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(54) Title: HIGH FREQUENCY PUSH-PUSH OSCILLATOR

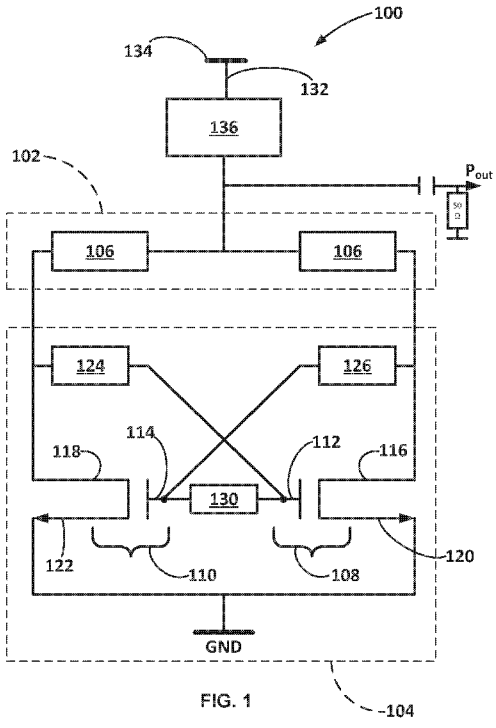


FIG. 1

(57) Abstract: A high frequency push-push oscillator is disclosed. The high frequency push-push oscillator includes a resonant circuit, including tank transmission lines or an inductor capacitor (LC) tank circuit, for generating a differential signal having a resonant frequency, and a Gm-core circuit for converting the differential signal to an output signal having an output frequency that is higher than the resonant frequency. The Gm-core circuit includes cross-coupled first and second transistors having first and second gates, drains, and sources, respectively, and first and second gate transmission lines. The first and second drains are in electrical communication with the resonant circuit. The first gate transmission line is joined with the first gate and the resonant circuit and the second gate transmission line is joined with the second gate and the resonant circuit. The Gm-core circuit includes a differential transmission line positioned between the first and second gates of the first and second transistors.

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HIGH FREQUENCY PUSH-PUSH OSCILLATOR

CROSS REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Application No. 62/359,756, filed July 8, 2016, which is incorporated by reference as if disclosed herein in its entirety.

BACKGROUND

[0002] Tera-Hertz (THz) communication is an emerging technology that uses the frequency spectrum between 100 to 300 GHz. The unique properties for the EM waves in this frequency band, i.e., penetration, absorption, scattering, etc., are interesting for research and industrial applications that could transform bio-medical, diagnosis, imaging, scanning, spectroscopy, short-distance high data-rate point-to-point communication, etc. applications. Existing implementations for THz systems are mostly bulky and based on non-integrated solutions, e.g., optical. Integrated systems using low-cost standard IC technologies are required to provide compact, portable, cost-effective and adaptive solutions. It remains that most of the used standard IC processes, e.g., CMOS or bipolar, have their own frequency limitations and increased parasitic losses at such high frequencies, which seriously reduce the transmission power and impede the THz architectures from moving towards integrated solutions.

[0003] Some techniques have been proposed to achieve high oscillation frequency with increased signal power level. However, these techniques present some disadvantages related to the large integration area, circuit implementation complexity, and high DC power consumption. Previous works proposed techniques to help prevent the common-mode power loss into the gates. These techniques were, however, based on single-ended oscillator structure and connected in a loop of four stages in order to exploit the 4th-harmonic to generate the common-mode signal quadruple push oscillator.

SUMMARY

[0004] The disclosed subject matter includes a high-frequency oscillator design operating in the sub-THz band, i.e., range of 100 GHz to 300 GHz, with a relatively high output power, i.e., above 10 micro-Watts. Oscillators according to the disclosed subject

matter exploit the push-push oscillator principle allowing higher oscillation frequencies than traditional LC-oscillators.

[0005] Technology according the disclosed subject matter provides means to overcome the frequency and transmitted power limitations for an integrated oscillator/signal generator function. This function is particularly important since it defines the transmission channels for any communication circuit used either in transmitter or receiver configuration.

[0006] Technology according the disclosed subject matter includes a high-frequency oscillator circuit using a two-stage, or push-push, design to generate a 250 GHz signal from the second harmonic of the oscillator core. Current oscillators operating in this frequency range rely on a four-stage design, as the fundamental frequency of the oscillator cores is limited to around 75 GHz due to the incorporation of gate-blocking circuits used to improve output power. Oscillators according to the disclosed subject matter incorporate a differential transmission line to achieve a fundamental frequency of 125 GHz, enabling the use of the second, rather than fourth, harmonic. This two-stage design provides a higher output power and smaller device footprint than current designs, as well as reducing power consumption.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The drawings show embodiments of the disclosed subject matter for the purpose of illustrating the invention. However, it should be understood that the present application is not limited to the precise arrangements and instrumentalities shown in the drawings, wherein:

[0008] FIG. 1 is a circuit diagram according to some embodiments of the disclosed subject matter;

[0009] FIG. 2 is a circuit diagram according to some embodiments of the disclosed subject matter; and

[0010] FIG. 3 is a circuit diagram according to some embodiments of the disclosed subject matter.

DETAILED DESCRIPTION

[0011] Referring to FIGS. 1-3, aspects of the disclosed subject matter include a high frequency push-push oscillator 100 including a resonant circuit 102 for generating a differential signal having a resonant frequency (fo) and a Gm-core circuit 104 for converting the differential signal to an output signal having an output frequency (2fo) that is higher than the resonant frequency. In some embodiments, the resonant frequency (fo) is about 100 GHz to about 125 GHz and the output frequency (2fo) is double the resonant frequency.

[0012] Referring now to FIG. 1, in some embodiments, resonant circuit 102 includes tank transmission lines 106. Typically, but not always, tank transmission lines 106 have a physical length equal to about one quarter of a wavelength. In some embodiments, depending on the application and characteristics of other components, tank transmission lines 106 have a predetermined physical length that is not equal to about one quarter of a wavelength.

[0013] Gm-core circuit 104 includes a first transistor 108 cross-coupled with a second transistor 110. First transistor 108 and second transistor 110 include first 112 and second 114 gates, drains 116 and 118, and sources 120 and 122, respectively, and first 124 and second 126 gate transmission lines. First drain 116 and second drain 118 are in electrical communication with resonant circuit 102. First source 120 and second source 122 are typically grounded. First gate transmission line 124 is joined with first gate 112 and resonant circuit 102. Second gate transmission line 126 is joined with second gate 114 and resonant circuit 102.

[0014] In some embodiments, first gate transmission line 124 and second gate transmission line126 are optimized to shift down the resonant frequency (fo) to a predetermined level while presenting a higher common-mode power rejection into first gate 112 and second gate 114 and increasing further an amount of common-mode power delivered. Optimization of first gate transmission line 124 and second first gate transmission line 126 is typically, but not always, achieved by including gate transmission lines having a predetermined electrical length or characteristic impedance.

[0015] Gm-core circuit 104 includes a differential transmission line 130 that is locally routed and positioned between first gate 112 and second gate 114 of first transistor 108 and second transistor 110, respectively. Differential transmission line 130 typically includes a predetermined length that is selected s to minimize power losses in Gm-core circuit 104.

[0016] High frequency push-push oscillator 100 also includes a supply node 132 joined with resonant circuit 102 for connecting the oscillator to a supply voltage 134. In some embodiments, a tee bias or signal blocker 136 is positioned between supply voltage 134 and resonant circuit 102. Although not shown, depending on the application, high frequency push-push oscillator 100 includes either pads for conducting an output signal or an antenna for radiating the output signal.

[0017] The output power (Pout) increase consists of increasing the conversion from resonant signal, which is a differential signal at a frequency (fo), the output signal, which is a common-mode signal at a frequency of (2f0). The differential mode signal describes an internal loop (in a differential oscillator structure), whereas the common-mode signal describes an external loop with parallel power paths through the Gm-core transistors from the ground (GND) to the output 50-Ohm impedance and back to GND. Unlike the oscillators using the 4th harmonic to generate the common-mode signal, oscillators according to the present application include a purely differential structure exploiting the 2nd harmonic to generate the common-mode signal. Being perfectly differential, differential transmission line 130 has no influence on the common-mode impedance presented at the gate levels. This will efficiently help increase resonant frequency (f0) and therefore output frequency (2f0).

[0018] Referring now to FIG. 2, some embodiments include a high frequency push-push oscillator 200 having a resonant circuit 202 that includes an inductor (L) capacitor (C) tank circuit 204. All other elements are substantially similar to those included in oscillator 100 and FIG. 1.

[0019] Referring now to FIG. 3, some embodiments include a high frequency push-push oscillator 300 substantially similar to oscillator 100 and oscillator 200 and FIGS. 1 and 2. However, oscillator 300 includes an inductor 302 positioned between first gate 112

and second gate 114 of first transistor 108 and second transistor 110, respectively. Other impedance types may be used providing they reduce the equivalent capacitance and improve either the output frequency or the output power.

[0020] Oscillators according the disclosed subject matter offer advantages over known devices. Oscillators according the disclosed subject matter have a more compact layout and a smaller integration area over known devices, which helps lower the global losses, simplify connections with the output access wires, and ease the circuit evolution towards an array structure.

[0021] Oscillators according the disclosed subject matter present a lower implementation complexity with improved high frequency performance and simpler bias current circuits in comparison to known technology.

[0022] Oscillators according the disclosed subject matter have a differential structure i.e., only two current branches, which presents an advantage with lower power consumption than known technologies that have four single-ended structures, i.e., four current branches connected in a loop.

[0023] Although the disclosed subject matter has been described and illustrated with respect to embodiments thereof, it should be understood by those skilled in the art that features of the disclosed embodiments can be combined, rearranged, etc., to produce additional embodiments within the scope of the invention, and that various other changes, omissions, and additions may be made therein and thereto, without parting from the spirit and scope of the present invention.

CLAIMS

What is claimed is:

1. A high frequency push-push oscillator including a resonant circuit for generating a differential signal having a resonant frequency comprising:

cross-coupled first and second transistors having first and second gates, drains, and sources, respectively, said first and second drains in electrical communication with said resonant circuit;

first and second gate transmission lines, said first gate transmission line joined with said first gate and said resonant circuit, said second gate transmission line joined with said second gate and said resonant circuit; and

a differential transmission line positioned between said first and second gates of said first and second transistors;

wherein said differential signal is converted to an output signal having an output frequency that is higher than said resonant frequency.

2. The high frequency push-push oscillator according to claim 1, further comprising a supply node connected to said resonant circuit for connecting said oscillator to a supply voltage.

3. The high frequency push-push oscillator according to claim 2, wherein a tee bias or signal blocker is positioned between said supply voltage and said resonant circuit.

4. The high frequency push-push oscillator according to claim 1, wherein said first and second sources are grounded.

5. The high frequency push-push oscillator according to claim 1, wherein said differential transmission line is locally routed between said first and second gates of said first and second transistors and includes a length that minimizes losses.

6. The high frequency push-push oscillator according to claim 1, wherein said first and second gate transmission lines are optimized to shift down said resonant frequency to a predetermined level while presenting a higher common-mode power rejection into said

first and second gates and increasing further an amount of common-mode power delivered.

7. The high frequency push-push oscillator according to claim 6, wherein said first and second gate transmission lines include a predetermined electrical length or character impedance.

8. The high frequency push-push oscillator according to claim 1, further comprising pads for conducting an output signal or an antenna for radiating said output signal.

9. The high frequency push-push oscillator according to claim 1, wherein said resonant frequency is about 100 GHz to about 125 GHz.

10. The high frequency push-push oscillator according to claim 1, wherein said output frequency is about double said resonant frequency.

11. A high frequency push-push oscillator comprising:

a resonant circuit for generating a differential signal having a resonant frequency, said resonant circuit including first and second tank transmission lines; and

a Gm-core circuit for converting said differential signal to an output signal having an output frequency that is higher than said resonant frequency, said Gm-core circuit including cross-coupled first and second transistors having first and second gates, drains, and sources, respectively, and first and second gate transmission lines, said first and second drains in electrical communication with said resonant circuit, said first gate transmission line joined with said first gate and said resonant circuit, said second gate transmission line joined with said second gate and said resonant circuit;

wherein said Gm-core circuit includes an inductor positioned between said first and second gates of said first and second transistors.

12. The high frequency push-push oscillator according to claim 11, wherein said first and second tank transmission lines of said resonant circuit have a predetermined physical length that is not equal to about one quarter of a wavelength.

13. The high frequency push-push oscillator according to claim 11, wherein said first and second gate transmission lines include a predetermined electrical length or character impedance.

14. The high frequency push-push oscillator according to claim 11, further comprising pads for conducting an output signal or an antenna for radiating said output signal.

15. A high frequency push-push oscillator comprising:

a resonant circuit for generating a differential signal having a resonant frequency; and

a Gm-core circuit for converting said differential signal to an output signal having an output frequency that is higher than said resonant frequency, said Gm-core circuit including cross-coupled first and second transistors having first and second gates, drains, and sources, respectively, and first and second gate transmission lines, said first and second drains in electrical communication with said resonant circuit, said first gate transmission line joined with said first gate and said resonant circuit, said second gate transmission line joined with said second gate and said resonant circuit;

wherein said Gm-core circuit includes a differential transmission line positioned between said first and second gates of said first and second transistors.

16. The high frequency push-push oscillator according to claim 15, wherein said resonant circuit includes tank transmission lines.

17. The high frequency push-push oscillator according to claim 16, wherein said tank transmission lines of said resonant circuit have a physical length equal to about one quarter of a wavelength.

18. The high frequency push-push oscillator according to claim 16, wherein said tank transmission lines of said resonant circuit have a predetermined physical length that is not equal to about one quarter of a wavelength.

19. The high frequency push-push oscillator according to claim 15, wherein said resonant circuit includes an inductor capacitor (LC) tank circuit.

20. The high frequency push-push oscillator according to claim 15, wherein said output frequency is about double said resonant frequency.

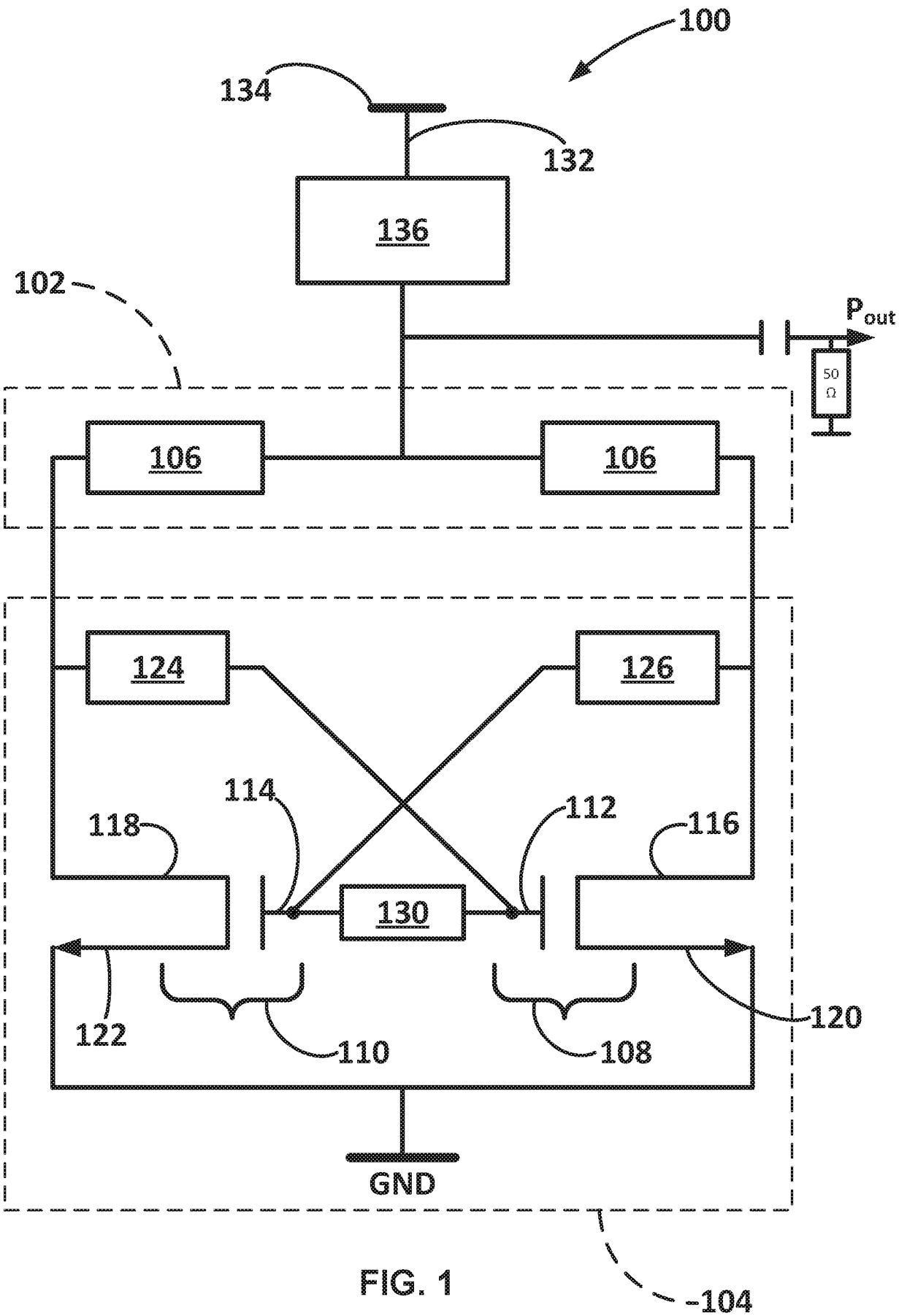

100
134
132
136
102
P_{out}
50 Ω
106
106
124
126
114
112
118
116
130
122
110
108
120
GND
104

FIG. 1

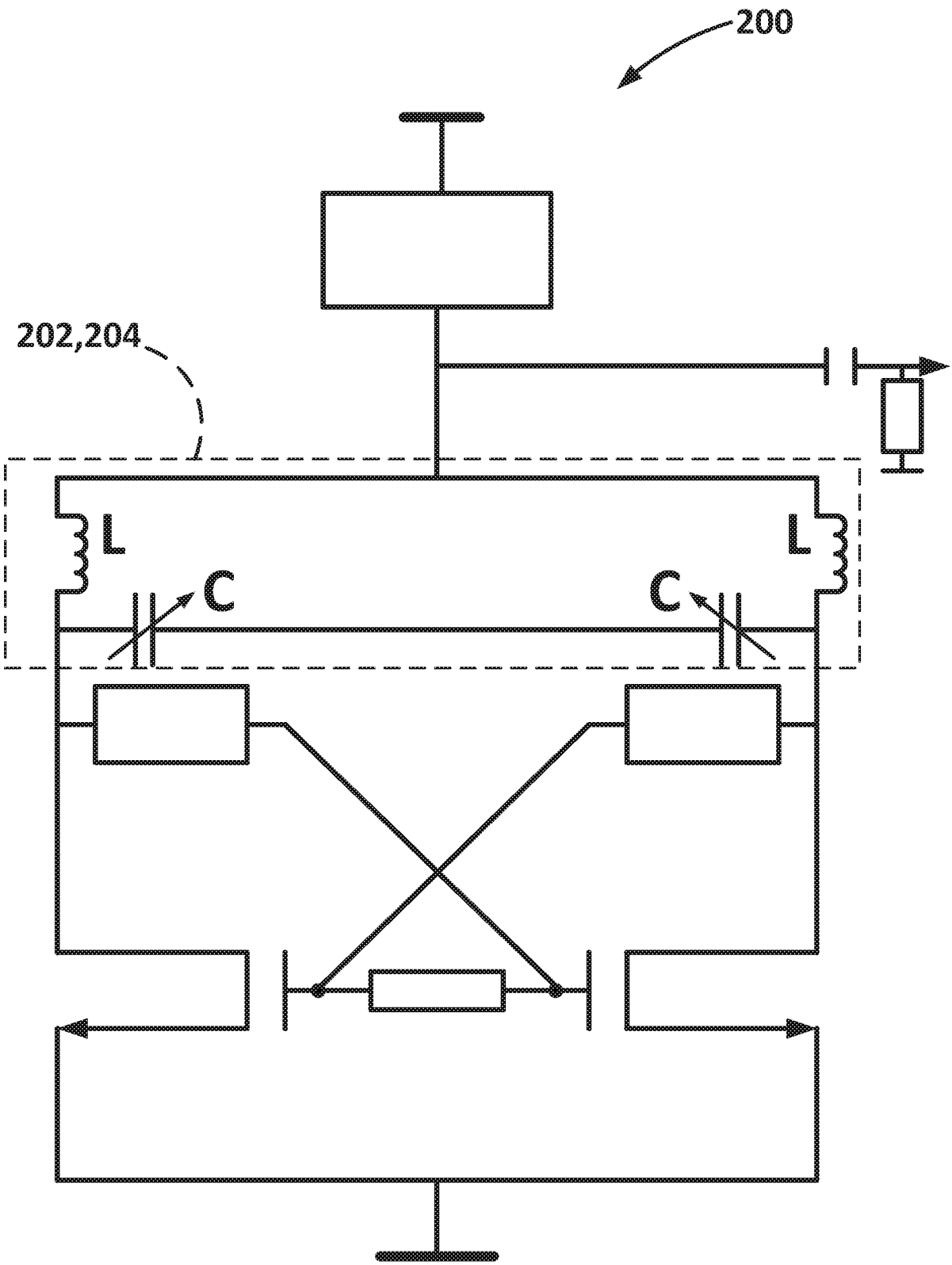


FIG. 2

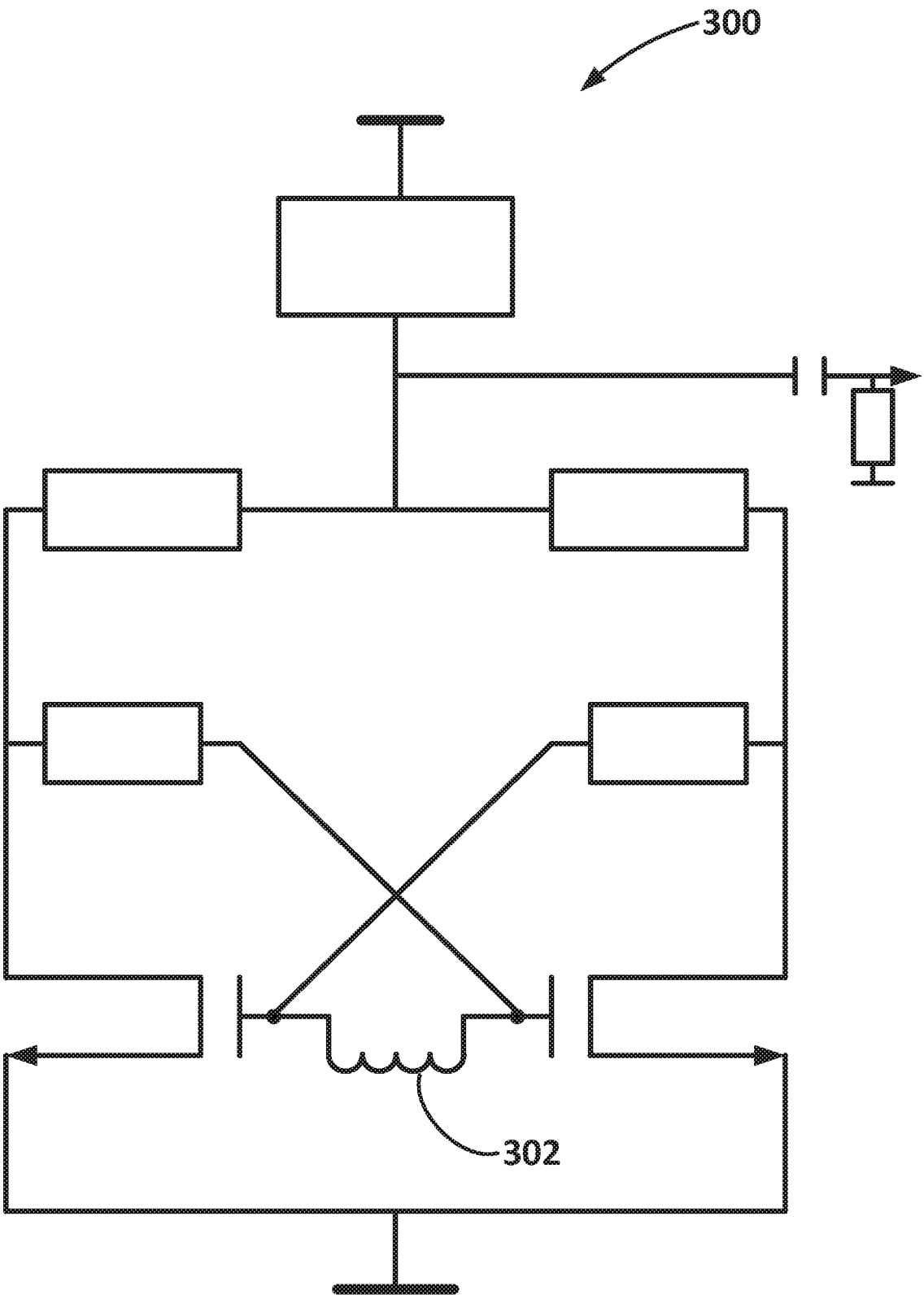


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/41322

A. CLASSIFICATION OF SUBJECT MATTER
IPC - H03B 5/02, 5/30, 5/32, 5/14, 5/12 (2017.01)
CPC - H03B 5/1206, 5/125, 5/1215, 5/1253, 5/1805, 5/1852, 5/1841, 5/1228

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,289,139 A (FIEDZIUSZKO, S et al.) February 22, 1994; abstract, figure 1, column 2, line 56- column 3, line 37, column 3, line 63- column 4, line 16	11-14
Y	US 2008/0174375 A1 (NAKAMURA, T et al.) July 24, 2008; abstract, figure 12	11-14
Y	US 2007/0182502 A1 (SHIN, H et al.) August 9, 2007; figure 3B, paragraph [0038]	11-14
Y	US 2,462,905 A (ROYDEN, G) March 1, 1949; column 3, line 74-coulmn 4, line 10, column 7, lines 10-30	12
A	US 4,763,084 A (PAVIO, A et al.) August 9, 1988; the entire document	1-20
A	US 2003/0090332 A1 (AIKAWA, M et al.) May 15, 2003; the entire document	1-20
A	US 2013/0271230 A1 (LI, M et al.) October 17, 2013; the entire document	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
08 September 2017 (08.09.2017)	06 OCT 2017
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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