(54) **NON-OVERLAPPING GENERATION TECHNIQUE FOR BOOTSTRAP SWITCHES**

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(57)   **ABSTRACT**

A system includes a bootstrap circuit having an input and an output. The bootstrap circuit includes a boost capacitor having a first terminal and a second terminal, a first transistor coupled between the first terminal of the boost capacitor and the output of the bootstrap circuit, a second transistor, and a third transistor, wherein the second transistor and the third transistor are coupled in series between a gate of the first transistor and the second terminal of the boost capacitor. The system also includes a switch transistor, wherein a gate of the switch transistor is coupled to the output of the bootstrap circuit, and a terminal of the switch transistor is coupled to the input of the bootstrap circuit.
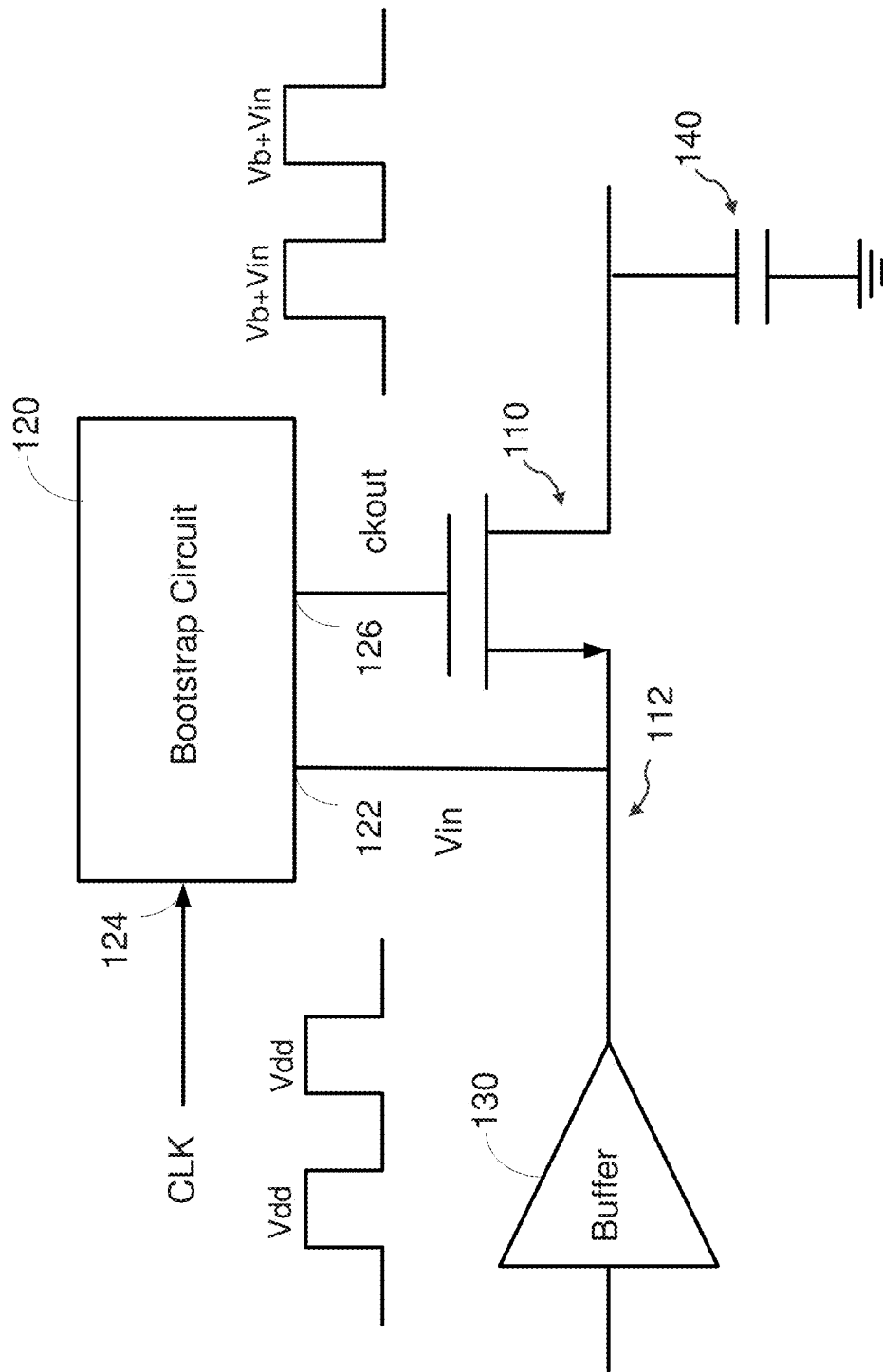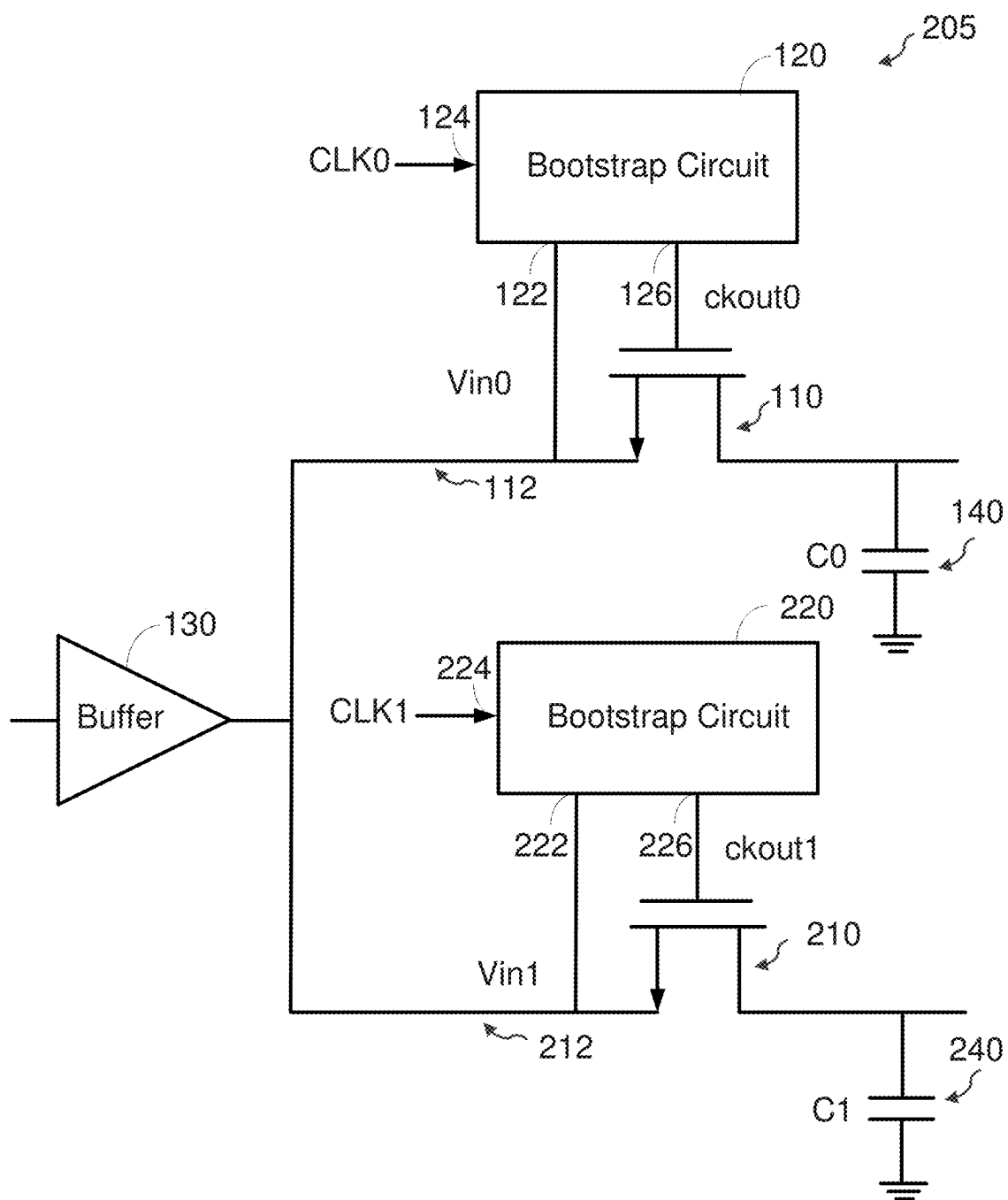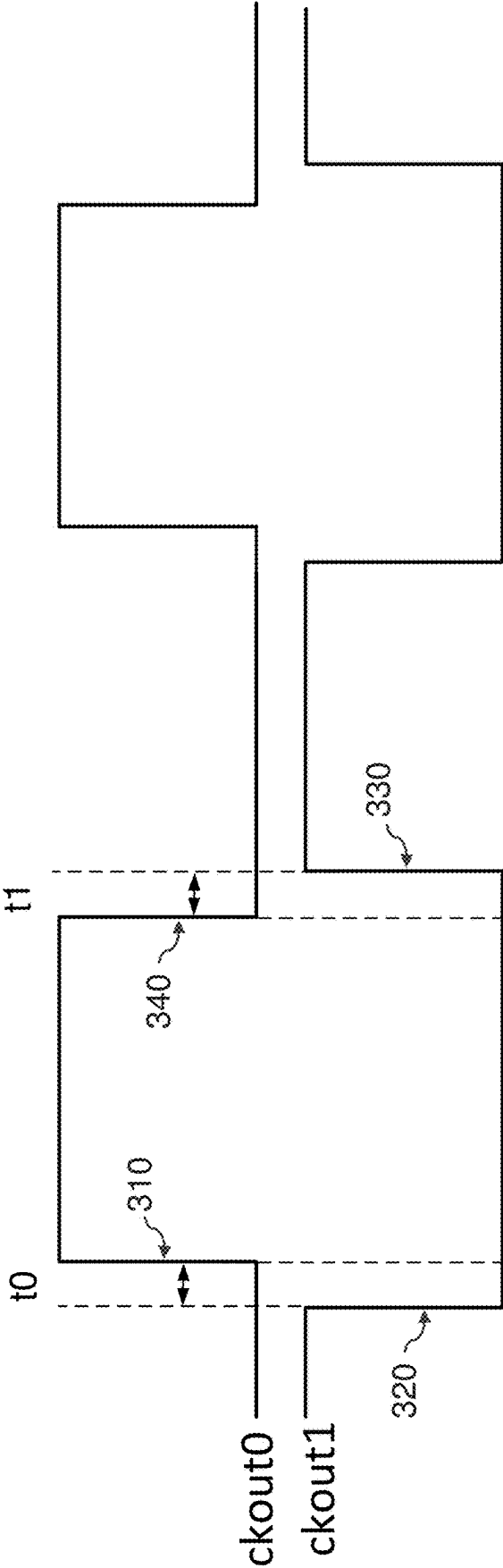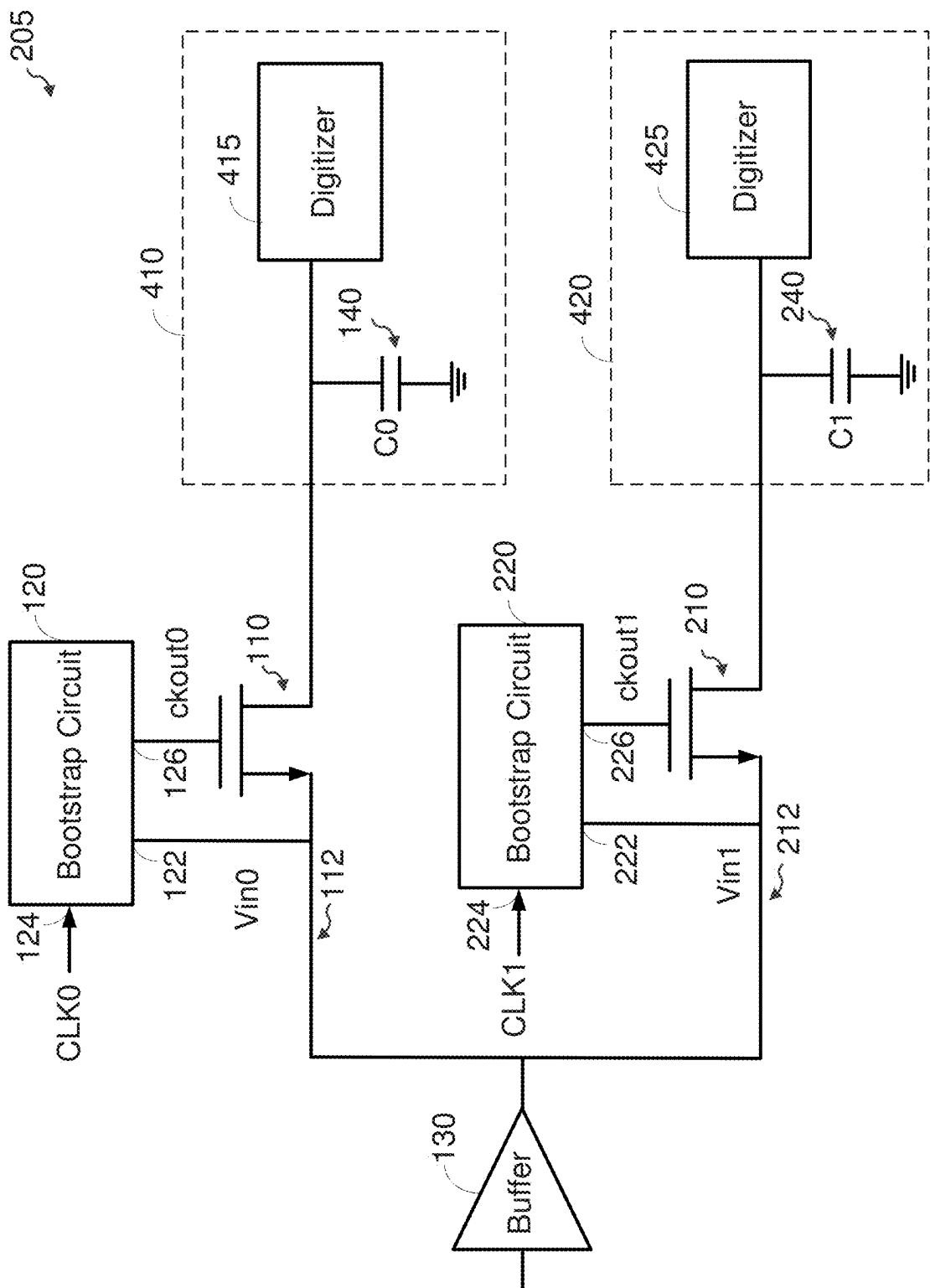
FIG. 1

FIG. 2

ckout0

ckout1

t0

t1

310

320

330

340
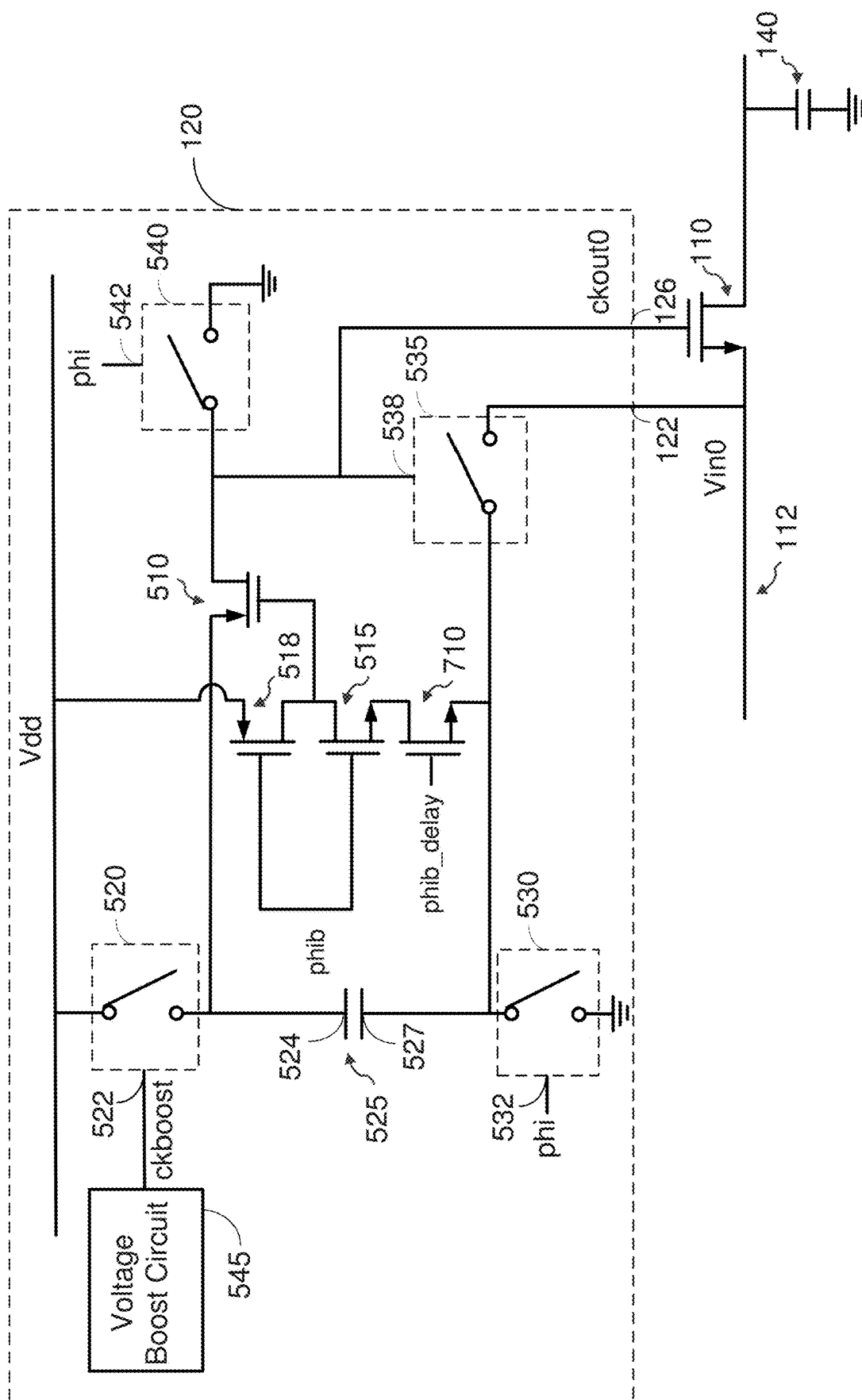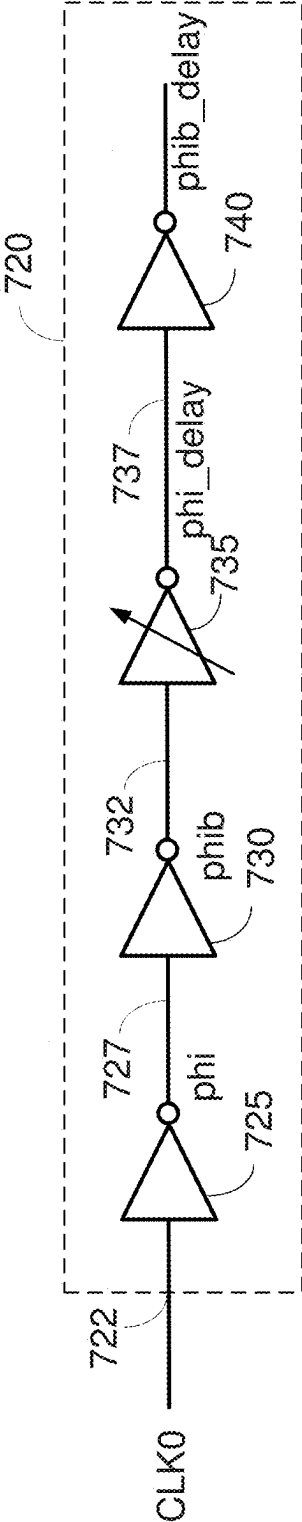
FIG. 3

FIG. 4
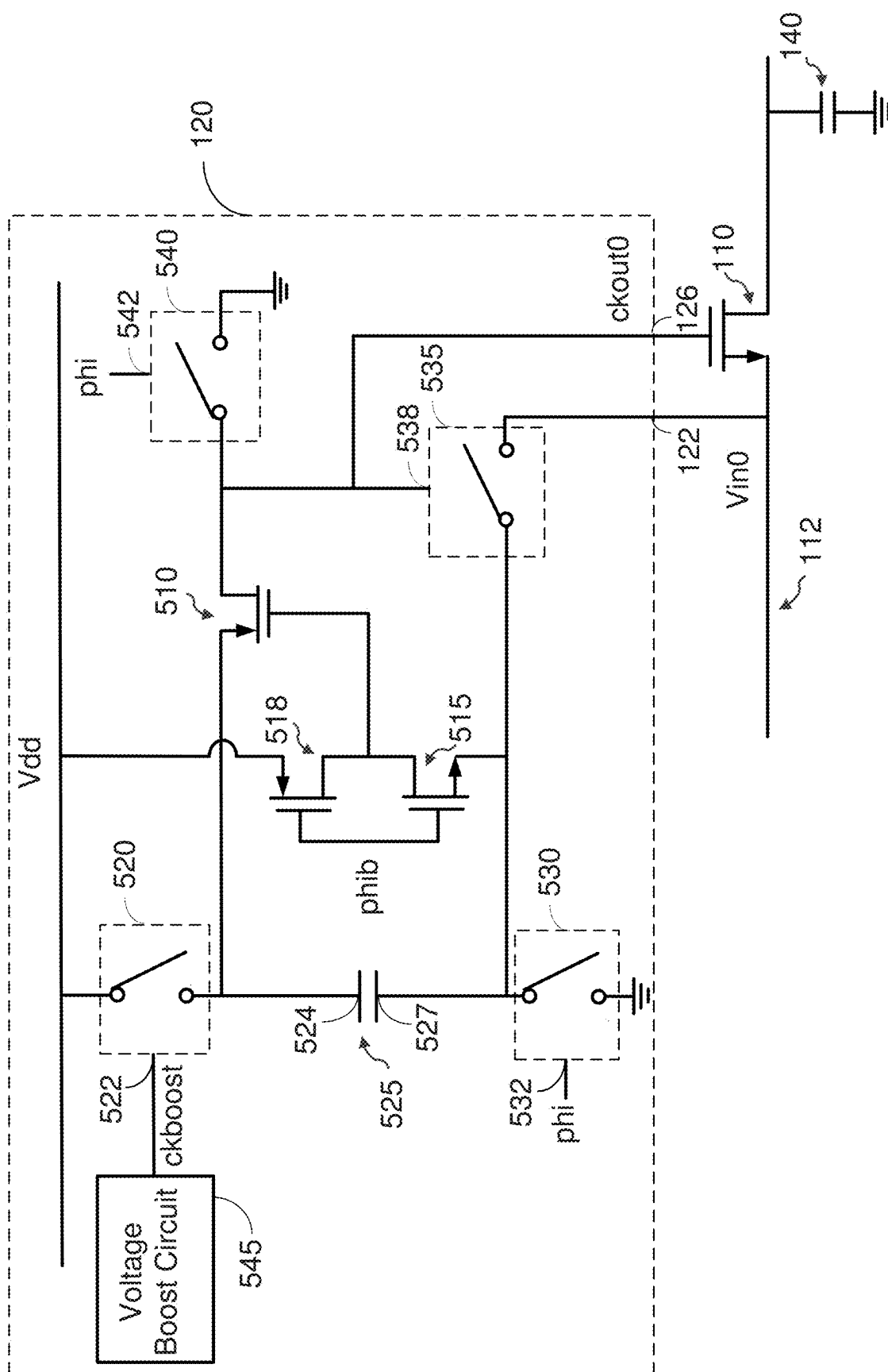
FIG. 5A
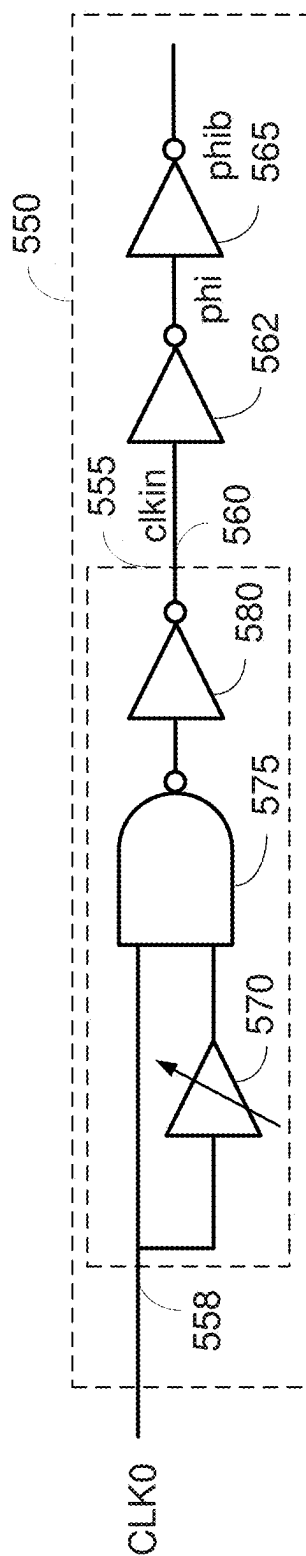
FIG. 5B
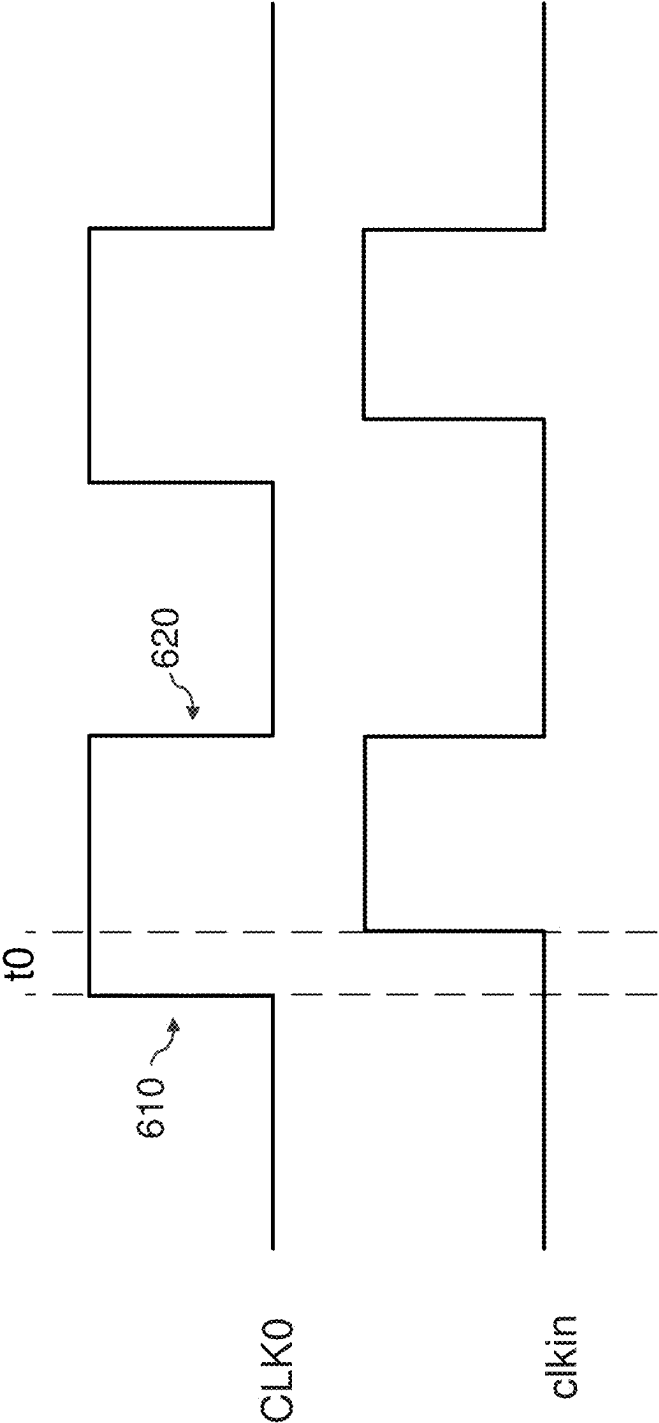
FIG. 6
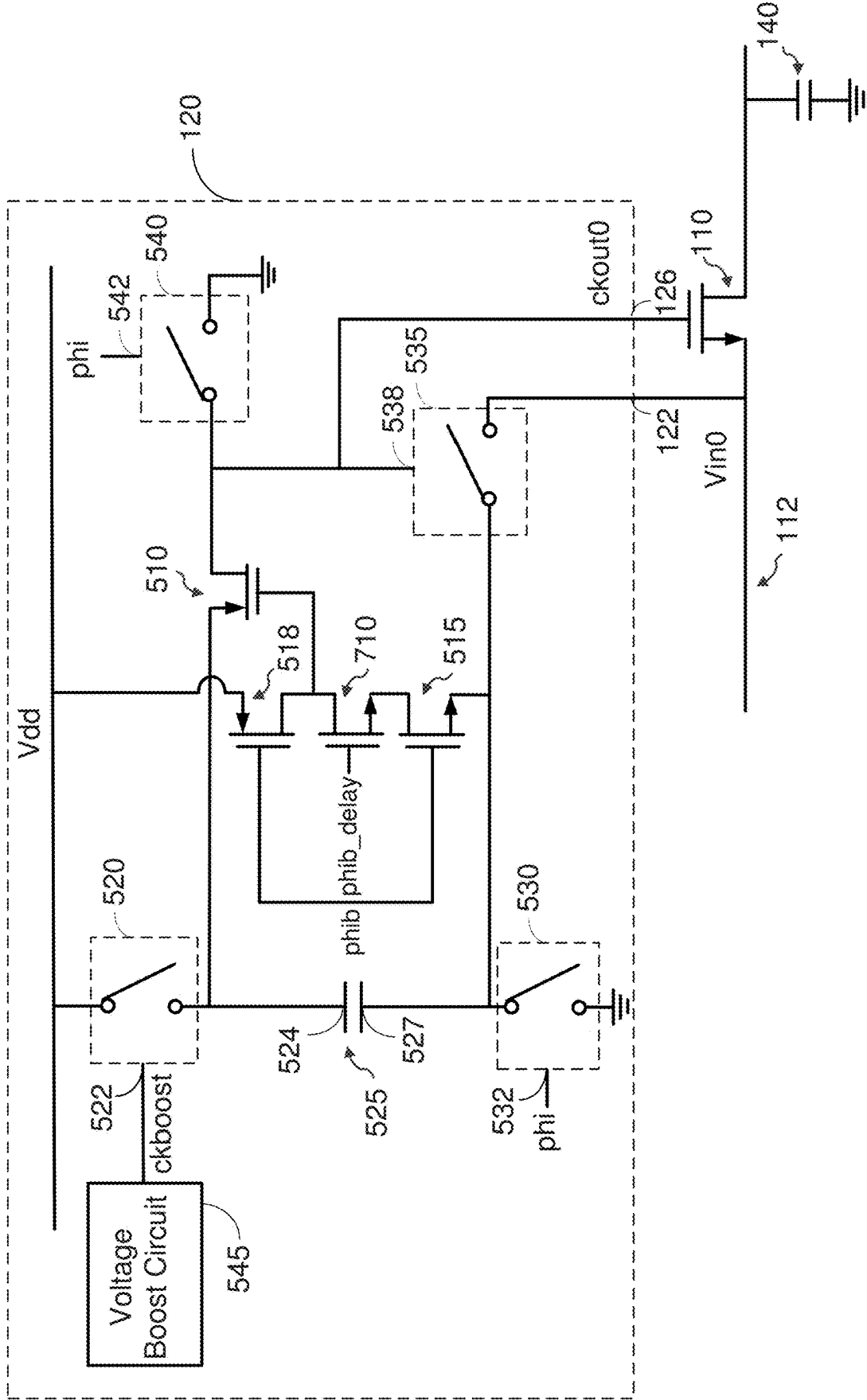
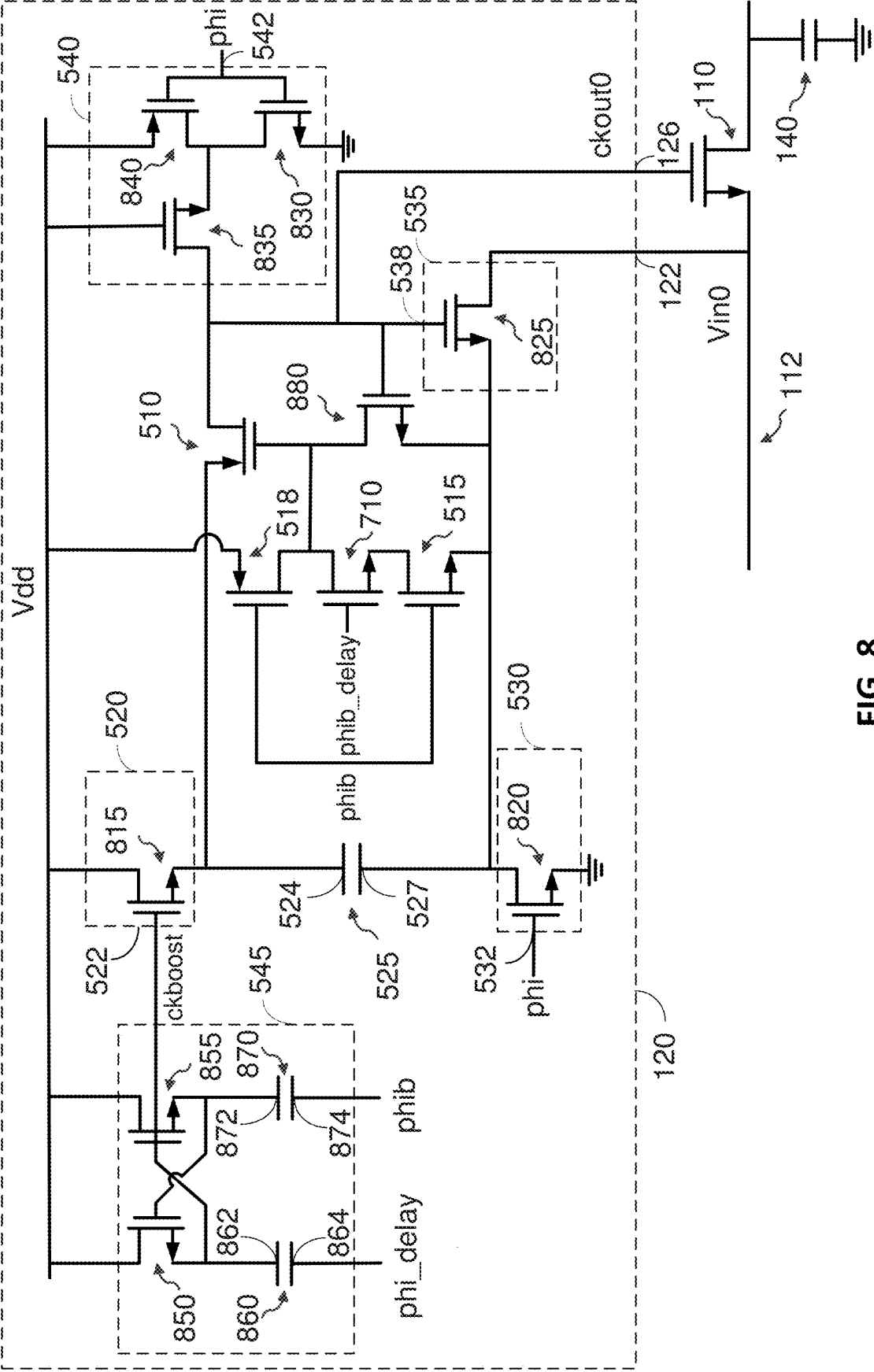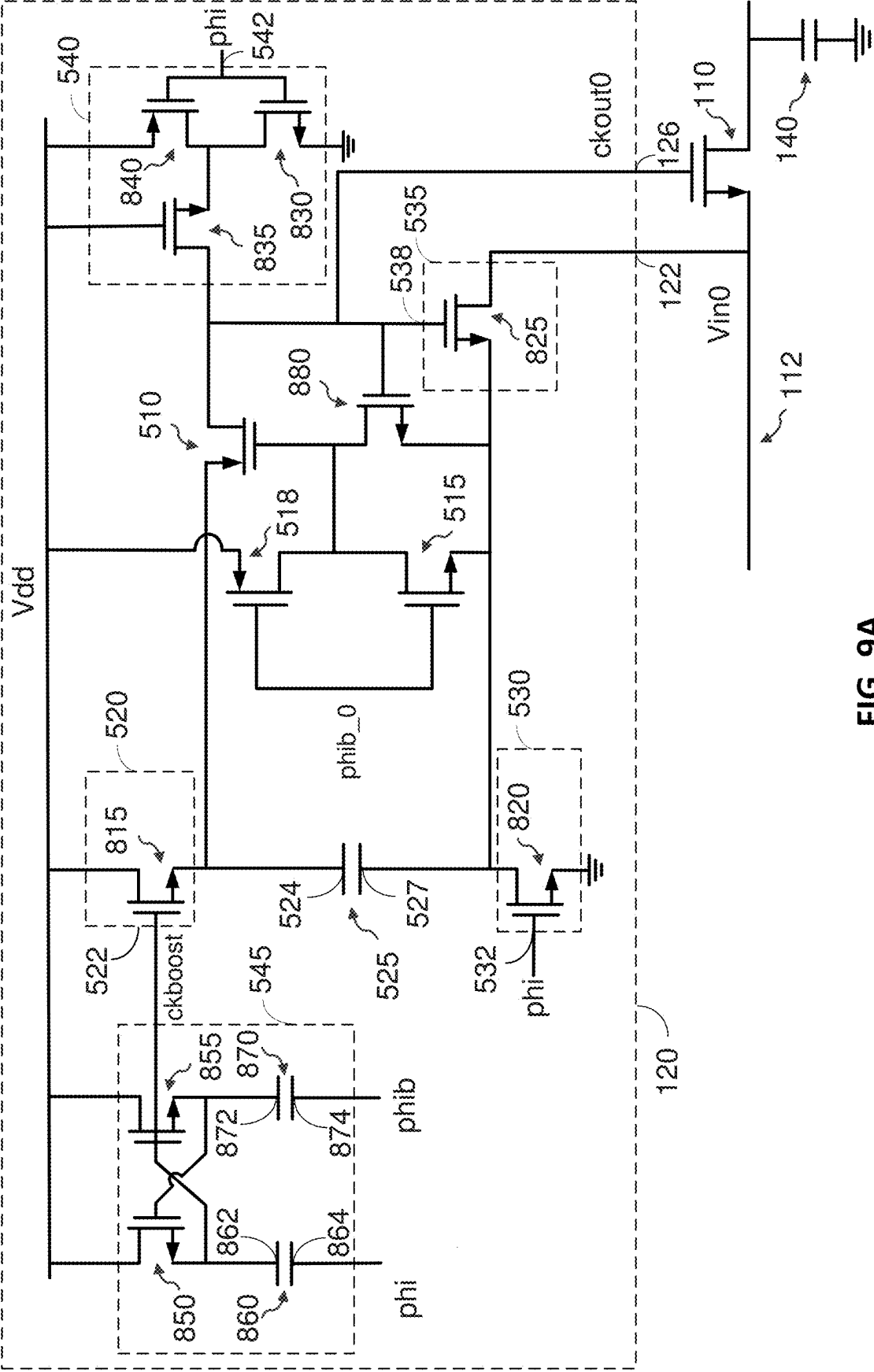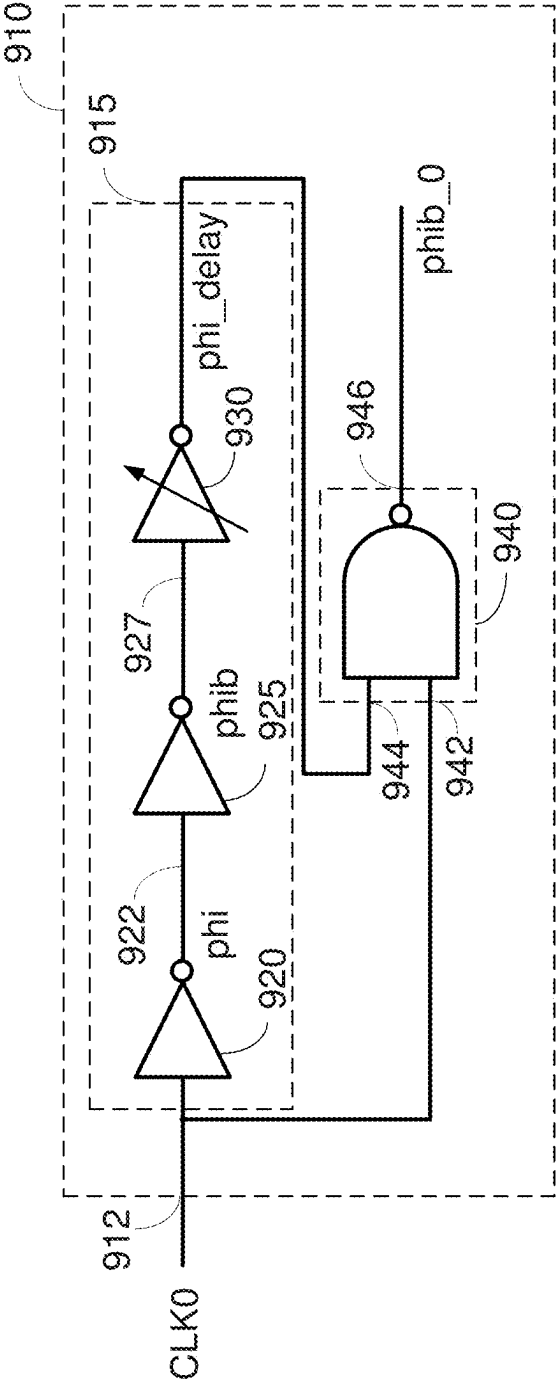**FIG. 7A**

FIG. 7B

FIG. 7C
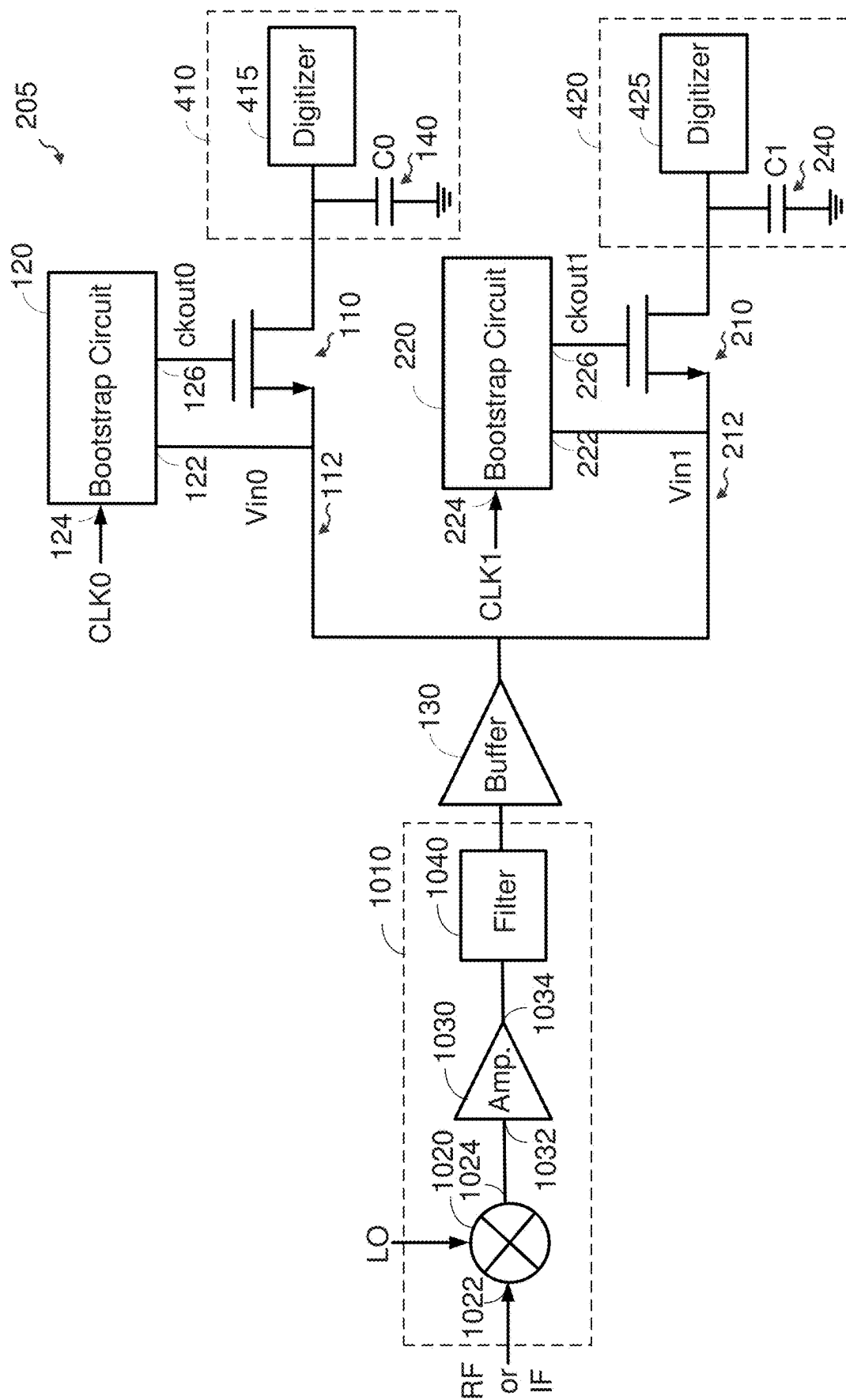
FIG. 8

FIG. 9A

FIG. 9B

FIG. 10

NON-OVERLAPPING GENERATION TECHNIQUE FOR BOOTSTRAP SWITCHES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present Application for Patent is a Divisional of pending U.S. Non-Provisional application Ser. No. 18/307,441, filed Apr. 26, 2023, and assigned to the assignee hereof and hereby expressly incorporated by reference herein as if fully set forth below and for all applicable purposes.

BACKGROUND

Field

[0002] Aspects of the present disclosure relate generally to switches, and, more particularly, to bootstrap switches.

Background

[0003] A system may include bootstrap switches for selectively blocking or passing signals in two or more channels of the system. To reduce crosstalk between the channels, timing circuits (e.g., clock paths) may be used to generate non-overlapping clock signals for timing switching operations of the bootstrap switches. A challenge with implementing the timing circuits is that the timing circuits include delay circuits and clock drivers, which introduce jitter/skew into the non-overlapping clock signals, degrading performance.

SUMMARY

[0004] The following presents a simplified summary of one or more implementations in order to provide a basic understanding of such implementations. This summary is not an extensive overview of all contemplated implementations and is intended to neither identify key or critical elements of all implementations nor delineate the scope of any or all implementations. Its sole purpose is to present some concepts of one or more implementations in a simplified form as a prelude to the more detailed description that is presented later.

[0005] A first aspect relates to a system. The system includes a bootstrap circuit having an input and an output. The bootstrap circuit includes a boost capacitor having a first terminal and a second terminal, a first transistor coupled between the first terminal of the boost capacitor and the output of the bootstrap circuit, a second transistor, and a third transistor, wherein the second transistor and the third transistor are coupled in series between a gate of the first transistor and the second terminal of the boost capacitor. The system also includes a switch transistor, wherein a gate of the switch transistor is coupled to the output of the bootstrap circuit, and a terminal of the switch transistor is coupled to the input of the bootstrap circuit.

[0006] A second aspect relates to a system. The system includes a bootstrap circuit having an input and an output. The bootstrap circuit includes a boost capacitor having a first terminal and a second terminal, a first transistor coupled between the first terminal of the boost capacitor and the output of the bootstrap circuit, a second transistor coupled between a gate of the first transistor and the second terminal of the boost capacitor, a first switch coupled between the output of the bootstrap circuit and a ground, and a timing circuit. The timing circuit includes a logic gate having a first input, a second input, and an output, wherein the first input of the logic gate is coupled to an input of the timing circuit, and the output of the logic gate is coupled to a gate of the second transistor. The timing circuit also includes a clock path coupled between the input of the timing circuit and the second input of the logic gate, wherein a control input of the first switch is coupled to the clock path. The system also includes a switch transistor, wherein a gate of the switch transistor is coupled to the output of the bootstrap circuit, and a terminal of the switch transistor is coupled to the input of the bootstrap circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 shows an example of a bootstrap circuit and a switch transistor according to certain aspects of the present disclosure.

[0008] FIG. 2 shows an example of a system including switch transistors and bootstrap circuits according to certain aspects of the present disclosure.

[0009] FIG. 3 is a timing diagram showing an example of output clock signals of the bootstrap circuit of FIG. 2 according to certain aspects of the present disclosure.

[0010] FIG. 4 shows an example of the system of FIG. 2 including analog-to-digital converters according to certain aspects of the present disclosure.

[0011] FIG. 5A shows an exemplary implementation of a bootstrap circuit according to certain aspects of the present disclosure.

[0012] FIG. 5B shows an example of a timing circuit according to certain aspects of the present disclosure.

[0013] FIG. 6 is a timing diagram illustrating signals in the timing circuit of FIG. 5B according to certain aspects of the present disclosure.

[0014] FIG. 7A shows another exemplary implementation of a bootstrap circuit according to certain aspects of the present disclosure.

[0015] FIG. 7B shows yet another exemplary implementation of a bootstrap circuit according to certain aspects of the present disclosure.

[0016] FIG. 7C shows another example of a timing circuit according to certain aspects of the present disclosure.

[0017] FIG. 8 shows an exemplary implementation of switches and a voltage boost circuit according to certain aspects of the present disclosure.

[0018] FIG. 9A shows another exemplary implementation of a bootstrap circuit according to certain aspects of the present disclosure.

[0019] FIG. 9B shows another example of a timing circuit according to certain aspects of the present disclosure.

[0020] FIG. 10 shows an example of a system including switch transistors, bootstrap circuits, and a receiver according to certain aspects of the present disclosure.

DETAILED DESCRIPTION

[0021] The detailed description set forth below, in connection with the appended drawings, is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of the various concepts. However, it will be apparent to those skilled in the art that these concepts

may be practiced without these specific details. In some instances, well-known structures and components are shown in block diagram form in order to avoid obscuring such concepts.

[0022] A switch transistor may be used in a signal path to selectively block or pass a signal in the signal path. As used herein, a "switch transistor" is a transistor that is used as a switch. A switch transistor may be implemented with an n-type field effect transistor (NFET), or another type of transistor. The on/off state of a switch transistor may be controlled by controlling the voltage at the gate of the switch transistor. For the example of a switch transistor implemented with an NFET, the switch transistor may be turned on by applying a high voltage to the gate of the switch transistor, and the switch transistor may be turned off by applying a low voltage to the gate of the switch transistor. The switch transistor has an on resistance, which is the resistance across the switch transistor when the switch transistor is turned on (i.e., switched on).

[0023] A challenge with using a switch transistor to selectively pass or block a signal in a signal path is that the on resistance of the switch transistor depends on the gate-to-source voltage of the switch transistor. This dependance causes the on resistance of the switch transistor to vary when the voltage of the signal in the signal path varies. The varying on resistance of the switch transistor causes distortion in the signal in the signal path.

[0024] To address the voltage-dependent on resistance of the switch transistor, a bootstrap circuit may be used. In this regard, FIG. 1 shows an example of a switch transistor 110 and a bootstrap circuit 120 according to certain aspects. In the example in FIG. 1, the switch transistor 110 is implemented with an NFET. However, it is to be appreciated that the switch transistor 110 may be implemented with another type of transistor such as a p-type field effect transistor (PFET).

[0025] The switch transistor 110 is used to selectively pass or block a signal in a signal path 112. In the example in FIG. 1, the signal path 112 is between the output of a buffer 130 and a sampling capacitor 140. The sampling capacitor 140 may be used in an analog-to-digital converter (ADC), a capacitive digital-to-analog converter (DAC), or another type of circuit to sample the signal. However, it is to be appreciated that the disclosure is not limited to these examples. It is also to be appreciated that the sampling capacitor 140 may be implemented with multiple capacitors (e.g., coupled in parallel) in some implementations.

[0026] The bootstrap circuit 120 is configured to switch the switch transistor 110 on and off based on a clock signal CLK. The bootstrap circuit 120 has an input 122 coupled to a terminal (e.g., a source) of the switch transistor 110, a clock input 124 configured to receive the clock signal CLK, and an output 126 coupled to the gate of the switch transistor 110. The clock signal CLK may have an amplitude equal to a supply voltage Vdd, as shown in the example in FIG. 1.

[0027] The bootstrap circuit 120 is configured to receive the voltage Vin of the signal at the terminal (e.g., the source) of the switch transistor 110, generate an output clock signal ckout based on the clock signal CLK and the voltage Vin, and output the output clock signal ckout to the gate of the switch transistor 110 to switch the switch transistor 110 on and off. The output clock signal ckout may have a period approximately equal to a period of the clock signal CLK. The output clock signal ckout has an amplitude equal to

Vb+Vin where Vb is a boost voltage (also referred to as an offset voltage). Thus, the output clock signal ckout boosts the voltage Vin by the boost voltage Vb when the output clock signal ckout is high. The boost voltage Vb may be greater than the threshold voltage of the switch transistor 110 to turn on the switch transistor 110 when the output clock signal ckout is high. In one example, the boost voltage Vb is approximately equal to the supply voltage Vdd. In this example, the amplitude of the output clock signal ckout is approximately equal to Vdd+Vin. The output clock signal ckout may have a voltage approximately equal to ground potential when the output clock signal ckout is low.

[0028] Thus, the voltage at the gate of the switch transistor 110 is equal to Vb+Vin and the voltage at the terminal (e.g., the source) of the switch transistor 110 is equal to Vin when the output clock signal ckout is high. This causes the gate-to-source voltage VGS of the switch transistor 110 to be approximately constant at Vb (i.e., VGS=Vb+Vin−Vin, which simplifies to Vb). The constant gate-to-source voltage VGS causes the on resistance of the switch transistor 110 to be approximately constant for good linearity. In this example, the switch transistor 110 is turned on during high phases of the output clock signal ckout (i.e., when the output clock signal ckout is high), and turned off during low phases of the output clock signal ckout (i.e., when the output clock signal ckout is low).

[0029] Two or more switch transistors and two or more bootstrap circuits may be used to implement time-interleaved channels. In this regard, FIG. 2 shows an example of a system 205 with two time-interleaved channels according to certain aspects of the present disclosure. The system 205 includes the switch transistor 110, the bootstrap circuit 120, the buffer 130, and the sampling capacitor 140 discussed above. The system 205 also includes a second switch transistor 210, a second bootstrap circuit 220, and a second sampling capacitor 240. In the discussion below, the switch transistor 110 is referred to as the first switch transistor, the bootstrap circuit 120 is referred to as the first bootstrap circuit, the sampling capacitor 140 is referred to as the first sampling capacitor 140, and the signal path 112 is referred to as the first signal path.

[0030] In this example, the second switch transistor 210 is used to selectively pass or block a signal in a second signal path 212. The second signal path 212 is between the output of the buffer 130 and the second sampling capacitor 240. The second sampling capacitor 240 may be used in an ADC, a capacitive DAC, or another type of circuit to sample the signal in the second signal path 212. It is also to be appreciated that the second sampling capacitor 240 may be implemented with multiple capacitors (e.g., coupled in parallel) in some implementations. The second bootstrap circuit 220 has an input 222 coupled to a terminal (e.g., a source) of the second switch transistor 210, a clock input 224, and an output 226 coupled to the gate of the second switch transistor 210. The second bootstrap circuit 220 may be a second instance (i.e., copy) of the first bootstrap circuit 120 in some implementations.

[0031] In this example, the first switch transistor 110 and the first bootstrap circuit 120 are used for sampling the signal in the first signal path 112 (also referred to as a first channel), and the second switch transistor 210 and the second bootstrap circuit 220 are used for sampling the signal in the second signal path 212 (also referred to as a second channel). In FIG. 2, the signals associated with the first

switch transistor **110** and the first bootstrap circuit **120** are appended with "0" and the signals associated with the second switch transistor **210** and the second bootstrap circuit **220** are appended with "1".

[0032] During operation, the first bootstrap circuit **120** receives a first clock signal CLK0 at the respective clock input **124**, and the second bootstrap circuit **220** receives a second clock signal CLK1 at the respective clock input **224**. In certain aspects, the second clock signal CLK1 may be the complement of the first clock signal CLK0 to provide time interleaving of the two channels, as discussed further below.

[0033] The first bootstrap circuit **120** receives the first clock signal CLK0 and the voltage Vin0 of the signal at the terminal (e.g., the source) of the first switch transistor **110**. The first bootstrap circuit **120** generates the output clock signal ckout0 based on the first clock signal CLK0 and the voltage Vin0, and outputs the output clock signal ckout0 to the gate of the first switch transistor **110** to switch the first switch transistor **110** on and off. The output clock signal ckout0 has a voltage of approximately Vb+Vin0 when the output clock signal ckout0 is high.

[0034] The second bootstrap circuit **220** receives the second clock signal CLK1 and the voltage Vin1 of the signal at the terminal (e.g., the source) of the second switch transistor **210**. The second bootstrap circuit **220** generates the output clock signal ckout1 based on the second clock signal CLK1 and the voltage Vin1, and outputs the output clock signal ckout1 to the gate of the second switch transistor **210** to switch the second switch transistor **210** on and off. The output signal ckout1 has a voltage of approximately Vb+Vin1 when the output clock signal ckout1 is high.

[0035] Because the first clock signal CLK0 and the second clock signal CLK1 are complementary, the output clock signals ckout0 and ckout1 are alternately high. As a result, the first switch transistor **110** and the second switch transistor **210** are alternately turned on by the output clock signals ckout0 and ckout1 (i.e., the first switch transistor **110** and the second switch transistor **210** are time-interleaved).

[0036] FIG. **3** is a timing diagram showing an example of the output clock signals ckout0 and ckout1 according to certain aspects. In this example, the rising edge **310** of the output clock signal ckout0 is delayed with respect to the falling edge **320** of the output clock signal ckout1 by time delay t0, and the rising edge **330** of the output clock signal ckout1 is delayed with respect to the falling edge **340** of the output clock signal ckout0 by time delay t1, as shown in FIG. **3**. The time delays help ensure there is no overlap between the high phases of the output clock signal ckout0 and the high phases of the output clock signal ckout1. This prevents the first switch transistor **110** and the second switch transistor **210** from being turned on at the same time, which reduces crosstalk between the first channel and the second channel. The time delays t0 and t1 may be programmable in some implementations.

[0037] As discussed above, the sampling capacitors **140** and **240** may be used in ADCs. In this regard, FIG. **4** shows an example in which the system includes a first ADC **410** and a second ADC **420**. In this example, the first ADC **410** includes the first sampling capacitor **140** and a first digitizer **415**, and the second ADC **420** includes the second sampling capacitor **240** and a second digitizer **425**.

[0038] In this example, the first sampling capacitor **140** samples the voltage of the signal in the first signal path **112** when the first switch transistor **110** is turned on by the output

clock signal ckout0. When the first switch transistor **110** is turned off by the output clock signal ckout0, the first sampling capacitor **140** holds the voltage of the sampled signal, and the first digitizer **415** converts the held voltage into a first digital signal (e.g., a first digital code). In this example, the falling edge of the output clock signal ckout0 determines the sampling instance of the first sampling capacitor **140**. This is because the first switch transistor **110** turns off on the falling edge of the output clock signal ckout0. As a result, the first sampling capacitor **140** holds the voltage of the signal in the first signal path **112** at the time of the falling edge of the output clock signal ckout0, and the first digitizer **415** converts this voltage into the first digital signal.

[0039] The second sampling capacitor **240** samples the voltage of the signal in the second signal path **212** when the second switch transistor **210** is turned on by the output clock signal ckout1. When the second switch transistor **210** is turned off by the output clock signal ckout1, the second sampling capacitor **240** holds the voltage of the sampled signal, and the digitizer **425** converts the held voltage into a second digital signal (e.g., a second digital code). In this example, the falling edge of the output clock signal ckout1 determines the sampling instance of the second sampling capacitor **240**. This is because the second switch transistor **210** turns off on the falling edge of the output clock signal ckout1. As a result, the second sampling capacitor **240** holds the voltage of the signal in the second signal path **212** at the time of the falling edge of the output clock signal ckout1, and the second digitizer **425** converts this voltage into the second digital signal.

[0040] FIG. **5A** shows an exemplary implementation of the first bootstrap circuit **120** according to certain aspects. The exemplary implementation shown in FIG. **5A** may also be used to implement the second bootstrap circuit **220**.

[0041] In this example, the first bootstrap circuit **120** includes a boost capacitor **525**, a first switch **520**, a second switch **530**, a third switch **535**, and a fourth switch **540**. Each of the switches **520**, **530**, **535**, and **540** has a respective control input **522**, **532**, **538**, and **542** for controlling the on/off state of the switch. Each of the switches **520**, **530**, **535**, and **540** may be implemented with one or more respective transistors. As discussed further below, the on/off states of the switches **520**, **530**, **535**, and **540** may be controlled by control signals (e.g., clock signals) that are generated from the clock signal CLK0.

[0042] In this example, the first switch **520** is coupled between a first terminal **524** of the boost capacitor **525** and a supply rail providing supply voltage Vdd. The second switch **530** is coupled between a second terminal **527** of the boost capacitor **525** and ground (also referred to as Vss). The third switch **535** is coupled between the second terminal **527** of the boost capacitor **525** and the input **122** of the first bootstrap circuit **120**. The control input **538** of the third switch **535** is coupled to the output **126** of the first bootstrap circuit **120**. The fourth switch **540** is coupled between the output **126** of the first bootstrap circuit **120** and ground. It is to be appreciated that a terminal of a capacitor may also be referred to as a plate, an electrode, or another term.

[0043] The first bootstrap circuit **120** also includes a transistor **510** coupled between the first terminal **524** of the boost capacitor **525** and the output **126** of the first bootstrap circuit **120**. In this example, the source of the transistor **510** is coupled to the first terminal **524** of the boost capacitor

525, and the drain of the transistor 510 is coupled to the output 126 of the first bootstrap circuit 120. In the example shown in FIG. 5A, the transistor 510 is implemented with a p-type field effect transistor (PFET). However, it is to be appreciated that the transistor 510 may be implemented with another type of transistor.

[0044] The first bootstrap circuit 120 also includes a transistor 515 coupled between the gate of the transistor 510 and the second terminal 527 of the boost capacitor 525. In this example, the drain of the transistor 515 is coupled to the gate of the transistor 510, and the source of the transistor 515 is coupled to the second terminal 527 of the boost capacitor 525.

[0045] The first bootstrap circuit 120 also includes a transistor 518 coupled between the gate of the transistor 510 and the supply rail. In this example, the source of the transistor 518 is coupled to the supply rail, the drain of the transistor 518 is coupled to the gate of the transistor 510, and the gate of the transistor 518 is coupled to the gate of the transistor 515.

[0046] In the example shown in FIG. 5A, the transistor 515 is implemented with an n-type field effect transistor (NFET) and the transistor 518 is implemented with a PFET. However, it is to be appreciated that the present disclosure is not limited to this example.

[0047] The first bootstrap circuit 120 also includes a voltage boost circuit 545 coupled to the control input 522 of the first switch 520. As discussed further below, the voltage boost circuit 545 is configured to generate the control signal ckboost used to control the first switch 520.

[0048] FIG. 5B shows an example of a timing circuit 550 (e.g., a clock path) configured to receive the clock signal CLK0 and generate control signals phi and phib (e.g., clock signals) based on the clock signal CLK0. The control signals phi and phib are used to control the on/off states of the switches 520, 530, 535, and 540 and the on/off states of the transistors 515 and 518, as discussed further below. The timing circuit 550 includes a rising-edge delay circuit 555, a first driver 562, and a second driver 565. In the example shown in FIG. 5B, each of the drivers 562 and 565 is implemented with a respective inverter. However, it is to be appreciated that the present disclosure is not limited to this example.

[0049] As used herein, a "driver" is a circuit that receives a signal (e.g., a clock signal) and drives a load (e.g., another driver, one or more switches, or any combination thereof) based on the signal. A driver may be inverting or non-inverting. For an example of a clock signal, a driver may also be referred to as a clock driver, a clock buffer, or another term.

[0050] The rising-edge delay circuit 555 has an input 558 configured to receive the clock signal CLK0 and an output 560. The rising-edge delay circuit 555 is configured to delay the rising edge of the clock signal CLK0 by a time delay (e.g., a programmable time delay). This is done to produce the time delay t0 between the rising edge 310 of the output clock signal ckout0 and the falling edge 320 of the output clock signal ckout1 discussed above to prevent overlap between the high phases of the output clock signal ckout0 and the high phases of the output clock signal ckout1.

[0051] In the example shown in FIG. 5B, the rising-edge delay circuit 555 includes a delay circuit 570, a NAND gate 575, and a driver 580 (e.g., an inverter). A first input of the NAND gate 575 is coupled to the input 558 of the rising-

edge delay circuit 555, and the delay circuit 570 is coupled between the input 558 of the rising-edge delay circuit 555 and a second input of the NAND gate 575. The input of the driver 580 is coupled to the output of the NAND gate 575 and the output of the driver 580 is coupled to the output 560 of the rising-edge delay circuit 555. The rising-edge delay circuit 555 outputs a clock signal clkin based on the clock signal CLK0, in which the rising edge of the clock signal clkin is delayed with respect to the rising edge of the clock signal CLK0 by the delay circuit 570.

[0052] FIG. 6 is a timing diagram showing an example of the clock signal CLK0 and the clock signal clkin according to certain aspects. As shown in FIG. 6, the rising-edge delay circuit 555 delays the rising edge 610 of the clock signal CLK0 by time delay t0, which is controlled by the delay of the delay circuit 570. This is because, when the rising edge 610 of the clock signal CLK0 is received at the input 558, the output 560 of the rising-edge delay circuit 555 does not transition from low to high until both inputs of the NAND gate 575 are high. This occurs when the rising edge of the clock signal CLK0 delayed by the delay circuit 570 reaches the second input of the NAND gate 575.

[0053] In the example in FIG. 6, the falling edge 620 of the clock signal CLK0 is not delayed (assuming the delays in the NAND gate 575 and the driver 580 are negligible compared to the delay of the delay circuit 570 for simplicity). This is because, when the falling edge 620 of the clock signal CLK0 is received at the input 558, the output 560 of the rising-edge delay circuit 555 transitions from high to low when the falling edge 620 of the clock signal CLK0 reaches the first input of the NAND gate 575 regardless of the logic state at the second input of the NAND gate 575. Although the delays in the NAND gate 575 and the driver 580 are assumed to be negligible in the example shown in FIG. 6 for simplicity, it is to be appreciated that this need not be the case.

[0054] Returning to FIG. 5B, the input of the first driver 562 is coupled to the output 560 of the rising-edge delay circuit 555, and the input of the second driver 565 is coupled to the output of the first driver 562. In this example, the control signals phi and phib are provided at the outputs of the first driver 562 and the second driver 565, respectively. The control signals phi and phib are complementary since the second driver 565 inverts the control signal phi to generate the control signal phib in this example. As shown in FIG. 5A, the control signal phi is input to the control inputs 532 and 542 of the second and fourth switches 530 and 540, and the control signal phib is input to the gates of the transistors 515 and 518. In this example, the second and fourth switches 530 and 540 are configured to turn on when the control signal phi is high (e.g., Vdd) and turn off when the control signal phi is low (e.g., zero volts)

[0055] In certain aspects, the voltage boost circuit 545 is configured to boost the voltage of the control signal phi to generate the control signal ckboost, which is input to the control input 522 of the first switch 520. For example, the voltage boost circuit 545 may boost the voltage of the control signal phi by the supply voltage Vdd to generate the control signal ckboost. In this example, the control signal phi may have a high voltage of approximately Vdd and a low voltage of approximately zero volts, and the control signal ckboost may have a high voltage of approximately 2Vdd and a low voltage of approximately Vdd. However, it is to be appreciated that the present disclosure is not limited to this example, and that the voltage boost circuit 545 may boost

the voltage of the control signal phi by a different voltage to generate the control signal ckboost. In this example, the first switch **520** is configured to turn on when the control signal ckboost is high (e.g., 2Vdd) and turn off when the control signal ckboost is low (e.g., Vdd).

[0056] Exemplary operations of the first bootstrap circuit **120** will now be discussed according to certain aspects. During a first phase of the clock signal CLK**0**, the control signal phi is high (e.g., approximately Vdd), the control signal ckboost is high (e.g., approximately 2Vdd), and the control signal phib is low. This causes the first switch **520**, the second switch **530**, and the fourth switch **540** to turn on. As a result, the first terminal **524** of the boost capacitor **525** is coupled to the supply rail through the first switch **520**, and the second terminal **527** of the boost capacitor **525** is coupled to ground through the second switch **530**. This causes the first terminal **524** of the boost capacitor **525** to charge to the supply voltage Vdd. Also, the gate of the switch transistor **110** is coupled to ground through the fourth switch **540**, which turns off the switch transistor **110**. The control input **538** of the third switch **535** is also coupled to ground through the fourth switch **540**, which turns off the third switch **535**.

[0057] As discussed above, the control signal phib is low during the first phase. Thus causes the transistor **515** to turn off and the transistor **518** to turn on. As a result, the gate of the transistor **510** is coupled to the supply rail through transistor **518**. This turns off the transistor **510**, which is implemented with a PFET in this example.

[0058] Thus, during the first phase, the boost capacitor **525** is charged to the supply voltage Vdd, and the switch transistor **110** is turned off. Also, the output clock signal ckout**0** is approximately equal to zero volts during the first phase since the output **126** of the first bootstrap circuit **120** is coupled to ground through the fourth switch **540**.

[0059] During a second phase of the clock signal CLK**0** (which follows the first phase), the control signal phi transitions from high to low, the control signal ckboost transitions from high to low, and the control signal phib transitions from low to high. This causes the first switch **520**, the second switch **530**, and the fourth switch **540** to turn off. As a result, the first terminal **524** of the boost capacitor **525** is decoupled from the supply rail, and the second terminal **527** of the boost capacitor **525** is decoupled from ground. In addition, the output **126** of the first bootstrap circuit **120** is decoupled from ground.

[0060] As discussed above, the control signal phib transitions from low to high during the second phase. This causes the transistor **515** to turn on and the transistor **518** to turn off. As a result, the gate of the transistor **510** is coupled to the second terminal **527** of the boost capacitor **525** through the transistor **515**. The source of the transistor **510** is coupled to the first terminal **524** of the boost capacitor **525**. Thus, the source-to-gate voltage of the transistor **510** is approximately equal to the voltage across the boost capacitor **525**. Since the boost capacitor **525** is charged to Vdd during the first phase, the source-to-gate voltage of the transistor **510** is approximately equal to Vdd. This turns on the transistor **510** assuming Vdd is greater than the threshold voltage of the transistor **510**. As a result, the first terminal **524** of the boost capacitor **525** is coupled to the output **126** through the transistor **510**.

[0061] The first terminal **524** of the boost capacitor **525** is also coupled to the control input **538** of the third switch **535**

through the transistor **510**, which turns on the third switch **535**. As a result, the second terminal **527** of the boost capacitor **525** is coupled to the input **122** of the first bootstrap circuit **120** through the third switch **535**. As a result, the input voltage Vin**0** at the input **122** is applied to the second terminal **527** of the boost capacitor **525** through the third switch **535**. This boosts the voltage at the first terminal **524** of the boost capacitor **525** to Vdd+Vin**0**. Since the first terminal **524** of the boost capacitor **525** is coupled to the output **126** of the first bootstrap circuit **120**, the voltage of the output clock signal ckout**0** at the output **126** is approximately equal to Vdd +Vin**0** during the second phase, which turns on the switch transistor **115**.

[0062] In this example, the rising edge of the output clock ckout**0** is delayed by the delay circuit **570** in the timing circuit **550**. This is because the delay circuit **570** delays the rising edge of the clock signal clkin by the delay of the delay circuit **570**. This delays the transition of the control signal phi from high to low since the control signal phi is the inverse of the clock signal clkin, and delays the transition of the control signal phib from low to high, which delays the rising edge of the output clock signal ckout**0**.

[0063] In this example, the falling edge of the output clock signal ckout**0** is determined at least in part by the time that the fourth switch **540** is turned on by the control signal phi. This is because turning on the fourth switch **540** couples the output **126** of the first bootstrap circuit **120** to ground, which causes the output clock signal ckout**0** to transition from high to low (e.g., ground). As discussed above, the sampling instance of the sampling capacitor **140** is determined by the falling edge of the output clock signal ckout**0**. Therefore, the timing of the falling edge of the output clock signal ckout**0** (which is controlled by the control signal phi) affects the sampling instance of the sampling capacitor **140**.

[0064] A drawback of the timing circuit **550** shown in FIG. **5B** is that the input clock signal CLK**0** needs to propagate through three gates (i.e., the NAND gate **575** and the drivers **580** and **562**) in the timing circuit **550** to provide the control signal phi, which controls the falling edge of the output clock signal ckout**0**. The three gates introduce jitter/skew into the control signal phi, and therefore introduce jitter/skew into the falling edge of the output clock signal ckout**0** which degrades performance. Therefore, a need for improving the quality of the control signal phi to improve the timing of the falling edge of the output clock signal ckout**0** is desirable.

[0065] Aspects of the present disclosure reduce jitter/skew in the falling edge of the output clock signal ckout**0** compared with the timing circuit **550** in FIG. **5B** by reducing the number of gates in the clock path of the control signal phi, as discussed further below. As used herein, a clock path is a path through which a clock signal propagates. A clock path may include one or more drivers, one or more delay circuits, or any combination thereof.

[0066] FIG. **7A** shows an example of the first bootstrap circuit **120** according to aspects of the present disclosure. In this example, the first bootstrap circuit **120** includes a transistor **710**, in which the transistor **710** and the transistor **515** are coupled in series between the gate of the transistor **510** and the second terminal **527** of the boost capacitor **525**. As used herein, transistors are coupled in series when the channels of the transistors are coupled in series. A channel of a transistor is between the source and the drain of the

transistor in which the conductance of the channel is controlled by the voltage applied to the gate of the transistor.

[0067] The transistor 710 is used to delay the rising edge of the output clock signal ckout0, as discussed further below. In the example shown in FIG. 7A, the transistor 710 is implemented with an NFET. However, it is to be appreciated that the transistor 710 may be implemented with another type of transistor in other implementations.

[0068] Although FIG. 7A shows an example in which the transistor 710 is on top of the transistor 515, it is to be appreciated that the positions of the transistors 710 and 515 may be swapped in other implementations such that the transistor 515 is on top of the transistor 710. In this regard, FIG. 7B shows an example in which the transistor 515 is on top of the transistor 710. In both FIG. 7A and FIG. 7B, the transistor 710 and the transistor 515 are coupled in series between the gate of the transistor 510 and the second terminal 527 of the boost capacitor 525.

[0069] FIG. 7C shows an example of a timing circuit 720 (e.g., a clock path) for generating the control signals phi and phib. The timing circuit 720 includes a first driver 725, a second driver 730, a delay circuit 735, and a third driver 740. The input of the first driver 725 is coupled to an input 722 of the timing circuit 720 and is configured to receive the clock signal CLK0. The input of the second driver 730 is coupled to the output of the first driver 725, the input of the delay circuit 735 is coupled to the output of the second driver 730, and the input of the third driver 740 is coupled to the output of the delay circuit 735. In the example shown in FIG. 7C, each of the drivers 725, 730, and 740 is implemented with a respective inverter. However, it is to be appreciated that the present disclosure is not limited to this example.

[0070] In this example, the control signal phi (which controls the falling edge of the output clock signal ckout0) is taken from a node 727 at the output of the first driver 725, and the control signal phib is taken from a node 732 at the output of the second driver 730. In this example, the node 727 is coupled to the control inputs 532 and 542 of the second and fourth switches 530 and 540 shown in FIGS. 7A and 7B to provide the control inputs 532 and 542 with the control signal phi, and the node 732 is coupled to the gates of the transistors 515 and 518 to provide the gates of the transistors 515 and 518 with the control signal phib.

[0071] In this example, the clock signal CLK0 propagates through one gate (i.e., the first driver 725) to generate the control signal phi instead of the three gates shown in the timing circuit 550 in FIG. 5B. This significantly reduces the introduction of jitter/skew into the control signal phi, and hence significantly reduces jitter/skew in the falling edge of the output clock signal ckout0 (which is controlled by the turning on of the fourth switch 540 by the control signal phi).

[0072] In this example, the clock signal CLK0 propagates to the delay circuit 735 where the clock signal CLK0 is delayed by the delay circuit 735 and inverted by the third driver 740 to generate control signal phib_delay at node 737. The control signal phib_delay is input to the gate of the transistor 710 (i.e., the gate of the transistor 710 is coupled to the node 737). The transistor 710 delays the rising edge of the output clock signal ckout0 based on the delay in the control signal phib_delay, which is controlled by the delay circuit 735. This is because the transistor 710 is coupled in series with the transistor 515. As a result, the transistor 710 does not allow the transistor 515 to couple the gate of the

transistor 510 to the second terminal 527 of the boost capacitor 525 until the transistor 710 is turned on by the control signal phib_delay, which is delayed by the delay circuit 735. Thus, in this example, the delay circuit 735 and the transistor 710 perform the function of delaying the rising edge of the output clock signal ckout, which is performed by the delay circuit 570 and the NAND gate 575 in FIG. 5B.

[0073] As shown in FIG. 7C, the delay circuit 735 and the drivers 730 and 740 are located after the control signal phi in the timing circuit 720, and therefore do not introduce jitter/skew into the control signal phi, which controls the falling edge of the output clock signal ckout0. In contrast, in the timing circuit 550 in FIG. 5B, the NAND gate 575 and the drivers 580 and 562 are located before the control signal phi, and therefore introduce jitter/skew into the control signal phi.

[0074] It is to be appreciated that the timing circuit 720 is not limited to the example shown in FIG. 7C. In general, the timing circuit 720 (e.g., a clock path) may include one or more drivers (e.g., one or more inverters) and the delay circuit 735 coupled in series, in which the node 727 that provides the control signal phi for the fourth switch 540 is located before the delay circuit 735, and the node 737 that provides the control signal phi_delay for the transistor 710 is located after the delay circuit 735.

[0075] FIG. 8 shows an exemplary implementation of the switches 520, 530, 535, and 540 according to certain aspects. In this example, the first switch 520 includes a transistor 815 (e.g., NFET) where the drain of the transistor 815 is coupled to the supply rail, the gate of the transistor 815 is coupled to the voltage boost circuit 545, and the source of the transistor 815 is coupled to the first terminal 524 of the boost capacitor 525. The second switch 530 includes a transistor 820 (e.g., NFET) where the drain of the transistor 820 is coupled to the second terminal 527 of the boost capacitor 525, the gate of the transistor 820 is coupled to the control input 532 of the second switch 530 (and hence receives the control signal phi), and the source of the transistor 820 is coupled to ground. The third switch 535 includes a transistor 825 (e.g., NFET) where the source of the transistor 825 is coupled to the second terminal 527 of the boost capacitor 525, the gate of the transistor 825 is coupled to the output 126 of the first bootstrap circuit 120, and the drain of the transistor 825 is coupled to the input 122 of the first bootstrap circuit 120.

[0076] In this example, the fourth switch 540 includes a first transistor 830 (e.g., first NFET), a second transistor 835 (e.g., second NFET), and a third transistor 840 (e.g., PFET). The gate of the first transistor 830 is coupled to the control input 542 of the fourth switch 540 (and hence receives the control signal phi), and the source of the first transistor 830 is coupled to ground. The drain of the second transistor 835 is coupled to the output 126 of the first bootstrap circuit 120, the gate of the second transistor 835 is coupled to the supply rail, and the source of the second transistor 835 is coupled to the drain of the first transistor 830. The source of the third transistor 840 is coupled to the supply rail, the gate of the third transistor 840 is coupled to the control input 542 of the fourth switch 540 (and hence receives the control signal phi), and the drain of the third transistor 840 is coupled to the source of the second transistor 835.

[0077] In operation, when the control signal phi is high, the first transistor 830 is turned on and the third transistor 840 is turned off. As a result, the first transistor 830 couples

the source of the second transistor **835** to ground. Because the gate of the second transistor **835** is coupled to the supply rail, the gate-to-source voltage of the second transistor **835** is approximately equal to Vdd, which turns on the second transistor **835**. Thus, the first transistor **830** and the second transistor **835** are both turned on, and the output **126** of the first bootstrap circuit **120** is coupled to ground through the first transistor **830** and the second transistor **835**. Therefore, the fourth switch **540** couples the output **126** of the first bootstrap circuit **120** to ground when the control signal phi is high (e.g., Vdd).

[0078] When the control signal phi is low, the first transistor **830** is turned off and the third transistor **840** is turned on. As a result, the third transistor **840** couples the source of the second transistor **835** to the supply rail. Because the gate of the second transistor **835** is coupled to the supply rail, the gate-to-source voltage of the second transistor **835** is approximately zero volts, which turns off the second transistor **835**. As a result, the first transistor **830** and the second transistor **835** are both turned off, and the output **126** of the first bootstrap circuit **120** is decoupled from ground. Therefore, the fourth switch **540** decouples the output **126** of the first bootstrap circuit **120** from ground when the control signal phi is low.

[0079] It is to be appreciated that the fourth switch **540** is not limited to the exemplary implementation shown in FIG. **8**. For example, the fourth switch **540** may be implemented with other arrangements of transistors, or may be implemented with a single transistor.

[0080] FIG. **8** also shows an exemplary implementation of the voltage boost circuit **545** according to certain aspects. In this example, the voltage boost circuit **545** includes a first transistor **850** (e.g., fist NFET), a second transistor **855** (e.g., second NFET), a first capacitor **860**, and a second capacitor **870**. In this example, the drain of the first transistor **850** is coupled to the supply rail, the gate of the first transistor **850** is coupled to the source of the second transistor **855**, and the source of the first transistor **850** is coupled to a first terminal **862** of the first capacitor **860**. A second terminal **864** of the first capacitor **860** receives the control signal phi_delay, which is provided at the output of the delay circuit **735**. The control signal ckboost is provided at the first terminal **862** of the first capacitor **860**, as discussed further below.

[0081] The drain of the second transistor **855** is coupled to the supply rail, the gate the second transistor **855** is coupled to the source of the first transistor **850**, and the source of the second transistor **855** is coupled to a first terminal **872** of the second capacitor **870**. A second terminal **874** of the second capacitor **870** receives the control signal phib.

[0082] Exemplary operations of the voltage boost circuit **545** will now be described according to certain aspects. In the discussion below, the high voltage of the control signal phib is assumed to be Vdd and the high voltage of the control signal phi_delay is assumed to be Vdd. However, it is to be appreciated that the present disclosure is not limited to this example.

[0083] When the control signal phi_delay is low and the control signal phib is high, the first transistor **850** is turned on and the second transistor **855** is turned off. As a result, the first terminal **862** of the first capacitor **860** is charged to the supply voltage Vdd through the first transistor **850**. Since the control signal ckboost is provided at the first terminal **862** of the first capacitor **860**, the control signal ckboost is approximately Vdd. During this time, the first terminal **872** of the

second capacitor **870** is approximately equal to 2Vdd assuming the first terminal **872** of the second capacitor **870** was previously charged to Vdd when the control signal phib was previously low.

[0084] When the control signal phi_delay is high and the control signal phib is low, the first transistor **850** is turned off and the second transistor **855** is turned on. In this case, the high voltage of Vdd of the control signal phi_delay is applied to the second terminal **864** of the first capacitor **860**. This boosts the voltage at the first terminal **862** of the first capacitor **860** to a boosted voltage of approximately 2Vdd. Since the control signal ckboost is provided at the first terminal **862** of the first capacitor **860**, the control signal ckboost is boosted to approximately 2Vdd. During this time, the first terminal **872** of the second capacitor **870** is charged to Vdd through the second transistor **855**.

[0085] Thus, in this example, the voltage boost circuit **545** boosts the voltage of the control signal phi_delay (e.g., voltage at node **727**) by Vdd to generate the control signal ckboost, which has a voltage of approximately 2Vdd when the control signal ckboost is high. The boosted voltage is needed to keep the transistor **815** (e.g., NFET) turned on to charge the first terminal **524** of the boost capacitor **525** to Vdd through the transistor **815**. This is because the gate-to-source voltage of the transistor **815** needs to be greater than the threshold voltage of the transistor **815** to keep the transistor **815** turned on, and the source of the transistor **815** is coupled to the first terminal **524** of the boost capacitor **525**. Thus, when the voltage at the first terminal **524** of the boost capacitor **525** approaches Vdd (and hence the voltage at the source of the transistor **815** approaches Vdd), the voltage at the gate of the transistor **815** needs to be greater than Vdd by the threshold voltage or more to keep the transistor **815** turned on.

[0086] In this example, the control signal ckboost has a low voltage of approximately Vdd. However, the low voltage of Vdd does not turn on the transistor **510** after the first terminal **524** of the boost capacitor **525** is charged to approximately Vdd. This is because the gate-to-source voltage of the transistor **510** is approximately zero volts, which keeps the transistor **510** turned off. The low voltage of Vdd also does not turn on the transistor **510** when the first terminal of **525** of the boost capacitor **525** is boosted to Vdd+Vin0. In this case, the source voltage of the transistor **815** is higher that the gate voltage of the transistor, which keeps the transistor **815** turned off.

[0087] In the example shown in FIG. **8**, the bootstrap circuit **120** also includes a transistor **880** where the drain of the transistor **880** is coupled to the gate of the transistor **510**, the source of the transistor **880** is coupled to the second terminal **527** of the boost capacitor **525**, and the gate of the transistor **880** is coupled to the output **126** of the bootstrap circuit **120**. The transistor **880** may be implemented with an NFET (as shown in the example in FIG. **8**) or another type of transistor.

[0088] When the voltage at the output **126** is approximately equal to Vdd+Vin0 during the second phase, the transistor **880** is turned on and couples the gate of the transistor **510** to the second terminal **527** of the boost capacitor **525** through the transistor **880**. When the voltage at the output **126** is approximately equal to zero volts during the first phase, the transistor **880** is turned off.

[0089] In this example, the transistor **880** helps the transistors **710** and **515** couple the gate of the transistor **510** to

the second terminal **527** of the boost capacitor **525** during the second phase. The transistor **880** is able to keep the gate of the transistor **510** coupled to the second terminal **527** of the boost capacitor **525** for cases where the input voltage Vin0 swings high since the transistor **880** is turned by the boosted voltage Vdd+Vin0. It is to be appreciated that the transistor **880** may be omitted in some implementations.

[0090] FIG. **9**A shows another example of the bootstrap circuit **120** according to aspects of the present disclosure. In this example, the transistor **710** shown in FIG. **8** is omitted, and the drain of the transistor **515** is coupled to the gate of the transistor **510**. Also, in this example, the gates of the transistor **515** and the transistor **518** receive control signal phib_0, and the second terminal **864** of the first capacitor **860** receives the control signal phi.

[0091] FIG. **9**B shows an example of a timing circuit **910** for generating the control signal phi, the control signal phib, and the control signal phib_0 shown in FIG. **9**A. In this example, the timing circuit **910** includes a clock path **915** and a logic gate **940**. As shown in the example in FIG. **9**A, the clock path **915** may include a first driver **920**, a second driver **925**, a delay circuit **930** coupled in series. In the example shown in FIG. **9**A, the input of the first driver **920** is coupled to an input **912** of the timing circuit **910** to receive the clock signal CLK0, the input of the second driver **925** is coupled to the output of the first driver **920**, and the input of the delay circuit **930** is coupled to the output of the second driver **925**. In the example shown in FIG. **9**B each of the drivers **920** and **925** is implemented with a respective inverter. However, it is to be appreciated that the drivers **920** and **925** are not limited to this example.

[0092] The logic gate **940** has a first input **942**, a second input **944**, and an output **946**. In the example shown in FIG. **9**B, the logic gate **940** includes a NAND gate. However, it is to be appreciated that the logic gate **940** is not limited to this example. In this example, the first input **942** of the logic gate **940** is coupled to the input **912** of the timing circuit **910** and is configured to receive the clock signal CLK0. The clock path **915** is coupled between the input **912** of the timing circuit **910** and the second input **944** of the logic gate **940**.

[0093] In this example, the control signal phi is provided by the output of the first driver **920** at node **922**, and the control signal phib is provided by the output of the second driver **925** at node **927**. Thus, the node **922** is coupled to the control input **532** of the second switch **530** and the control input **542** of the fourth switch **540** to provide the control signal phi. In the example shown in FIG. **9**B, the nodes **922** and **927** are located before the delay circuit **930** in the clock path **915**, and the delay circuit **930** is located between node **927** and the second input **944** of the logic gate **940**. Also, in this example, the control signal phib_0 is provided at the output **946** of the logic gate **940** (e.g., NAND gate). Thus, the output **946** is coupled to the gates of the transistors **515** and **518** to provide the control signal phib_0.

[0094] In this example, the control signal phi controls the falling edge of the output clock signal ckout0. This is because the control signal phi causes the fourth switch **540** to turn on and couple the output **126** of the first bootstrap circuit **120** to ground when the control signal phi transitions from low to high. As discussed above, the control signal phi is provided by the output of the first driver **920** at the node **922** in the timing circuit **910**. Thus, in this example, the clock signal CLK0 propagates through one gate (i.e., the first

driver **920**) to generate the clock signal phi instead of the three gates shown in FIG. **5**B. This significantly reduces the introduction of jitter/skew into the control signal phi, and therefore reduces jitter/skew in the falling edge of the output clock signal ckout0 (which is controlled by the control signal phi).

[0095] In this example, the delay circuit **930** and the logic gate **940** (e.g., NAND gate) are configured to generate the control signal phib_0 shown in FIG. **9**A. The control signal phib_0 is input to the gates of transistors **515** and **518** to control the rising edge of the output clock signal ckout0. Since the rising edge of the control signal phib_0 is delayed by the delay circuit **930**, the rising edge of the output clock signal ckout0 is also delayed by the delay circuit **930**.

[0096] As shown in FIGS. **9**A and **9**B, the delay circuit **930**, the second driver **925**, and the logic gate **940** are located outside the clock path between the input **912** of the timing circuit **910** and the control input **542** of the fourth switch **540**. As a result, the delay circuit **930**, the second driver **925**, and the logic gate **940** (e.g., NAND gate) do not affect the falling edge of the output clock signal ckout0, which reduces jitter/skew in the falling edge of the clock signal ckout0.

[0097] In certain aspects, the system **205** may be used to digitize a signal from a receiver in a wireless device. In this regard, FIG. **10** shows an example of a receiver **1010** coupled to the input of the buffer **130**. In this example, the receiver **1010** includes a mixer **1020**, an amplifier **1030** (e.g., a transimpedance amplifier), and a filter **1040**. The mixer **1020** has an input **1022** and an output **1024**. The mixer **1020** is configured to receive a radio frequency (RF) or an intermediate frequency (IF) signal at the input **1022**, mix the RF signal or the IF signal with a local oscillator (LO) signal to frequency downconvert the RF signal or the IF signal into a baseband signal, and output the baseband signal at the output **1024**. The RF signal may come from an antenna (not shown) and may be processed by one or more front-end components (e.g., low noise amplifier) before being input to the mixer **1020**. For the example of the IF signal, the IF signal may come from a preceding mixer (not shown) that downconverts an RF signal into the IF signal.

[0098] The amplifier **1030** has an input **1032** coupled to the output **1024** of the mixer **1020**, and an output **1034**. The amplifier **1030** is configured to amplify the baseband signal from the mixer **1020**, and output the amplified baseband signal at the output **1034**. The filter **1040** is couped between the output **1034** of the amplifier **1030** and the input of the buffer **130**. For example, the filter **1040** may be a low pass filter (e.g., low pass resistor-capacitor (RC) filter) configured to filter out out-of-band signals, and output the filtered baseband signal to the buffer **130**. The switch transistors **110** and **210** and the ADCs **410** and **420** may then sample and digitize the baseband signal into a digital baseband signal. The digital baseband signal may be processed by a baseband processor (not shown) to recover data and/or control information from the baseband signal.

[0099] Although FIGS. **2**, **4** and **10**, show the system **205** with two channels, it is to be appreciated that the system **205** may include more than two channels in some implementations (i.e., the system **205** may include one or more additional channels in addition to the channels shown in FIGS. **2**, **4**, and **10**). In general, aspects of the present disclosure

may be used in time-interleaved systems with multiple channels where the number of channels may be equal to two or greater than two.

[0100]   Implementation examples are described in the following numbered clauses:

[0101]   1. A system, comprising:

[0102]   a bootstrap circuit having an input and an output, comprising:

[0103]   a boost capacitor having a first terminal and a second terminal;

[0104]   a first transistor coupled between the first terminal of the boost capacitor

[0105]   and the output of the bootstrap circuit;

[0106]   a second transistor; and

[0107]   a third transistor, wherein the second transistor and the third transistor are coupled in series between a gate of the first transistor and the second terminal of the boost capacitor; and

[0108]   a switch transistor, wherein a gate of the switch transistor is coupled to the output of the bootstrap circuit, and a terminal of the switch transistor is coupled to the input of the bootstrap circuit.

[0109]   2. The system of clause 1, wherein the bootstrap circuit further comprises a switch coupled between the output of the bootstrap circuit and a ground.

[0110]   3. The system of clause 2, wherein the bootstrap circuit further comprises a clock path comprising one or more drivers and a delay circuit coupled in series, wherein:

[0111]   a control input of the switch is coupled to a first node on the clock path located before the delay circuit; and

[0112]   a gate of the third transistor is coupled to a second node on the clock path located after the delay circuit.

[0113]   4. The system of clause 3, wherein a gate of the second transistor is coupled to a third node on the clock path located before the delay circuit.

[0114]   5. The system of clause 4, wherein one of the one or more drivers is between the second node and the third node.

[0115]   6. The system of clause 4 or 5, wherein:

[0116]   the bootstrap circuit further comprises a fourth transistor coupled between the gate of the first transistor and a supply rail; and

[0117]   a gate of the fourth transistor is coupled to the third node on the clock path.

[0118]   7. The system of any one of clauses 3 to 6, wherein the delay circuit has a programmable delay.

[0119]   8. The system of any one of clauses 3 to 7, wherein each of the one or more drivers includes a respective inverter.

[0120]   9. The system any one of clauses 1 to 8, wherein:

[0121]   the bootstrap circuit further comprises a fourth transistor coupled between the gate of the first transistor and a supply rail;

[0122]   the second transistor comprises a first n-type field effect transistor (NFET);

[0123]   the third transistor comprises a second NFET; and

[0124]   the fourth transistor comprises a p-type field effect transistor (PFET).

[0125]   10. The system of clause 1, wherein the bootstrap circuit further comprises:

[0126]   a first switch coupled between the first terminal of the boost capacitor and a supply

[0127]   rail;

[0128]   a second switch coupled between the second terminal of the boost capacitor and a ground;

[0129]   a third switch coupled between the second terminal of the boost capacitor and the input of the bootstrap circuit; and

[0130]   a fourth switch coupled between the output of the bootstrap circuit and the ground.

[0131]   11. The system of clause 10, wherein the bootstrap circuit further comprises a clock path comprising one or more drivers and a delay circuit coupled in series, wherein:

[0132]   a control input of the second switch and a control input of the fourth switch are coupled to a first node on the clock path located before the delay circuit; and

[0133]   a gate of the third transistor is coupled to a second node on the clock path located after the delay circuit.

[0134]   12. The system of clause 11, wherein a gate of the second transistor is coupled to a third node on the clock path located before the delay circuit.

[0135]   13. The system of clause 12, wherein:

[0136]   the bootstrap circuit further comprises a fourth transistor coupled between the gate of the first transistor and the supply rail; and

[0137]   a gate of the fourth transistor is coupled to the third node on the clock path.

[0138]   14. The system of clause 13, further comprising a fifth transistor coupled between the gate of the first transistor and the second terminal of the boost capacitor, wherein a gate of the fifth transistor is coupled to the output of the bootstrap circuit.

[0139]   15. The system of any one of clauses 11 to 14, wherein the bootstrap circuit further comprises a voltage boost circuit coupled to a control input of the first switch, wherein the voltage boost circuit is configured to boost a voltage at the first node on the clock path to generate a boosted control signal, and output the boosted control signal to the control input of the first switch.

[0140]   16. The system of any one of clauses 10 to 15, wherein the bootstrap circuit further comprises a voltage boost circuit coupled to a control input of the first switch.

[0141]   17. The system of any one of clauses 10 to 16, wherein a control input of the third switch is coupled to the output of the bootstrap circuit.

[0142]   18. The system of any one of clauses 1 to 17, further comprising:

[0143]   a buffer; and

[0144]   a sampling capacitor, wherein the switch transistor is coupled between an output of the buffer and the sampling capacitor.

[0145]   19. The system of clause 18, further comprising a receiver coupled to an input of the buffer.

[0146]   20. The system of clause 19, wherein the receiver comprises a mixer.

[0147] 21. A system, comprising:

[0148] a bootstrap circuit having an input and an output, comprising:

[0149] a boost capacitor having a first terminal and a second terminal;

[0150] a first transistor coupled between the first terminal of the boost capacitor and the output of the bootstrap circuit;

[0151] a second transistor coupled between a gate of the first transistor and the second terminal of the boost capacitor;

[0152] a first switch coupled between the output of the bootstrap circuit and a ground; and

[0153] a timing circuit, comprising:

[0154] a logic gate having a first input, a second input, and an output, wherein the first input of the logic gate is coupled to an input of the timing circuit, and the output of the logic gate is coupled to a gate of the second transistor; and

[0155] a clock path coupled between the input of the timing circuit and the second input of the logic gate, wherein a control input of the first switch is coupled to the clock path; and

[0156] a switch transistor, wherein a gate of the switch transistor is coupled to the output of the bootstrap circuit, and a terminal of the switch transistor is coupled to the input of the bootstrap circuit.

[0157] 22. The system of clause 21, wherein:

[0158] the bootstrap circuit further comprises a third transistor coupled between the gate of the first transistor and a supply rail; and

[0159] a gate of the third transistor is coupled to the output of the logic gate.

[0160] 23. The system clause 22, wherein:

[0161] the second transistor comprises an n-type field effect transistor (NFET); and

[0162] the third transistor comprises a p-type field effect transistor (PFET).

[0163] 24. The system of any one of clauses 21 to 23, wherein the logic gate comprises a NAND gate.

[0164] 25. The system of any one of clauses 21 to 24, wherein the clock path comprises one or more drivers and a delay circuit coupled in series, and the control input of the first switch is coupled to a node on the clock path located before the delay circuit.

[0165] 26. The system of any one of clauses 21 to 25, wherein the bootstrap circuit further comprises:

[0166] a second switch coupled between the first terminal of the boost capacitor and a supply rail;

[0167] a third switch coupled between the second terminal of the boost capacitor and the ground; and

[0168] a fourth switch coupled between the second terminal of the boost capacitor and the input of the bootstrap circuit.

[0169] 27. The system of clause 26, wherein the clock path comprises one or more drivers and a delay circuit coupled in series, the control input of the first switch and a control input of the third switch are coupled to a node on the clock path located before the delay circuit.

[0170] 28. The system of clause 27, wherein the bootstrap circuit further comprises a voltage boost circuit coupled to a control input of the second switch, and wherein the voltage boost circuit is configured to boost a voltage at the node on the clock path to generate a boosted control signal, and output the boosted control signal to the control input of the second switch.

[0171] 29. The system of any one of clauses 26 to 28, wherein a control input of the fourth switch is coupled to the output of the bootstrap circuit.

[0172] 30. The system of any one of clauses 26 to 39, wherein the bootstrap circuit further comprises a voltage boost circuit coupled to a control input of the second switch.

[0173] 31. The system of clause 22 or 23, further comprising a fourth transistor coupled between the gate of the first transistor and the second terminal of the boost capacitor, wherein a gate of the fourth transistor is coupled to the output of the bootstrap circuit.

[0174] It is to be appreciated that the present disclosure is not limited to the terminology used above to describe aspects of the present disclosure. For example, a buffer may also be referred to as a driver, an amplifier, or another term. A switch transistor may also be referred to as a switch, a transistor, a bootstrap switch, a bootstrapped switch, a sampling switch (e.g., in the context of analog-to-digital conversion), or another term. A bootstrap circuit may also be referred to as a bootstrap switch, a boost circuit, or another term. In general, a bootstrap circuit covers any circuit configured to drive the gate of a switch transistor with a boosted voltage that tracks the voltage of a signal in a signal path (e.g., voltage at a terminal (e.g., source) of the switch transistor). It is also to be appreciated that a bootstrap circuit and a switch transistor may also collectively be referred to as a bootstrap switch.

[0175] It is to be appreciated that a transistor may be physically implemented on a chip using two or more transistors arranged in parallel in which the gates of the two or more transistors are coupled together.

[0176] Within the present disclosure, the word "exemplary" is used to mean "serving" as an example, instance, or illustration." Any implementation or aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects of the disclosure. Likewise, the term "aspects" does not require that all aspects of the disclosure include the discussed feature, advantage or mode of operation. The term "coupled" is used herein to refer to the direct or indirect electrical coupling between two structures.

[0177] Any reference to an element herein using a designation such as "first," "second," and so forth does not generally limit the quantity or order of those elements. Rather, these designations are used herein as a convenient way of distinguishing between two or more elements or instances of an element. Thus, a reference to first and second elements does not mean that only two elements can be employed, or that the first element must precede the second element.

[0178] The previous description of the disclosure is provided to enable any person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Thus, the disclosure is not intended to be limited to the examples described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A system, comprising:

a bootstrap circuit having an input and an output, comprising:

a boost capacitor having a first terminal and a second terminal;

a first transistor coupled between the first terminal of the boost capacitor and the output of the bootstrap circuit;

a second transistor coupled between a gate of the first transistor and the second terminal of the boost capacitor;

a first switch coupled between the output of the bootstrap circuit and a ground; and

a timing circuit, comprising:

a logic gate having a first input, a second input, and an output, wherein the first input of the logic gate is coupled to an input of the timing circuit, and the output of the logic gate is coupled to a gate of the second transistor; and

a clock path coupled between the input of the timing circuit and the second input of the logic gate, wherein a control input of the first switch is coupled to the clock path; and

a switch transistor, wherein a gate of the switch transistor is coupled to the output of the bootstrap circuit, and a terminal of the switch transistor is coupled to the input of the bootstrap circuit.

2. The system of claim 1, wherein:

the bootstrap circuit further comprises a third transistor coupled between the gate of the first transistor and a supply rail; and

a gate of the third transistor is coupled to the output of the logic gate.

3. The system of claim 2, wherein:

the second transistor comprises an n-type field effect transistor (NFET); and

the third transistor comprises a p-type field effect transistor (PFET).

4. The system of claim 1, wherein the logic gate comprises a NAND gate.

5. The system of claim 1, wherein the clock path comprises one or more drivers and a delay circuit coupled in series, and the control input of the first switch is coupled to a node on the clock path located before the delay circuit.

6. The system of claim 1, wherein the bootstrap circuit further comprises:

a second switch coupled between the first terminal of the boost capacitor and a supply rail;

a third switch coupled between the second terminal of the boost capacitor and the ground; and

a fourth switch coupled between the second terminal of the boost capacitor and the input of the bootstrap circuit.

7. The system of claim 6, wherein the clock path comprises one or more drivers and a delay circuit coupled in series, the control input of the first switch and a control input of the third switch are coupled to a node on the clock path located before the delay circuit.

8. The system of claim 7, wherein the bootstrap circuit further comprises a voltage boost circuit coupled to a control input of the second switch, and wherein the voltage boost circuit is configured to boost a voltage at the node on the clock path to generate a boosted control signal, and output the boosted control signal to the control input of the second switch.

9. The system of claim 6, wherein a control input of the fourth switch is coupled to the output of the bootstrap circuit.

10. The system of claim 6, wherein the bootstrap circuit further comprises a voltage boost circuit coupled to a control input of the second switch.

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