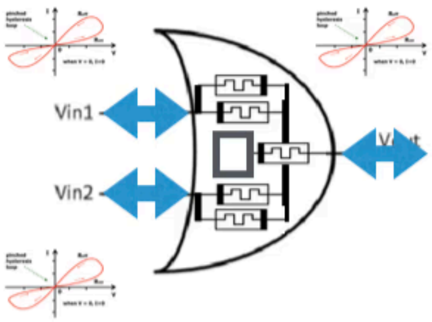
Dynex Neuromorphic Quantum Circuits' Equations of Motion

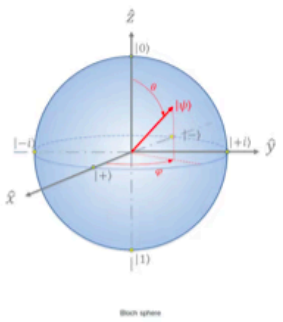
Dynex's neuromorphic quantum circuits are individually constructed based on the specific computational problem, typically represented in the form of QUBO (Quadratic Unconstrained Binary Optimization), Ising models, Binary Quadratic Models (BQM), or Constrained Quadratic Models (CQM). These circuits are composed of linear and quadratic quantum gates. Given that these quantum gates utilize physical, electric components such as memristors, their behavior can be efficiently simulated by solving the resultant system of equations of motion through Ordinary Differential Equation (ODE) integration. The following differential equations are applied within the Dynex platform.

Dynex Gate



in/out voltages [-1,+1] (superposition)

Quantum Gate



Qubit: 0 or 1 or both (superposition)

The optimal values for the applied parameters $\alpha, \beta, \gamma, \delta, \epsilon, \varepsilon, \zeta$ are being automatically identified by the Dynex platform. Note that these are different for each computational problem class.

Linear quantum gates

$$v_n = \sum_m QG_m W_m p_i$$ (qubit voltage) (1)

Whereas:

$$QG_m = \frac{1.0 - p_i v_i}{2.0}$$ (quantum gate state) (2)

W_m (quantum gate weight)

$$p_i = \begin{cases} 1.0 & i > 0 \\ -1.0 & i <= 0 \end{cases}$$ (quantum gate polarity) (3)

Quadratic quantum gates

$$v_n = \sum_m G_{i,j}(W_m a_m b_m) + R_{i,j}\zeta(1 - a_m) \qquad \text{(qubit voltage)} \qquad (4)$$

Whereas:

$$W_m \qquad \text{(quantum gate weight)}$$

$$p_{i,j} = \begin{cases} 1.0 & i,j > 0 \\ -1.0 & i,j <= 0 \end{cases} \qquad \text{(quantum gate polarity)} \qquad (5)$$

$$QG_m = \frac{min((1.0 - p_i v_i), (1.0 - p_j v_j))}{2.0} \qquad \text{(quantum gate state)} \qquad (6)$$

$$G_i = \frac{p_i(1.0 - p_j v_j)}{2.0} \qquad \text{(gradient term)} \qquad (7)$$

$$G_j = \frac{p_j(1.0 - p_i v_i)}{2.0} \qquad \text{(gradient term)} \qquad (8)$$

$$R_i = \begin{cases} 0.0 & QG \neq \frac{1.0 - p_i v_i}{2.0} \\ \frac{p_i(1.0 - p_i v_i)}{2.0} & QG = \frac{1.0 - p_i v_i}{2.0} \end{cases} \qquad \text{(rigidity term)} \qquad (9)$$

$$R_j = \begin{cases} 0.0 & QG \neq \frac{1.0 - p_j v_j}{2.0} \\ \frac{p_j(1.0 - p_j v_j)}{2.0} & QG = \frac{1.0 - p_j v_j}{2.0} \end{cases} \qquad \text{(rigidity term)} \qquad (10)$$

Auxiliary variables:

$$a_m = \beta(a_m + \epsilon)(QG - \gamma) \qquad \text{(memristive function)}$$

$$b_m = \alpha(1.0 + W)(QG - \delta) \qquad \text{(memristive function)}$$