

## Human blood plasma-based electronic integrated circuit amplifier configuration

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### Dear Editor:

There is accumulating evidence that human blood electronic circuit components and their application circuits become more and more important to cyborg implant/engineering, man-machine interface, human disease detection and healing, and artificial brain evolution<sup>[1-5]</sup>. Here, we report the first development of human plasma-based amplifier circuit in the discrete as well as integrated circuit (IC) configuration mode. Electrolytes in the human blood contain an enormous number of charge carriers such as positive and negative molecule/atom ions, which are electrically conducting media and therefore can be utilized for developing electronic circuit components and their application circuits. These electronic circuits obviously have very high application impact potential towards bio-medical engineering and medical science and technology.

The experimental human blood plasma serum sample amplifier circuit layout with theoretical amplifier circuit is shown in **Fig. 1** and **2**. Theoretically, a transistor has two diodes in the back to back configuration with three probes made of rectangular cooper strips (1-8 mm), probe B (the base terminal), C (the collector terminal) and E (the emitter terminal) placed in human plasma serum electrolytes (**Fig. 1**). Under direct current (DC) voltage bias conditions, electrical field

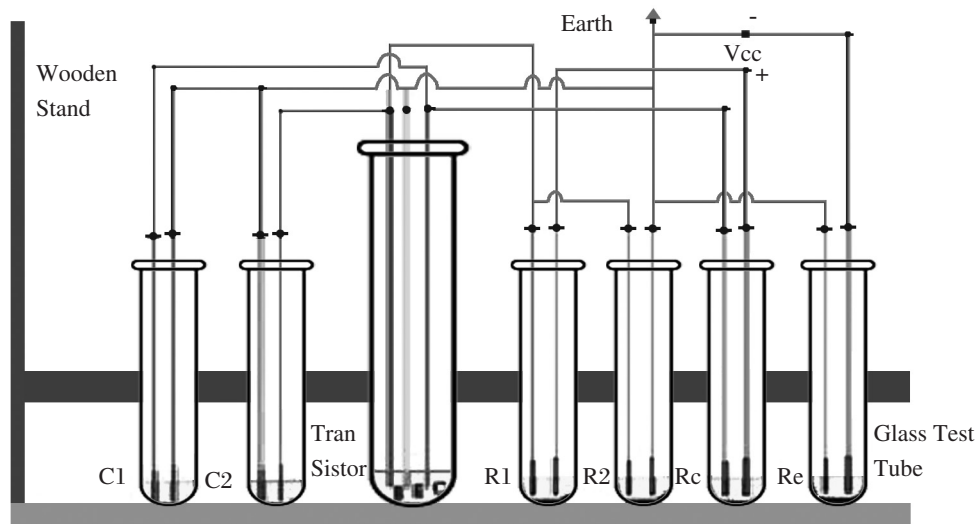
coupling between the base and the emitter probes and the collector-emitter probes occurred due to inherent capacitance/inductance coupling. The geometry and distance between the forming diode (set of 3 probes B, E, C) play vital roles in the practical realization of the transistor. The input circuit (base-emitter) contained variable voltage power supply with current measuring multi-meter to measure voltage/current input characteristics ( $V_{BE}$  v/s  $I_{BE}$  by keeping  $V_{CE}$  constant) between the base and the emitter. Similar output circuit was realized by another variable voltage supply with multi-meter ( $V_{CE}$  v/s  $I_{CE}$  by keeping  $V_{BE}$  constant) between the collector and the emitter. The developed bio-logical transistor showed technically acceptable (compared with conventional semi-conductor device<sup>[3]</sup>) input and output characteristics of the device (**Fig. 3A, 3B**). The  $\beta$  was found to vary from 5 to 15.

For the realization of resistance R and capacitance C, two rectangular (1 mm × 2 mm) shaped cooper wire probes were inserted in the human blood plasma serum sample and the distance between the two probes was varied to realize appropriate resistance and capacitance values. The charged particles under the influence of EMF acquire dynamism and face collisions and thus they manifest resistance R. Similarly, charged molecules and atoms in human blood plasma serum dynamically manifest capacitance C.

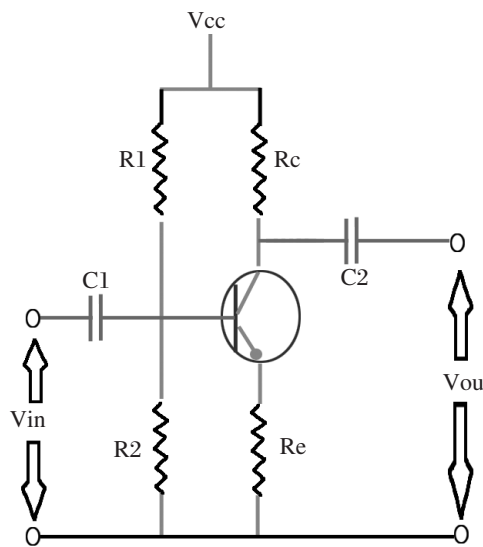
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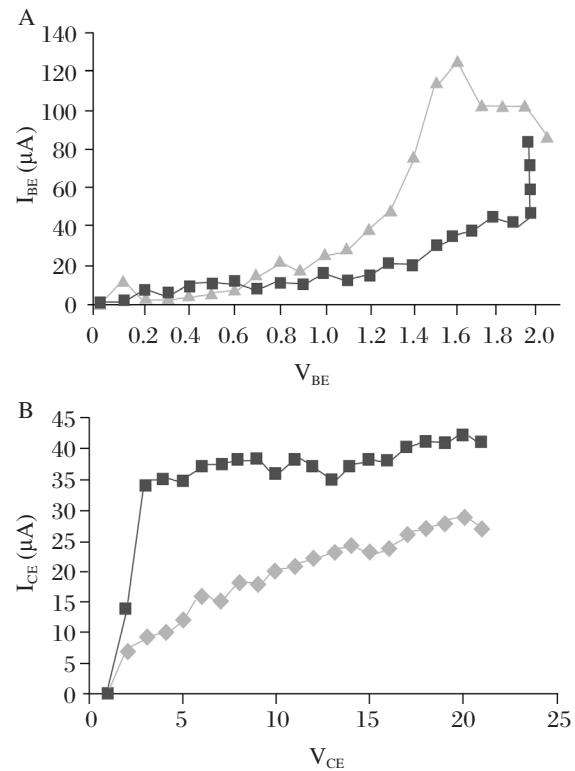


**Fig. 1** Human blood plasma serum amplifier circuit layout.



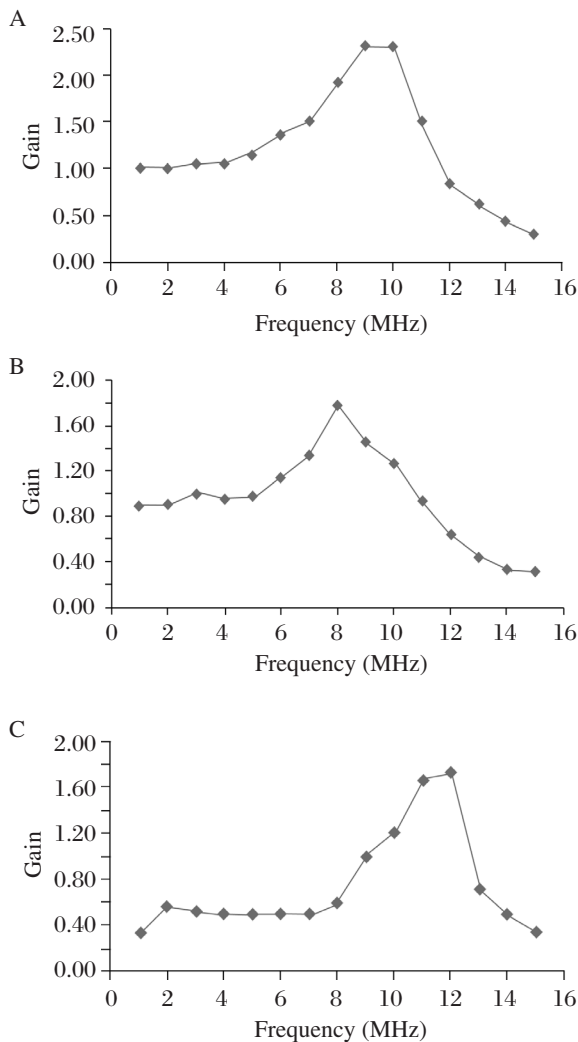
**Fig. 2** Theoretical amplifier circuit.

Under configuration 1, only the electrolyte based transistor with discrete passive components  $C_1$ ,  $C_2$ ,  $R_1$ ,  $R_2$ ,  $R_c$  and  $R_e$  were connected in the amplifier circuit. The electrolyte based transistor functioned as conventional semiconductor transistor. The amplification was varied from 1 to 7 db over narrow band of frequencies (6-11 MHz) (**Fig. 4A**). Under configuration 2, only the electrolyte based transistor with two electrolyte based capacitors  $C_1$ ,  $C_2$  and discrete passive components  $R_1$ ,  $R_2$ ,  $R_c$  and  $R_e$  were connected in the amplifier circuit. The electrolyte based transistor and the capacitors functioned as conventional semiconductor transistor and composite capacitors. The amplification was varied from a few db to 7-8 db over narrow band of frequencies (6-11 MHz) (**Fig.**



**Fig. 3** Blood transistor input (A) and output (B) characteristics.

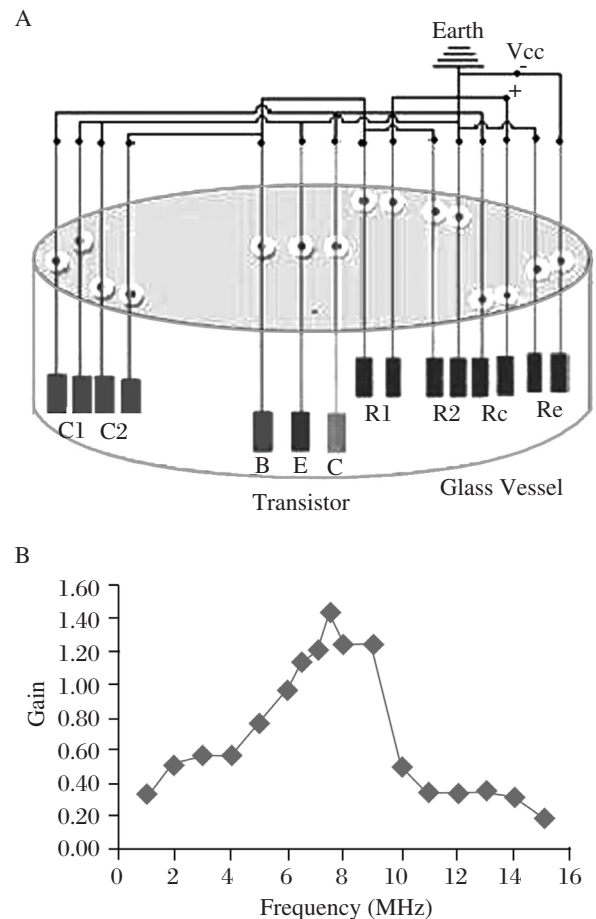
**4B**). Under configuration 3, the electrolyte based transistor, two electrolyte based capacitors  $C_1$  and  $C_2$  and electrolyte based passive components  $R_1$ ,  $R_2$ ,  $R_c$  and  $R_e$  were connected in the amplifier circuit. The electrolyte based transistor, the capacitors, the resistors functioned as conventional semiconductor transistor and composite capacitors and resistors. The amplification was varied from a few db to 7-8 db over narrow band of frequencies (6-11 MHz) (**Fig. 4C**).



**Fig. 4** Electronic integrated circuit amplifier characteristics.

To realize human blood plasma serum based electronic amplifier IC, we filled a glass beaker with human blood plasma serum and components of the theoretical circuit ( $C_1$ ,  $C_2$ ,  $R_1$ ,  $R_2$ ,  $R_c$ ,  $R_e$  and transistor) were realized by inserting into human blood plasma serum sample. Various probe terminals were appropriately connected using wire harness and measuring instruments such as cathode ray oscilloscope (CRO), function generator and power supply VCC unit as shown in **Fig. 5**. Function generator was used to input signal to the amplifier circuit and the output was measured by CRO. Necessary voltage power supply Vcc was administered using voltage source. The performance characteristics of human blood plasma serum based electronic amplifier IC are shown in **Fig. 5B**, which indicated that liquid bio-material human blood plasma serum sample based amplifier circuit in integrated configuration was feasible. The gain varied from 1 to 6 db over frequency band (6 to 8 MHz).

Our experimental study demonstrated that human blood plasma serum based electronic passive /active



**Fig. 5** Amplifier liquid interated circuit concept.

components and electronic amplifier circuit is feasible and a total electrolyte components based IC amplifier circuits is also realizable. However, further studies to standardize/optimize the performance of these biological circuits are envisaged.

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