Claims

1. A Micro-Electro-Mechanical System (MEMS) structure-based adjustable capacitor, comprising a lower plate A, a movable plate B, an upper plate C, a fixed apparatus D and one or more connecting conductors E; wherein a lower end of the fixed apparatus D is fixedly connected to the lower plate A, an upper end of the fixed apparatus D is fixedly connected to the upper plate C, the movable plate B is provided with a structure B4 which is able to move freely in parallel in cooperation with the fixed apparatus D, the movable plate B is mounted on the fixed apparatus D by means of the structure B4, and the movable plate B is able to move up and down along the fixed apparatus D;

the lower plate A is provided with a lower electrode A1, and the movable plate B is provided with a movable electrode B1 and adjustment electrodes B2 isolated from one another by means of a dielectric;

the lower electrode A1 and the movable electrode B1 constitute a unit capacitor, and the lower electrode A1 and the movable electrode B1 are isolated by means of a dielectric;

the upper plate C is provided with an upper electrode C1 and adjustment electrodes C2 isolated from one another by means of a dielectric; two ends of each of the one or more connecting conductors E are respectively electrically connected to the upper electrode C1 and the movable electrode B1;

the adjustment electrodes C2 and the adjustment electrodes B2 constitute adjustment units, and the adjustment electrodes C2 and the adjustment electrodes B2 are isolated by means of a dielectric; and

in a working state, the lower electrode A1 is constantly applied with a working voltage, the working voltage generates an electrostatic attraction force on the movable electrode B1, and an electrostatic attraction force of the adjustment electrodes C2 on the adjustment electrodes B2 is adjusted by controlling an adjustable voltage applied to the adjustment electrodes C2, so that a magnitude relationship between an attraction force of the lower electrode A1 on the movable plate B and an attraction force of the adjustment electrodes C2 on the movable plate B changes, thereby enabling the movable plate B to move up and down along the fixed apparatus D to adjust a capacitance value of the MEMS structure-based adjustable capacitor.

2. The MEMS structure-based adjustable capacitor according to claim 1, wherein the lower electrode A1 is provided with one or more dielectric isolation layers A2 for isolating the lower electrode A1 from the movable electrode B1.

3. The MEMS structure-based adjustable capacitor according to claim 1, wherein the

adjustment electrodes C2 and the adjustment electrodes B2 constitute adjustment units, the adjustment electrodes C2 are provided with dielectric isolation layers C3 for isolating the adjustment electrodes C2 from the adjustment electrodes B2, the adjustment electrodes C2 do not overlap with the movable electrode B1 and the lower electrode A1, and the adjustment electrodes B2 do not overlap with the upper electrode C1 and the lower electrode A1.

4. The MEMS structure-based adjustable capacitor according to claim 1, wherein the lower plate A is made of a dielectric material, a metal conductor covered or embedded on the surface of the dielectric material of the lower plate A forms the lower electrode A1, one or more dielectric isolation layers A2 are provided on the surface of the lower electrode A1, for isolating the lower electrode A1 from the movable electrode B1, and also for adjusting the capacitance value and a Q value of the MEMS structure-based adjustable capacitor.

5. The MEMS structure-based adjustable capacitor according to claim 1, wherein the movable plate B is made of a dielectric material, the structure B4 which is able to move freely in parallel in cooperation with the fixed apparatus D is provided in the middle of the movable plate B, and the movable plate B is sleeved on the fixed apparatus D by means of the movable plate B itself or by means of the structure B4; and metal conductors covered or embedded on the surface of the dielectric material of the movable plate B form the movable electrode B1 and the adjustment electrodes B2, the adjustment electrodes B2 are distributed on the periphery of the movable electrode B1, the adjustment electrodes B2 and the movable electrode B1 are isolated from one another by means of a dielectric, the movable electrode B1 has the same shape as the lower electrode A1 and the upper electrode C1, and is aligned with the lower electrode A1 and the upper electrode C1 on a vertical plane, and the adjustment electrodes B2 and the adjustment electrodes C2 have the same shape, and are aligned on the vertical plane.

6. The MEMS structure-based adjustable capacitor according to claim 1, wherein the upper plate C is made of a dielectric material, a metal conductor covered or embedded on the surface of the dielectric material of the upper plate C forms the upper electrode C1, metal conductors covered or embedded on the surfaces of the dielectric material at the periphery of the upper electrode C1 form the adjustment electrodes C2, the upper electrode C1 and the adjustment electrodes C2 are isolated from one another by means of the dielectric material, dielectric isolation layers C3 are provided on the surfaces of the adjustment electrodes C2, the upper plate C is provided with a control layer C4, each of the adjustment electrodes C2 is connected to one end of a switch in a control layer C4, and the other end of the switch in the control layer C4 is connected to an adjustable voltage pin of the adjustable unit capacitor.

7. The MEMS structure-based adjustable capacitor according to claim 1, wherein the fixed apparatus D has one end fixed to the upper electrode C1 of the upper plate C, and the other end fixed to the lower electrode A1 of the lower plate A, and is used for supporting the upper plate C and the lower plate A and maintaining the upper plate C and the lower plate A parallel, and a fixing method of the fixed apparatus D comprises welding, pressing or bonding.

8. The MEMS structure-based adjustable capacitor according to claim 1, wherein the one or more connecting conductors E consist of 1 to M connecting conductors; 1 to M slots are correspondingly provided on an upper surface of the movable electrode B1, and 1 to M slots are correspondingly provided on a lower surface of the upper electrode C1; one end of each of the 1 to M connecting conductors is electrically connected to a corresponding slot of the 1 to M slots on the lower surface of the upper electrode C1, and the other end of each of the 1 to M connecting conductors is electrically connected to a corresponding slot of the 1 to M slots on the upper surface of the movable electrode B1; the upper electrode C1 is electrically connected to the movable electrode B1 by means of the 1 to M connecting conductors, and resistance values of the 1 to M connecting conductors are set to be less than a preset value; and the 1 to M connecting conductors have equal lengths, so that the movable plate B is kept parallel to the upper plate C and the lower plate A in a natural state.

9. The MEMS structure-based adjustable capacitor according to claim 8, wherein the one or more connecting conductors E are not short-circuited to the adjustment electrodes C2 and the adjustment electrodes B2 in a static state or a moving state; and the one or more connecting conductors E have extension and retraction performances with extending forces and elastic forces remaining unchanged, and have sizes which are able to satisfy that the movable plate B is able to be in close contact with the upper plate C when being compressed, and is able to be in close contact with the lower plate A when being extended downwards.

10. The MEMS structure-based adjustable capacitor according to claim 1, wherein the one or more connecting conductors E, the lower electrode A1, the movable electrode B1, the adjustment electrodes B2, the upper electrode C1, and the adjustment electrodes C2 are made of metal materials, and substrate materials of the upper plate C, the movable plate B and the lower plate A are dielectric materials.

11. The MEMS structure-based adjustable capacitor according to claim 1, wherein an electrostatic attraction force Fx is generated on the movable electrode B1 by the lower electrode A1 after the lower electrode A1 is applied with a working voltage, and an electrostatic attraction force Fs generated on the adjustment electrodes B2 by the adjustment electrodes C2 after the adjustment electrodes C2 are applied with an adjustable voltage, and in a case where Fs is smaller than Fx, the

movable plate B moves towards and finally gets close to the lower plate A, and at this time, the capacitance value of the adjustable unit capacitor reaches the maximum; in a case where Fs is greater than Fx, the movable plate B moves towards and finally gets close to the upper plate C, and at this time, the capacitance value of the adjustable unit capacitor reaches the minimum; and in a case where the adjustable voltage applied to the adjustment electrodes C2 is zero and the working voltage applied to the lower electrode A1 is not zero, the movable plate B moves towards the lower plate A, to keep the adjustable unit capacitor in a state of a maximum capacitance value.

12. The MEMS structure-based adjustable capacitor according to claim 1, wherein the unit capacitor and the adjustment units form an adjustable unit capacitor by means of the movable plate B, the lower electrode A1 of the adjustable unit capacitor is connected to a working voltage pin, the upper electrode C1 is connected to a grounding pin, each of the adjustment electrodes C2 is connected to one end of a switch on a control layer C4 by means of a metal via hole, and the other end of the switch in the control layer C4 is connected to an adjustable voltage pin; and a switch data transceiving bus is connected to a control pin, and a processor controls on/off of the switch and a voltage on the adjustable voltage pin by means of the switch data transceiving bus, so as to control the movement of the movable electrode B1 in the adjustable unit capacitor, thereby changing the capacitance value of the adjustable unit capacitor.

13. The MEMS structure-based adjustable capacitor according to claim 1, wherein the upper plate and the lower plate are packaged by using a non-metallic material, two pins of a capacitor are led out, and ground, a working voltage pin or a control pin is marked, the control pin is located at a vacated position of a capacitor pin or a gap position in a grounding pin, and finally packaging and sealing are performed; or the upper plate C and the lower plate A serve as a part of device packaging, and are externally added with a packaging material to achieve packaging of the MEMS structure-based adjustable capacitor.

14. The MEMS structure-based adjustable capacitor according to claim 1, wherein by setting parameters of shape and thickness of the one or more dielectric material layers A2 covering the lower electrode A1, two paths of signals are enabled to have equal amplitudes and opposite phases, so that the two paths of signals are able to cancel each other or resonance generated after a radio frequency signal is applied is prevented.

15. The MEMS structure-based adjustable capacitor according to claim 1, wherein N adjustable unit capacitors constitute a combined capacitor;

a first composition manner of the combined capacitor is that N adjustable unit capacitors are superposed longitudinally to form the combined capacitor, wherein the lower electrode A1 of each of

N unit capacitors is connected to a working voltage pin of the combined capacitor by means of a lead-out wire, and the upper electrode C1 of each of N unit capacitors is connected to a grounding pin of the combined capacitor by means of a lead-out wire, each of adjustment electrodes C21 to C2N of the N unit capacitors is respectively connected to one end of a corresponding one of N switches of the upper plates C of the N unit capacitors by means of a lead-out wire, the other end of each of the N switches is led out to a corresponding one of N adjustable voltage control pins of the combined capacitor, N lower electrodes A1 are connected to a working voltage pin, and N upper electrodes C1 are connected to the ground;

or,

a second composition manner of the combined capacitor is that: in the combined capacitor, N upper electrodes C1 are distributed on one upper plate C, and are connected to a grounding pin of the combined capacitor by means of leads, N lower electrodes A1 are distributed on one lower plate A, and are connected to a working voltage pin of the combined capacitor by means of leads; and each of N adjustment electrodes C21 to C2N are connected to one end of a corresponding one of N switches distributed on a control layer C4 through metal via holes, the other end of each of the N switches is connected to a corresponding one of N adjustable voltage control pins of the combined capacitor, and all the leads do not overlap with the upper electrode C1, the movable electrode B1 and the lower electrode A1;

or,

a third composition manner of the combined capacitor is that M combined capacitors are laterally expanded, and N combined capacitors each formed by M unit capacitors that are laterally expanded are longitudinally superposed and expanded to form a combined capacitor; M upper electrodes C1 of M unit capacitors at each layer of the combined capacitor are connected together by means of leads and then are connected to a grounding pin of the combined capacitor, M lower electrodes A1 are connected together by means of leads and then are connected to a working voltage pin of the combined capacitor, each of M adjustment electrodes C21 to C2M are respectively connected to one end of a corresponding one of M switches, the other end of each of the M switches a respectively connected to a corresponding one of M adjustable voltage control pins of the combined capacitor by means of a lead, and the combined capacitor has M*N adjustable voltage pins in total.

16. The MEMS structure-based adjustable capacitor according to claim 15, wherein a bus controller of each of N switches of a control layer C4 in the combined capacitor is connected to a control bus, each of the N switches connected to the bus is allocated with an address, a bus control protocol is used for specifically identifying each switch by means of the address, and an external or

internal main controller controls the on/off of each switch by means of the address; the bus is connected to a corresponding bus control pin outside a package of the MEMS structure-based adjustable capacitor by means of a corresponding conductive wire, the conductive wire does not overlap with the upper electrode C1 of an upper plate electrode layer, the movable electrode B1 of the movable plate B and the lower electrode A1 of a lower plate electrode layer, and an external processor controls on/off of the N switches according to the address of each switch, so as to achieve step adjustment of the combined capacitor and arbitrary adjustment of the capacitance value of the combined capacitor; wherein an internal controller is connected to an external controller by means of the bus, so as to transfer a magnitude of a required capacitance value of the MEMS structure-based adjustable capacitor.

17. The MEMS structure-based adjustable capacitor according to claim 16, wherein a usage mode of N adjustable unit capacitors in the combined capacitor is:

a working mode during initial use or reset use is: sequentially controlling, by a controller, a switch matrix so that an adjustable voltage is applied or not applied to adjustment electrodes C2 on an upper plate C of each adjustable unit capacitor, and a working voltage is applied or not applied to a lower electrode A1 of each lower plate A, such that a capacitance value of each of the N adjustable unit capacitors in the combined capacitor is a minimum value or a maximum value, to complete initial set or reset;

after power on, in a case where the capacitance value of the combined capacitor reaches the minimum, applying a working voltage to all the lower electrodes A1 of the combined capacitor, and adjusting the total capacitance value of the combined capacitor to a desired capacitance value by adjusting the controller to control on/off of switches of the switch matrix and adjusting or not adjusting a magnitude of the adjustable voltage, while maintaining states of all switches of the switch matrix and storing the states of all switches of the switch matrix;

after power on, in a case where the capacitance value of the combined capacitor reaches the maximum, by controlling to apply an adjustable voltage to all adjustment electrodes of the combined capacitor and to apply a working voltage to all the lower electrodes A1, controlling on/off of switches of the switch matrix and adjusting or not adjusting a magnitude of the adjustable voltage, thereby adjusting the total capacitance value of the combined capacitor to a desired capacitance value, while maintaining states of all switches of the switch matrix, and storing the states of all switches of the switch matrix;

in a case where the combined capacitor has been adjusted to a desired capacitance value, after power on again, by recalling the states of the switches of the switch matrix from a main controller,

adjusting the switch matrix to an on/off state of the switch matrix of the desired capacitance value of the combined capacitor, and then applying the working voltage of the lower electrodes A1 and the adjustable voltage of the adjustment electrodes, thereby achieving the desired capacitance value of the combined capacitor, wherein after achieving the desired capacitance value, the capacitance value of the combined capacitor is able to be further adjusted to a new capacitance value by controlling on/off of corresponding switches in the switch matrix by the controller;

in a case where adjustment or change of a power on sequence and the capacitance value of the adjustable unit capacitor, and the initial capacitance value have an effect on use of a circuit, designing a protection measure in the circuit applying the combined capacitor, wherein the protection measure is enabling the circuit to be in a working state after adjusting the capacitance value of the adjustable capacitor to the required capacitance value.

18. The MEMS structure-based adjustable capacitor according to any one of claims 15-17, wherein a package housing of the combined capacitor packages the N adjustable unit capacitors in a sealed space, and an external working voltage pin, a grounding pin, adjustable voltage pins and a control pin of the combined capacitor are respectively connected to the lower electrodes A1, the upper electrodes C1, the adjustment electrodes and control switches on the upper plate C and the lower plate A through leads and via holes, so as to achieve packaging of the N adjustable unit capacitors.

19. The MEMS structure-based adjustable capacitor according to claim 14, wherein a material coating is welded on the surfaces of a power supply pin, the grounding pin and the control pin, and the package housing is of a non-metallic material.

20. The MEMS structure-based adjustable capacitor according to any one of claims 15 to 19, wherein each adjustable unit capacitor in the combined capacitor is able to be individually adjusted, and a plurality of adjustable unit capacitors is able to be adjusted in any combination, so as to achieve a plurality of step adjustments of the combined capacitor, and a exemplary implementation is that an internal or external processor controls on/off of N radio frequency switches in a control layer C4, so as to adjust the capacitance values of the N adjustable unit capacitors, thereby adjusting the capacitance value of the combined capacitor.