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Title of the invention

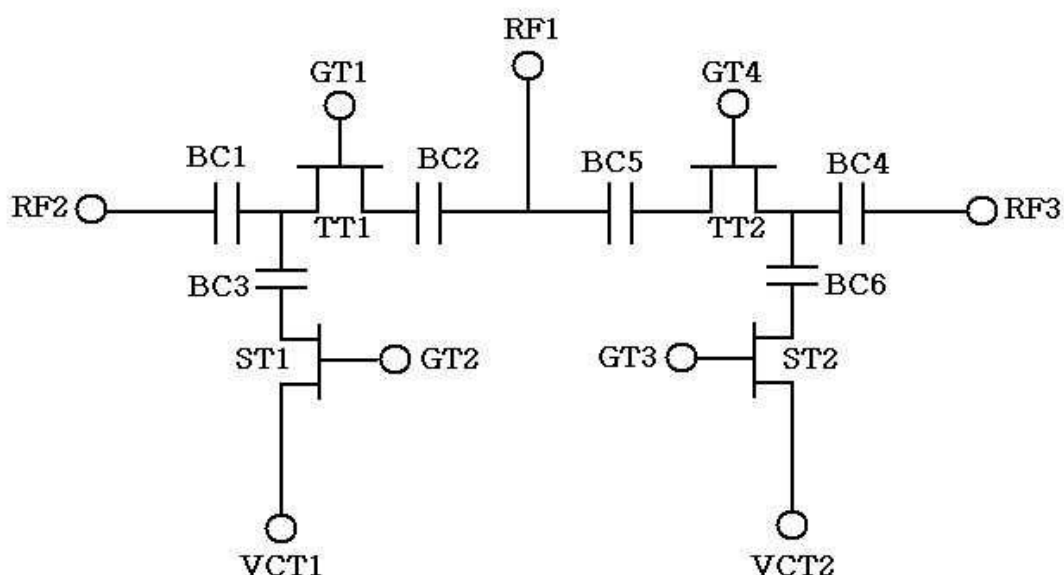
High frequency switching circuit using propagation elements

summation

The high-frequency switch circuit according to the present invention uses a DC blocking capacitor to DC-isolate each transistor, thereby enabling a deeper pinch off of the off-state transistor and providing a bias for maximum current to flow to the on-state transistor. In addition, an enhancement mode transistor is used to enable a deeper pinch off with the same gate voltage compared to a depletion mode transistor, and the high-frequency switch has a large Pmax.

High frequency switch circuit, DC blocking capacitor, multiplication transistor

Representative drawing



Scope of the claim

Claim 1:

A high-frequency switch circuit for conducting at least one of a plurality of high-frequency signal paths and blocking the remainder, wherein each of the plurality of high-frequency signal paths comprises: a first capacitor coupled to one end of the high-frequency signal path; a capacitive through-switch element coupled between the first capacitor and the other end of the high-frequency signal path; and a capacitive shunt switch element having one end connected between the first capacitor and the capacitive through-switch element and the other end coupled between a voltage control terminal.

Claim 2:

A high frequency switch circuit in accordance with claim 1, wherein the capacitive through-switch element is a single second capacitor and a single through-switch transistor, and the capacitive shunt switch element is a single third capacitor and a single shunt transistor.

Claim 3:

A high frequency switch circuit in accordance with claim 1, wherein the through switch elements are a plurality of second capacitors and a plurality of transistors, and the shunt switch elements are a plurality of third capacitors and a plurality of transistors.

Claim 4:

In the first paragraph, a high-frequency switch circuit in which the voltage control terminals of each of the plurality of high-frequency signal paths and the voltage control means for the through switch element simultaneously apply the same voltage, and the voltage control means for the shunt switch element simultaneously applies opposite voltages to conduct or block each of the plurality of high-frequency signal paths.

Claim 5:

A high frequency switch circuit according to claim 2 or 3, wherein the first capacitor, the second capacitor and the third capacitor are MIM capacitors.

Claim 6:

A high-frequency switching circuit according to claim 2 or 3, wherein the plurality of through field-effect transistors and the plurality of shunt field-effect transistors are multiplication-type field-effect

transistors.

Background Technology

The present invention relates to an antenna switch circuit, and more particularly to a high-frequency switch used in a portable wireless communication system such as a mobile phone.

In mobile communication devices such as mobile phones, GHz-band microwaves are often used, and switching elements for switching these high-frequency signals are often used in antenna switching circuits or transmission/reception switching circuits. High-frequency transistors such as HEMTs and MESFETs are used for these switching elements, and they have the form of SPDT (single pole single throw), SPNT (single pole N throw), or NPNT (N pole N throw). Fig. 1 shows an example of an antenna switch circuit for a mobile phone. This antenna switch circuit has an SPDT (Single Pole Dual Throw) configuration, and switches the signal path between the antenna (ANT) and a high-frequency signal input/output terminal (T1) and the signal path between the antenna (ANT) and a high-frequency signal input/output terminal (T2). For this reason, this antenna switch circuit is composed of a through-side field effect transistor (QT1, QT2), a shunt-side field effect transistor (QS1, QS2), and a shunt capacitor (CS1, CS2). The through-side field effect transistor (QT1, QT2) and the shunt-side field effect transistor (QS1, QS2) are turned on and off according to a control signal given to the control terminal (CT1, CT3, CT2, CT4).

To keep a field-effect transistor used in a high-frequency switch in the off state, the threshold voltage (V_{TH}) must be applied to the gate, and a voltage sufficiently lower than the threshold voltage must be applied to the gate to deep pinch off in order to prevent the off state from being released when a high-frequency signal of large power enters the switch. In reality, a negative voltage is not created and used, but the voltage of the drain and source is boosted to positive (V_B) and use it as if the gate voltage in the ground state is a negative voltage. When the mobile phone is in use, there are transistors that are on and transistors that are off inside the switch, and the same voltage (V) is applied to the drain and source of all transistors in the switch. B) is applied, so the off-state gate voltage is $-V_B$, and the ON state gate voltage is V_{DD} (Battery maximum voltage) $-V_B$ It becomes.

One of the major trends in recent portable wireless communication devices is that the battery voltage is continuously decreasing. This is because when the battery voltage decreases, power consumption decreases, which has the advantage of allowing the cell phone to be used for a long time. When the battery voltage decreases, the transistor in the off state cannot maintain the off state when a high-frequency signal of high power enters the switch. In addition, when the battery voltage decreases, the transistor in the on state cannot be sufficiently turned on, so it operates in a state where the resistance is slightly increased rather than in a state where the resistance is minimum. That is, in a conventional switch circuit such as Fig. 1, when the battery voltage decreases, the performance of the high-frequency switch is deteriorated.

In addition, high-frequency switches using depletion mode HEMTs or depletion mode MESFETs have been widely used in the past. Depletion mode transistors have a negative threshold voltage (V_{TH}) has a voltage lower than the negative threshold voltage. Therefore, to use it as a high-frequency transistor, a voltage lower than the negative threshold voltage must be applied to the gate. However, as the battery voltage decreases, the negative voltage that can be applied to the gate decreases. In other words, the common voltage (V) of the source and drain that is practically sufficient B) cannot be applied. Therefore, the depletion transistor cannot maintain the off state when a high-frequency signal of large power is input to the switch. At this time, the maximum power of the high-frequency signal that maintains the switch in the off state is called P_{max} . P_{max} increases when stacked FETs or multiple gates are used. However, there is a disadvantage in that the number of required FETs or gates increases as the battery voltage decreases, which increases the area of the switch circuit.

Contents of the invention

Effect of invention

The switch circuit according to the present invention is configured to turn off the transistor at the maximum voltage of the battery, V_{DD} It can deplete the channel, making it a deep pinch off counterpart and having a large P_{max} .

and having a large Pmax.

The switch circuit according to the present invention turns on the channel of the ON-state transistor with VDD, which is the maximum voltage of the battery, and operates the transistor in a state where the resistance is minimum.

The switch circuit according to the present invention can achieve deeper pinch off with the same gate voltage than a depletion mode transistor by using an enhancement mode transistor, and the high-frequency switch has a large Pmax.

Technical challenges

An object of the present invention is to provide a high-frequency switch circuit for a wireless communication device having good on-off performance even at low voltage.

Another object of the present invention is to provide a high-frequency switching circuit for a wireless communication device having a large Pmax even at low voltage.

Composition and operation of the invention

A high-frequency switch circuit according to the present invention is a high-frequency switch circuit that conducts at least one of a plurality of high-frequency signal paths and blocks the rest, wherein each of the plurality of high-frequency signal paths includes a first capacitor coupled to one end of the high-frequency signal path, a capacitive through-switch element coupled between the first capacitor and the other end of the high-frequency signal path, and a capacitive shunt switch element having one end connected between the first capacitor and the capacitive through-switch element and the other end coupled between a voltage control terminal.

In the high-frequency switch circuit according to the present invention, it is preferable that the capacitive through-switch element is a single second capacitor and a single through-transistor, and the capacitive shunt switch element is a single third capacitor and a single shunt transistor.

In the high-frequency switch circuit according to the present invention, it is preferable that the through switch elements are a plurality of second capacitors and a plurality of transistors, and the shunt switch elements are a plurality of third capacitors and a plurality of transistors.

In the high-frequency switch circuit according to the present invention, it is preferable that the voltage control terminals of each of the plurality of high-frequency signal paths and the voltage control means for the through switch element simultaneously apply the same voltage, and the voltage control means for the shunt switch element simultaneously apply opposite voltages to conduct or block each of the plurality of high-frequency signal paths.

In the high-frequency switch circuit according to the present invention, it is preferable that the first capacitor, the second capacitor and the third capacitor are MIM capacitors.

In the high-frequency switch circuit according to the present invention, it is preferable that the plurality of through field-effect transistors and the plurality of shunt field-effect transistors are multiplication-type field-effect transistors.

In advance, the terms or words used in this specification and claims should not be interpreted as limited to their usual or dictionary meanings, and should be interpreted as meanings and concepts that conform to the technical idea of the present invention based on the principle that the inventor can appropriately define the concept of the term in order to explain his or her own invention in the best way.

Therefore, the embodiments described in this specification and the configurations illustrated in the drawings are only the most preferred embodiments of the present invention and do not represent all of the technical ideas of the present invention. Therefore, it should be understood that there may be various equivalents and modified examples that can replace them at the time of filing this application.

Hereinafter, an embodiment of the present invention will be described in more detail with reference to the attached drawings.

FIG. 2 illustrates a high-frequency switch circuit according to one embodiment of the present invention.

The core of the high-frequency switch circuit according to the present invention is to DC-isolate each transistor by using a DC blocking capacitor (BC1, BC2, BC3, BC4, BC5, BC6). Here, SPDT (Single pole

double throw) is explained as an example. In the circuit, only 0 V and positive voltage exist, and there is no negative voltage. Here, unlike the prior art, each transistor is DC-isolated by a DC blocking capacitor. In each signal path between RF1 and RF2 or between RF1 and RF3, a through field-effect transistor (TT1, TT2) and a shunt field-effect transistor (ST1, ST2) are coupled with a capacitor. Each capacitor (BC1, BC2, BC3, BC4, BC5, BC6) becomes a DC blocking capacitor, and these capacitors (BC1, BC2, BC3 or BC4, BC5, BC6) and a through field-effect transistor (TT1 or TT2) and a shunt field-effect transistor (ST1 or ST2) become switching elements for one signal path. In addition, unlike the conventional method, the other terminal of the shunt capacitor is not grounded, but is connected to a voltage control terminal (VCT1, VCT2) so that a voltage is applied during switching operation.

In addition, according to another embodiment of the present invention, each of the through field-effect transistors (TT1, TT2) and the shunt field-effect transistors (ST1, ST2) may be formed by combining multiple field-effect transistors with a capacitor in between, rather than being a single transistor.

The gate voltage of the transistor in the off state is $V_{GS.OFF} = -V_{DD}$, and the gate voltage of the transistor in the on state is $V_{GS.ON} = V_{DD}$. Therefore, all transistors are subject to the maximum voltage of the battery, V_{DD} is turned on or off. Therefore, in the conventional technology, either the on-state gate voltage or the off-state gate voltage is 0.5 V_{DD} . Compared to what should be done below, the circuit according to the present invention has a significantly increased control voltage. That is, the switch circuit according to the present invention can pinch off the off-state transistor more deeply than the existing circuit and also provides a bias for the on-state transistor to flow the maximum current.

The signal path conduction or blocking operation of the switch circuit illustrated in Fig. 2 is described as follows. In each signal path (e.g., between RF1 and RF2), the gate terminal (GT1) of the through field-effect transistor (TT1) and the voltage control terminal (VCT1) are controlled with the same voltage, and the gate terminal (GT2) of the shunt field-effect transistor (ST1) is controlled with the opposite voltage. In the conducting signal path (e.g., between RF1 and RF2), the gate terminal (GT1) of the through field-effect transistor (TT1) and the voltage control terminal (VCT1) are connected to V_{DD} , and the gate terminal (GT2) of the shunt field-effect transistor (ST1) is connected to ground (GND). Conversely, in the signal path to be blocked (e.g., between RF1 and RF3), the gate terminal (T4) GT and the voltage control terminal (VCT2) of the through field-effect transistor (TT2) are connected to ground, and the gate terminal (GT3) of the shunt field-effect transistor (ST2) is connected to V_{DD} . The voltage control means for applying voltage to the gate terminals (GT1, GT2, GT3, GT4) and voltage control terminals (VCT1, VCT2) of each of these field effect transistors can be appropriately adjusted according to the purpose of use of the present technology.

In addition, when an enhancement mode transistor is used in a high-frequency switch circuit using a DC blocking capacitor, there is an advantage in that the P_{max} becomes larger than that of a switch using a depletion mode transistor. Figures 3a and 3b show the V of a depletion mode transistor and an enhancement mode transistor, respectively. G_{S-ID} is a curve. $V_{GS.OFF}$ is the voltage applied to the gate to turn off the transistor and R_{FIN} is a high-frequency signal applied to the switch. V of the multiplication transistor $TH-V_{GS.OFF}$ It can be seen that the RF that can be applied is larger than that of the depletion transistor. IN It can be said that the size of is larger and P_{max} is also larger.

If a signal path having the switch element described above is further added to the SPDT type circuit shown in the above embodiment, a SPNT (single pole N throw) or NPNT (N pole N throw) type switch circuit according to the present invention is obtained, and its characteristics and operation are similar to those described for SPDT.

It is desirable to use an On-chip MIM (metal insulator metal) capacitor instead of bonding an external capacitor for the DC blocking capacitor. It is possible to use an external capacitor, but since multiple capacitors are required, the cost of the external capacitor itself and the cost of connecting it to the switch increase significantly, and the pad area for capacitor bonding in the switch IC becomes very large, which can be a problem. An On-chip MIM capacitor can be easily manufactured through a semiconductor process and does not require additional work such as capacitor bonding from an external user.

The size of the capacitance varies depending on the specifications such as the frequency of use, but larger is better. To obtain large capacitance with a MIM capacitor, the capacitor area must be increased or the insulator film must be thinned. Increasing the area of the MIM capacitor leads to an increase in the area of the chip, which increases the price of the switch. In general, reducing the thickness of the insulator in capacitors may cause insulation breakdown, but the DC blocking capacitor used in high-frequency switches has a low possibility of insulation breakdown. In order to cause insulation

frequency switches has a low possibility of insulation breakdown. In order to cause insulation breakdown, a high voltage of DC or low frequency must be applied to the capacitor, but each transistor

used in the switch is connected to GND or VDD through a resistance of several kilohms to several megaohms, so the possibility that a high voltage higher than VDD will be applied to the capacitor as DC or low frequency is very low. Therefore, it is desirable to obtain sufficient capacitance by reducing the thickness of the insulator.

Figure 4 is a switch IC manufactured according to the present invention.

VTH = + 0.3V enhancement mode HEMT was used and it is SPDT type. It showed input loss of less than 0.5dB and isolation characteristic of 25dBm at VDD = 2.4V and 900MHz. As a result of simulation, Pmax is expected to be more than 34dBm.

A brief description of the drawing

Figure 1 is a circuit diagram showing a conventional high-frequency switch circuit.

Figure 2 is a circuit diagram showing a switch circuit according to one embodiment of the present invention.

Figure 3 shows the V of a depletion transistor and a proliferation transistor.GS-IDSA graph that represents a curve,

Figure 4 is an actual design drawing of a switch circuit according to the present invention.

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