We investigate the second-order von Neumann approach from a diagrammatic point of view and demonstrate its equivalence with the resonant tunneling approximation. The investigation of higher order diagrams shows that the method correctly reproduces the equation of motion for the single-particle reduced density matrix of an arbitrary non-interacting many-body system. This explains why the method reproduces the current exactly for such systems. We go on to show, however, that diagrams not included in the method are needed to calculate exactly higher cumulants of the charge transport. This thorough comparison sheds light on the validity of all these self-consistent second-order approaches. We analyze the discrepancy between the noise calculated by our method and the exact Levitov formula for a simple non-interacting quantum dot model. Furthermore, we study the noise of the canyon of current suppression in a two-level dot, a phenomenon that requires the inclusion of electron–electron interaction as well as higher order tunneling processes.