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# The Electron Transport Through Strongly Coupled Double Quantum Dots : Effect of Spin Exchange Interaction

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**Abstract**
We introduce model calculation for the electron transport through a system consists of two serially coupled quantum dots, embedded between two nonmagnetic leads (source and drain). In our treatment, the time independent Anderson-Newns Hamiltonian model is considered as a basis to study the system dynamics and then to derive spin-dependent analytical formula to calculate the occupation numbers of the quantum dots energy levels, the corresponding quantum dots energy levels and the molecular virtual energy levels, as a function of bias voltage. These relations are solved self-consistently, which are all employed to calculate the tunneling current considering the strong coupling regime. The differential conductance is calculated numerically by using finite differences method. And as the efficiency of electron transport through coupled quantum dots depends on the system parameters, the effective exchange energy is highlighted and studied in details and the role of this parameter in the tunneling current and the differential conductance calculations is presented. Our treatment is utilized to study the following The role of the spin exchange interaction in determining the type of interaction (if it is attractive or repulsive) between the quantum dots. For all values of exchange energy less than $0.2\ \mathrm{eV}$, the bias voltage between the two resonance peaks is equal to $V_{12}+\Gamma_{i\alpha}^{\pm\sigma}+J$ . This result is very important to determine the Nano device feature that depends in its operation on two serially coupled quantum dots.

## 1-Introduction

The electron transport through double quantum dots structure has been the subject of many experimental and theoretical studies during the past few years [1-3]. In particular, a lot of interest and experimental techniques were developed to discover and control double quantum dot systems. A double quantum dots connected in series and coupled to external leads is one of great interest due it possibility of using this kind of systems in quantum computer hard ware, with applications in optical spin manipulation spintronics, spin memories and transistors [4]. The transport properties of the two quantum dots depend on the strength of the inter-dot coupling between the quantum dots, since the weak tunnel coupling between QDs can form ionic like bond, while the strong tunnel coupling can form covalent like bond. In the weak coupling, the electrons are localized in individual quantum dots, while in the strong one, the DQDs can be treated as a molecule. In the weak coupling regime the coupling between the two dots is small as compared with the coupling between the dots and the leads. While in the strong coupling regime the coupling between the two dots is large as compared with the coupling between the dots and the leads. One of the most important interaction is the spin exchange interaction which may called the effective exchange interaction. This interaction is studied and investigated in our study.

## 2- The Mathematical Model

A mathematical model is performed for a system consists of double quantum dots (DQD) serially connected (regarded as an artificial molecule) and placed between two leads, as in Figure (1). $V_{1R}$ in figure (1) represents the coupling interaction between QD1 and right lead, and $V_{2L}$ represents the coupling interaction between QD2 and the left lead . $V_{12}$ represents the direct interaction between QD1 and QD2. The interactions that will be taken into consideration here are the interactions between the right lead and first quantum dot $\Gamma_{1R}^{\pm\sigma}$ , the left lead and the second quantum dot $\Gamma_{2L}^{\pm\sigma}$ , the interaction between the two quantum dots ( $V_{12}$ ) in addition to the effective spin exchange interaction between them ( $J$ ) . The efficiency of electron transport in this system depends on the electronic system properties such as the electrochemical potential of the two leads, the energy band characteristics (such as bandwidth and density of electronic state) as well as energy level of quantum dots. The characteristics of quantum dots are of a great important because of it's role in determining the dynamical properties of electron transfer between the right and left leads, as a function of the bias voltage $(eV_{bias})$ that applied to the leads which is defined as follow [5]: