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APPLICATION OF MOSFET FOR DEVELOPING OF NEURON MODEL

[1]Taslima Ahmed, [2]Hitendra Singh, [3]Tarun Hiteshi, [4]Punam Kumari,

[1]Associate professor, [4]Undergratute student, Department of ECE

IIMT college of Engineering, Greater Noida

[2]Assistant professor, [3]Associate professor, Department of ECE

Accurate college of engineering, Greater noida

ABSTRACT

The important application of bifurcation analysis of a system is estimated by the variables of H-H model. Matlab is essential tool for proper visualization of results and therefore, here, we are discussing some GUI based bifurcation panels. Based on these panels, we can investigate different abnormal disorders in neuron model applications. Understanding complex neurobiological systems is one of the most difficult challenges in modern science. From these above results and discussion, we can conclude that H-H equation is the foundation of neuroscience as these parameters values are used for computational brain modeling.

Key word: HH, Neuron

1 INTRODUCTION:

Modeling and simulation of the electrical activity of neuron including the synapse provides important tools for characterization and prediction of neuronal function. Such model has important applications in the field of neurobioengineering for simulation of receptor function and electrical activity of the postsynaptic cell. In the field of neuromorphology, such model may be used for simulation of agonist-receptor function of postsynaptic cell.

The electrical mechanism of synapse is shown in Fig. 1(a). The synaptic equivalent circuit is shown in Fig. .1(b), where I is the total current from ionic channels of all synapses and $E_1, E_2, \ldots, E_M$ represent the chemical potentials of each corresponding ions. For example, E_M may be E_{Na} or may be E_{Cl}. The total current I

help to stimulate the postsynaptic neuron to initiate an action potential [1]. Fig. .1(c) shows the equivalent circuit of a synapse which consists of a presynaptic neuron, synaptic cleft and postsynaptic neuron. Here, C_M represents the capacitance of the lipid bilayer of postsynaptic membrane. The conductance g_{Na}, g_K, g_{Cl}, and g_o represent the membrane permeability of Sodium, Potassium, Chloride and other ions. E_{Na}, E_{Cl}, and E_K are the chemical potentials of Sodium, Chloride and Potassium. E_o is the resting potential.

From the Fig. 1(b), the total current can be written as

$$I = I_m + I_o - I_{Na} + I_{Cl} + I_K$$

If V_m be the postsynaptic membrane potential established by the ionic and capacitive membrane current then

$$I = C(dV_m/dt) + g_O(V_m - E_O) - g_{Na}(V_m - E_{Na}) + g_{Cl}(V_m - E_{Cl}) + g_K(V_m - E_K)$$

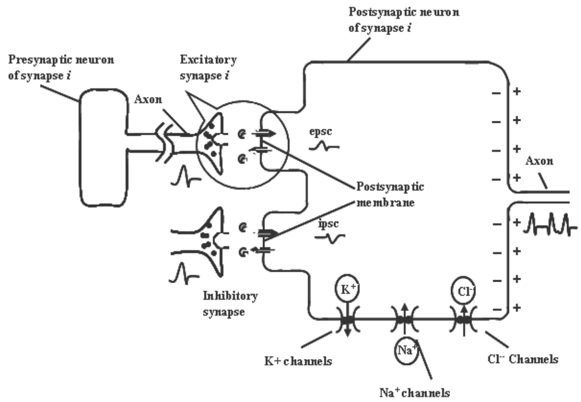

Fig. 1(a): Electrical mechanism of synapse

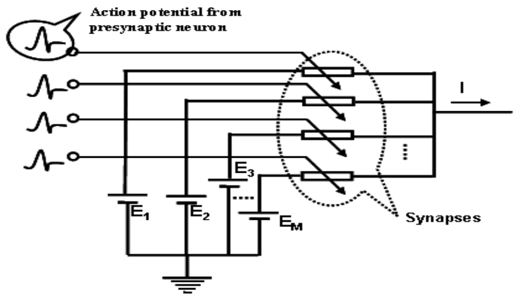

Fig. 1(b): Equivalent circuit of a presynaptic neuron

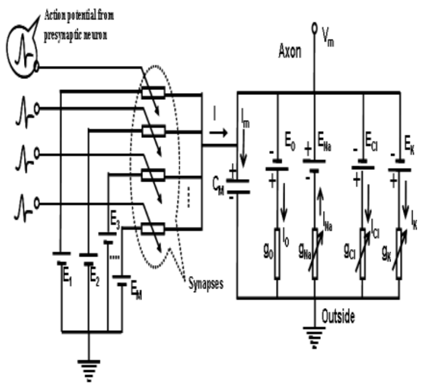

Fig. 1(c): Electrical equivalent circuit of synapse

II SYNAPTIC NEURON MODELS

Modeling and simulation of neuron provides important tools for prediction of function of neurons at excitatory and inhibitory states. Such model has important applications in the field of neurobioengineering for simulation of receptor binding function and electrical activity of the postsynaptic cell. It is stated in literature [2] that FET is the ideal electronic element to simulate the axon membrane conductances. Theory of Metal-oxide Semiconductor Field-Effect Transistor (MOSFET) is therefore essential to understand the synaptic neuron model.

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2.1 Theory of Metal-oxide Semiconductor Field-Effect Transistor (MOSFET):

The basic structure of Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is shown in Fig. 2. MOSFET is a Metal Oxide Semiconductor (MOS) capacitor that has been made between two n^+ (i.e., heavily doped *n*-type) contact regions in a *p*-type semiconductor. The *gate (G)* (or MOS capacitor electrode) has a length *L* and a width *Z*, as shown in Fig. 2.

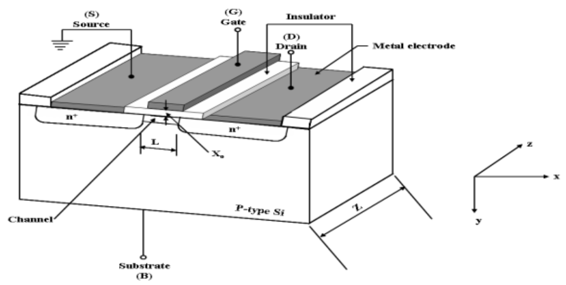

Fig. 2: Structure of an *n*-channel enhancement-mode MOSFET

The n^+ regions are called the *source (S)* and *drain (D)* regions. Their main function is to establish a low-resistance contact to the two ends of the n^+-type inversion layer, and a very high resistance contact to the *p*-type semiconductor substrate. Indeed the n^+ regions can supply electrons to the inversion layer, as is required there for conduction, but they can not supply holes to the *p*-type substrate, so they are a very poor ohmic contact to the substrate. They form *pn* junctions with the substrate, with the polarity of bias between the source and drain regions and the substrate being such as to inhibit current flow (actually a leakage current will flow across the n^+p junction at the drain, but it is very small, so the source and drain are effectively isolated when there is no inversion layer connecting them). In practice, only a negligible current can flow between the two n^+ regions unless a surface inversion layer is formed. This implies that current flows between source and drain only when we apply a voltage between gate and substrate that is greater than the threshold voltage for the MOS capacitor.

The device shown in Fig. 2 is called an *n-channel enhancement-mode* MOSFET: a *p-channel enhancement-mode* MOSFET can be made by using p^+ contact regions in an *n*-type semiconductor substrate.

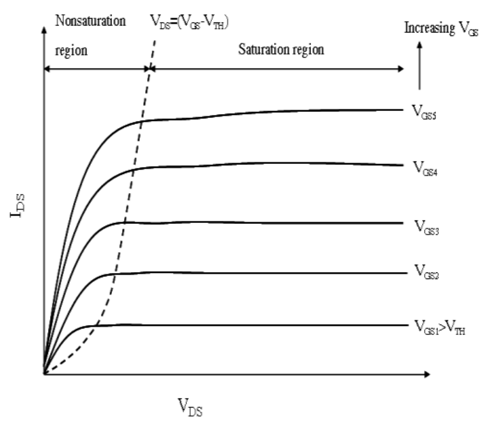

Fig. 2(a): Output Characteristics of an *n*-channel enhancement mode MOSFET

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The drain nonsaturation characteristics are defined by the equation

$$I_{DS} = \beta[(V_{GS} - V_{TH})V_{DS} - \frac{V_{DS}^2}{2}]$$

The quantities β and V_{TH} are device parameters that must be either measured or calculated. The drain characteristics shown in Fig. 2(a) indicates that there are two basic regions of operation of the MOSFET, corresponding to very low V_{DS}«$(V_{GS}-V_{TH})$ *(nonsaturation region)* and very high V_{DS}»$(V_{GS}-V_{TH})$ *(saturation region)* values of the drain voltage. The basic characteristics for these two regions can be derived now. The locus of points dividing the saturation region from the nonsaturation region is defined by

$$V_{DS} = (G_{VS} - V_{TH})$$

For digital applications, the MOSFET operates on both sides of the curves specified by equation. For analog applications, the MOSFET is usually operated in saturation. A drain voltage V_{DS} is applied to MOSFET under the condition $V_{GS}>V_{TH}$, necessary to ensure that a conducting channel has been formed between the source and drain regions, where *x* is the distance coordinate measured along the length of the channel from source to drain. when $V_{DS}=(V_{GS}-V_{TH})$ the channel will (in principle) be reduced to zero width at the drain end. The physical situation is shown in Fig. 2(b): the channel is said to be *pinched off* at the drain. The drain current that flows under this condition can be calculated from equation by substituting $V_{DS}=(V_{GS}-V_{TH})$. The result is

$$I_{DS} = \frac{\beta}{2}(V_{GS} - V_{TH})^2$$

differentiating equation , we find that the drain current has a horizontal tangent at $V_{DS}=(V_{GS}-V_{TH})$, as indicated in the drain characteristics of Fig. 2(a).

For the current given by equation to flow, it is necessary that some very high velocity electrons exist in a thin region near the drain. Then, the channel is in practice not pinched down to exactly zero width, but rather to a point where there are just enough electrons to carry the drain current when each electron is traveling at its maximum velocity.

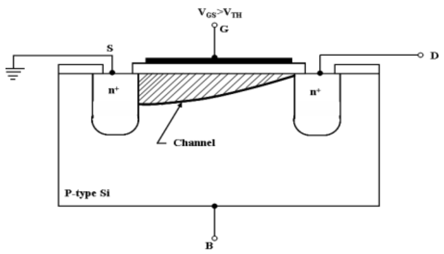

Fig. 2(b): Shape of the channel width of an *n*-channel enhancement mode MOSFET for $V_{DS}=(V_{GS}-V_{TH})$

Gate & drain bias conditions	Channel conditions	Drain haracteristics
$V_{GS} \leq V_{TH}$ and $V_{DS} \geq 0$	No inversion layer: $Q_n = 0$	$I_{DS} = 0$
$V_{GS} > V_{TH}$ and $0 < V_{DS} \ll (V_{GS} - V_{TH})$	Inversion layer exists: $Q_n = C_{ox}(V_{GS} - V_{TH})$	$I_{DS} = \beta(V_{GS} - V_{TH})V_{DS}$ Voltage controlled conductance
$V_{GS} > V_{TH}$ and $0 < V_{DS} \leq (V_{GS} - V_{TH})$	Inversion layer exists: Decreasing channel thickness near drain	$I_{DS} = \beta[(V_{GS} - V_{TH})V_{DS} - \frac{V_{DS}^2}{2}]$
$V_{GS} > V_{TH}$ and $V_{DS} \geq (V_{GS} - V_{TH})$	Inversion layer exists: pinch-off near drain	$I_{DS} = \frac{\beta}{2}(V_{GS} - V_{TH})^2$ Voltage controlled current source

Table 1: Basic properties of an *n*-Channel Enhancement-Mode MOSFET

III CONCLUSION

The postsynaptic membrane of a single neuron can have excitatory and inhibitory transmitter-gated ion channels. Generally, excitatory channels are specific to sodium ions and inhibitory channels are specific to chloride ions. The excitatory and inhibitory ionic current control the change in membrane potential. The influx of sodium ions causes an excitatory postsynaptic membrane potential (EPSP), whereas the influx of chloride ions causes an inhibitory postsynaptic membrane potential (IPSP). When excitation predominates, the membrane potential increases. If a sufficient number of transmitter gated sodium channels are open, then the membrane potential exceeds the threshold for initiating an action potential. When inhibition predominates, the membrane potential decreases (or hyperpolarizes), and triggering of an action potential is impeded.

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