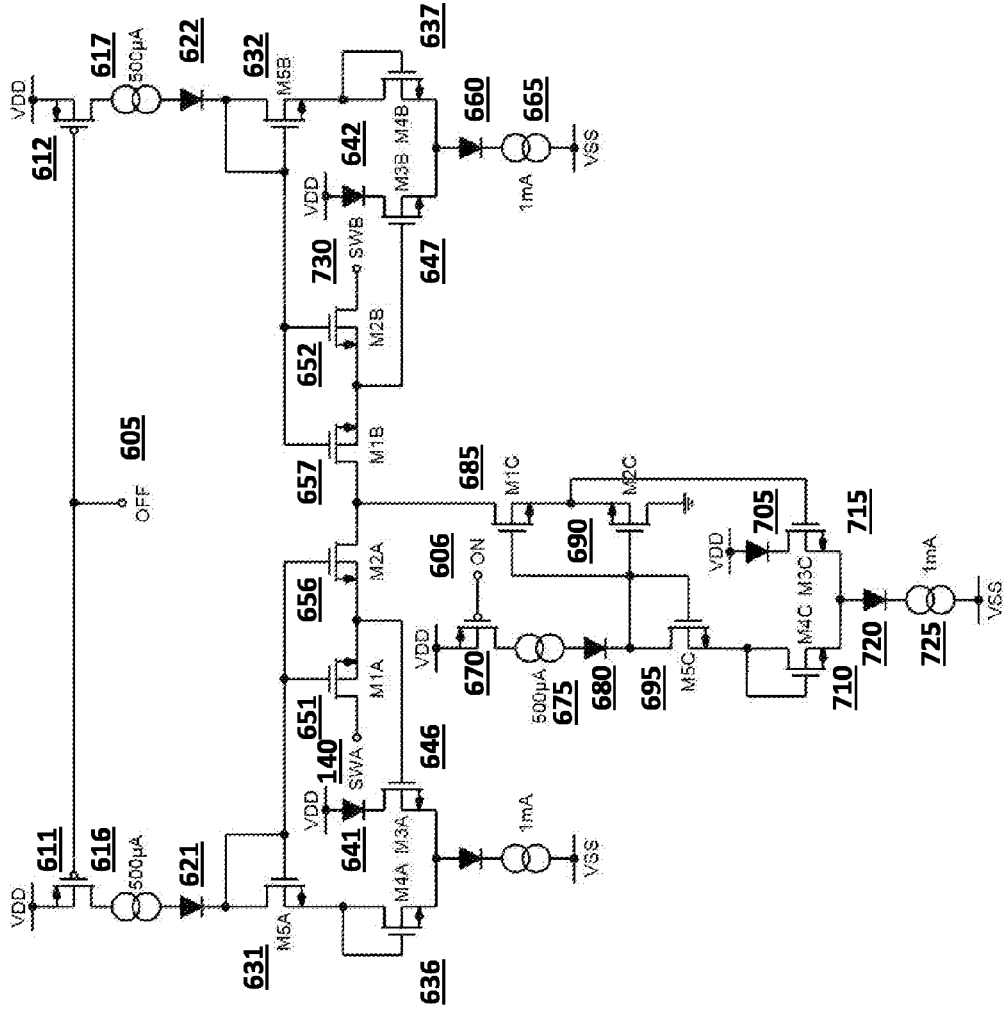


FIGURE 6

600



700

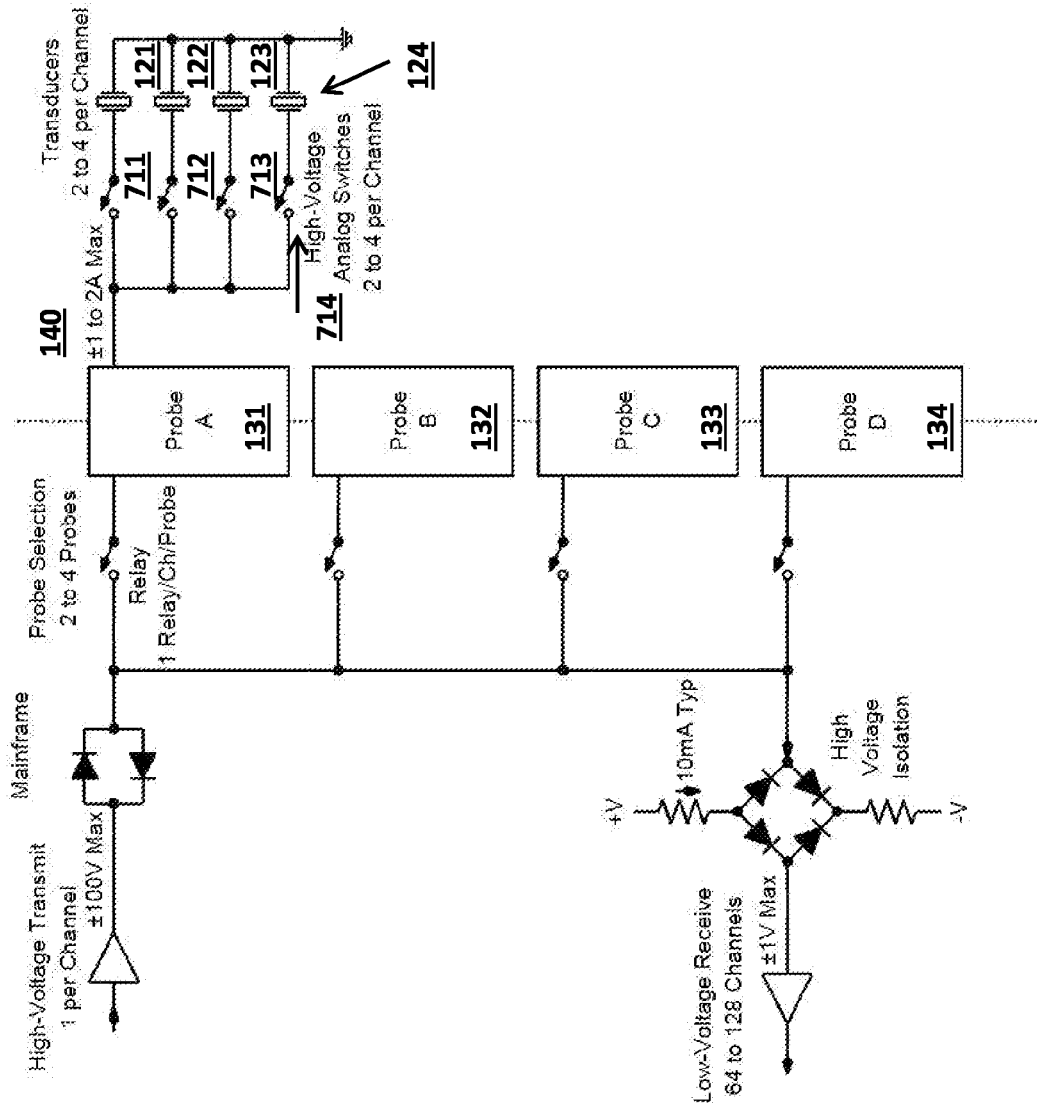


FIGURE 7

ANALOG SWITCH FOR TRANSMITTING HIGH VOLTAGE SIGNALS WITHOUT UTILIZING HIGH VOLTAGE POWER SUPPLIES

TECHNICAL FIELD

[0001] Described herein are multiple designs for an improved analog switch for use in transmitting high voltage signals without using high voltage power supplies for the switch. The analog switches are able to pass and block input signals in the approximate range of -100V to $+100\text{V}$. The use of translinear loops and a bootstrap configuration results in a constant on-resistance of the symmetrical switches and matches the conductance of each analog switch to the transconductance of an NMOS transistor, which can be easily stabilized with a constant g_m biasing scheme. In certain embodiments, a shunt termination (T-switch) configuration is used for better off-isolation, and each of the symmetrical switches has its own translinear loop and thus flexibility of on-resistance and termination voltage.

BACKGROUND OF THE INVENTION

[0002] Numerous prior art devices require the use of an analog switch that can pass or block a high voltage input signal. An example of such a device is depicted in FIG. 1. Medical ultrasound system **100** comprises a plurality of probes, here labeled as exemplary probes **131**, **132**, **133**, and **134**. Additional probes may be utilized. Each probe is coupled to one or more sets of an analog switch and transducer. In this example, probe **131** is coupled to analog switches **111**, **112**, **113**, and **114**, each of which receives high voltage input signal **140** from probe **131**. Analog switch **111** is coupled to transducer **121**, analog switch **112** is coupled to transducer **122**, analog switch **113** is coupled to transducer **123**, and analog switch **114** is coupled to transducer **124**. Additional sets of an analog switch and transducer can be utilized. The role of each of the analog switches **111**, **112**, **113**, and **114** is to connect or disconnect the probe (such as probe **131**) to the switch's respective transducer.

[0003] An example of a prior art analog switch is shown in FIG. 2. Analog switch **111** receives high voltage input signal **140**, which in this example ranges from $+100\text{V}$ to -100V . Analog switch **111** comprises transistors **211**, **212**, **240**, **261**, and **262** as depicted. Transistors **261** and **262** receive control signal **270**. Control signal **270** turns analog switch **111** on or off. When control signal **270** is low, transistor **261** (which is a PMOS transistor) turns on and its drain is pulled to V_{PP} (which here is $+100\text{V}$), and transistor **262** (which is an NMOS transistor) turns off. When control signal **270** is high, transistor **261** turns off, and transistor **262** turns on and its drain is pulled down to V_{NN} (which here is -100V).

[0004] The drain of transistor **261** and the drain of transistor **262** form a node that connects to the gates of transistors **211** and **212**. When control signal **270** is low, transistors **211** and **212** will turn on, which will allow high voltage input signal **140** to be sent to transducer **121**.

[0005] When control signal **270** is high, transistors **211** and **212** will turn off. Control signal **270** will turn on transistor **240**, which will pull the node between transistors **211** and **212** down to V_{NN} (which is -100V). Transistor **240** provides a shunt termination function and improves the off-isolation of switch **111**. Notably, however, transistor **240** requires a high-voltage negative supply (here, $V_{NN}=-100\text{V}$).

[0006] There are numerous drawbacks with the prior art design of FIG. 2. First, it requires significant board space and has a complicated board design and layout, which results in high manufacturing costs. Second, the presence of high DC voltages ($\pm 100\text{V}$) in the probe could cause a bad shock for the operator or patient. Third, the system requires a low-impedance, high-voltage power cord that is neither thin nor flexible. Fourth, a stringent power-up sequence must be followed to prevent transistor breakdown and latch-up. Fifth, the system requires the use of thick gate oxide and may not be feasible with nominal BCD (Bipolar-CMOS-DMOS) processes.

[0007] The prior art includes one attempted solution. FIG. 3 depicts analog switch **300**. Under this design, the positive high voltage supply can be lowered down to 5V instead of 100V if transistors **310** and **320** are low threshold transistors and their gates are clamped to their sources with zener diode **330**. However, analog switch **300** still requires a high negative voltage (here, -100V) for the shunt termination function, which still causes the drawbacks described previously.

[0008] What is needed is an improved analog switch design that can transmit high voltages to a load without requiring high voltage DC power supplies.

SUMMARY OF THE INVENTION

[0009] The embodiments disclosed herein are improved analog switch designs that are able to transmit high voltage signals without using high voltage DC power supplies.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 depicts a prior art medical ultrasound device.

[0011] FIG. 2 depicts a prior art analog switch.

[0012] FIG. 3 depicts another prior art analog switch.

[0013] FIG. 4 depicts an embodiment of an analog switch.

[0014] FIG. 5 depicts another embodiment of an analog switch.

[0015] FIG. 6 depicts another embodiment of an analog switch.

[0016] FIG. 7 depicts and embodiment of a medical ultrasound device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] FIG. 4 depicts analog switch **400**. Analog switch **400** comprises a shunt that terminates to ground instead of to a high voltage negative power supply as in the prior art.

[0018] Analog switch **400** is controlled by control signal **405** and its inverse, control signal **406**, and receives input signal **140** and generates output signal **480**.

[0019] When control signal **405** is low and control signal **406** is high, transistors **411** and **412** (which both are PMOS transistors) are turned on and allow voltage V_{DD} to pass through to the gates of transistors **426**, **427**, **431**, and **432**. Transistor **440** (which is a PMOS transistor) is turned off, and transistor **405** (which is an NMOS transistor) is turned on, which pulls the gates of transistors **465** and **470** to V_{SS} , which results in transistors **465** and **470** being turned off. The input signal **140** flows through transistors **426**, **427**, **431**, and **432**, and appears as output signal **427**.

[0020] When control signal **405** is high and control signal **406** is low, transistors **411** and **412** are turned off and transistors **436** and **437** are turned on, which pulls the gates of transistors **426**, **427**, **431**, and **432** to V_{SS} , which results in

transistors **426**, **427**, **431**, and **432** being turned off. Transistor **440** is turned on, transistor **460** is turned off, resulting in the gates of transistors **465** and **470** being pulled to V_{DD} , which results in transistors **465** and **470** being turned on, which in turn results in the node between transistors **431** and **432** being pulled to ground. This provides off-isolation. The end result is that the input signal **140** is blocked and does not appear as output signal **427**, as analog switch **400** is off.

[0021] Another embodiment is shown in FIG. 5. Analog switch **500** eliminates harmonic distortion and supply modulation through the use of translinear loops.

[0022] When control signal **505** is low, transistor **510** (which is a PMOS transistor) is turned on, which results in V_{DD} being applied to the gates of transistor **525**, **535**, and **540**, which each is turned on as a result. The input signal **140** propagates to output signal **570**.

[0023] When control signal **505** is high, transistor **510** is turned off, and the gate of transistors **525**, **535**, and **540** are pulled down to V_{SS} and are turned off. The input signal **140** is blocked from appearing as output signal **570**.

[0024] In this embodiment, because V_{GS} of transistor **535** and V_{GS} of transistor **540**= V_{GS} of transistor **525**, the conductance of transistors **535** and **540** equals the transconductance of transistor **525** and is independent of the input signal **140** and supply voltages V_{DD} and V_{SS} . Thus, harmonic distortion and supply modulation are eliminated.

[0025] Another embodiment is shown in FIG. 6 as analog switch **600**. Analog switch **600** is controlled by control signal **605** and its inverse, control signal **606**.

[0026] When control signal **605** is low and control signal **606** is high, transistors **611** and **612** (which are PMOS transistors) are turned on, and the gates of transistors **631**, **632**, **651**, **652**, **656**, and **657** are pulled to V_{DD} and those transistors are turned on. Input signal **140** propagates to output signal **730**.

[0027] When control signal **605** is high and control signal **606** is low, transistors **611** and **612** are turned off, and the gates of transistors **631**, **632**, **651**, **652**, **656**, and **657** are pulled to V_{SS} and those transistors are turned off. Transistor **670** is turned on, and the gates of transistors **685** and **690** are pulled to V_{DD} and those transistors are turned on, which pulls the node between transistors **656** and **657** to ground. This provides off-isolation but without a high voltage negative power supply.

[0028] The embodiments described above can be used in devices, such as a medical ultrasound system, that require analog switches that can pass or block high voltage signals. FIG. 7 depicts medical ultrasound system **700**. Medical ultrasound system **700** comprises a plurality of probes, here labeled as exemplary probes **131**, **132**, **133**, and **134** as in FIG. 1. Additional probes may be utilized. Each probe is coupled to one or more sets of an analog switch and transducer. In this example, probe **131** is coupled to analog switches **711**, **712**, **713**, and **714**, each of which receives high voltage signal **140** from probe **131**, and each of which is built according to the design of one of the embodiments described above with reference to FIGS. 4-6.

[0029] Analog switch **711** is coupled to transducer **121**, analog switch **712** is coupled to transducer **122**, analog switch **713** is coupled to transducer **123**, and analog switch **714** is coupled to transducer **124**. Additional sets of an analog switch and transducer can be utilized. The role of each of the analog switches **711**, **712**, **713**, and **714** is to connect or disconnect the probe (such as probe **131**) to the switch's respective trans-

ducer. Due to the design of analog switches **711**, **712**, **713**, and **714**, medical ultrasound system **700** is a significant improvement over the prior art medical ultrasound system **100** of FIG. 1.

[0030] The advantages of the embodiments described above are numerous. First, high voltage DC power supplies are not required or utilized, which eliminates the drawbacks of the prior art systems. Second, adding translinear loops makes the analog switch conductance constant, which eliminates harmonic distortion and supply modulation. Third, a nominal BCD process can be used, and no thick gate oxide devices are required, which increases the ease and decreases the cost of manufacturing.

[0031] References to the present invention herein are not intended to limit the scope of any claim or claim term, but instead merely make reference to one or more features that may be covered by one or more of the claims. Materials, processes and numerical examples described above are exemplary only, and should not be deemed to limit the claims. It should be noted that, as used herein, the terms "over" and "on" both inclusively include "directly on" (no intermediate materials, elements or space disposed there between) and "indirectly on" (intermediate materials, elements or space disposed there between).

What is claimed is:

1. An analog switch, comprising:
 - an input node on a terminal of a first transistor for receiving a high voltage input signal;
 - one or more control nodes for receiving a control signal;
 - an output node on a terminal of a second transistor for presenting the high voltage input signal when the control signal is at a first voltage and for blocking the high voltage input signal when the control signal is at a second voltage; and
 - a shunt circuit connected to a node between the first transistor and the second transistor, wherein the shunt circuit terminates to ground and is not connected to a power supply that supplies a voltage with an absolute value greater than the absolute value of the voltage of the high voltage input signal.
2. The analog switch of claim 1, wherein the high voltage input signal ranges between +100 volts and -100 volts.
3. The analog switch of claim 1, wherein the shunt circuit receives the control signal and pulls the node between the first transistor and the second transistor to ground when the when the control signal is at the second voltage.
4. The analog switch of claim 1, wherein the shunt circuit receives the control signal and does not alter the voltage of the node between the first transistor and the second transistor when the when the control signal is at the first voltage.
5. An analog switch, comprising:
 - a first circuit;
 - a second circuit;
 - the first circuit comprising one or more control nodes for receiving a control signal and an input node for receiving a high voltage input signal;
 - the second circuit comprising one or more control nodes for receiving the control signal and an output node for presenting the high voltage input signal when the control signal is at a first voltage and for blocking the high voltage input signal when the control signal is at a second voltage; and
 - a shunt circuit connected to a node shared by the first circuit and the second circuit, wherein the shunt circuit termi-

- nates to ground and is not connected to a power supply that supplies a voltage with an absolute value greater than the absolute value of the voltage of the high voltage input signal.
- 6.** The analog switch of claim **5**, wherein the high voltage input signal ranges between +100 volts and -100 volts.
- 7.** The analog switch of claim **5**, wherein the first circuit and second circuit are symmetrical.
- 8.** The analog switch of claim **5**, wherein the first circuit comprises a first set of transistors connected in series and the second circuit comprises a second set of transistors connected in series, the first set of transistors and the second set of transistors connected in series.
- 9.** The analog switch of claim **8**, wherein the input node is located at one end of the first set of transistors and the output node is located at one end of the second set of transistors.
- 10.** An analog switch, comprising:
 a first circuit for receiving a control signal and providing a supply voltage when the control signal is at a first voltage and providing a ground voltage when the control signal is at a second voltage;
 a second circuit coupled to the first circuit, the second circuit comprising a translinear loop;
 wherein the second circuit comprises an input node for receiving a high voltage input signal and an output node for presenting the high voltage input signal when the control signal is at the first voltage and for blocking the high voltage input signal when the control signal is at a second voltage.
- 11.** The analog switch of claim **10**, wherein the high voltage input signal ranges between +100 volts and -100 volts.
- 12.** An analog switch, comprising:
 a first circuit;
 a second circuit;
 the first circuit comprising a translinear loop and one or more control nodes for receiving a control signal and an input node for receiving a high voltage input signal;
 the second circuit comprising a translinear loop and one or more control nodes for receiving the control signal and an output node for presenting the high voltage input signal when the control signal is at a first voltage and for blocking the high voltage input signal when the control signal is at a second voltage; and
- a shunt circuit connected to a node shared by the first circuit and the second circuit, wherein the shunt circuit is not connected to a power supply that supplies a voltage with an absolute value greater than the absolute value of the voltage of the high voltage input signal.
- 13.** The analog switch of claim **12**, wherein the high voltage input signal ranges between +100 volts and -100 volts.
- 14.** The analog switch of claim **12**, wherein the first circuit and second circuit are symmetrical.
- 15.** The analog switch of claim **12**, wherein the first circuit comprises a first set of transistors connected in series and the second circuit comprises a second set of transistors connected in series, the first set of transistors and the second set of transistors connected in series.
- 16.** The analog switch of claim **15**, wherein the input node is located at one end of the first set of transistors and the output node is located at one end of the second set of transistors.
- 17.** A medical ultrasound device, comprising:
 a probe;
 a plurality of transducers, each transducer coupled to the probe through an analog switch;
 each analog switch comprising:
 an input node for receiving a high voltage input signal from the probe;
 one or more control nodes for receiving a control signal;
 an output node for presenting the high voltage input signal to one of the plurality of transducers when the control signal is at a first voltage and for blocking the high voltage input signal when the control signal is at a second voltage; and
 a shunt circuit connected to a node between the input node and the output node, wherein the shunt circuit is not connected to a power supply that supplies a voltage with an absolute value greater than the absolute value of the voltage of the high voltage input signal.
- 18.** The medical ultrasound device of claim **17**, wherein the shunt circuit terminates to ground.
- 19.** The medical ultrasound device of claim **17**, wherein the analog switch comprises one or more translinear circuits.
- 20.** The medical ultrasound device of claim **17**, wherein the high voltage input signal ranges between +100 volts and -100 volts.

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