# Supporting Information

## S1 Model Equations

The Dual Oscillator Model equations are as follows.

Glycolysis:

$$dG_i/dt = J_{\mathrm{GLUT}} - J_{\mathrm{GK}}$$

$$d\mathrm{F6P}/dt = (1 + k_{\mathrm{GPI}})^{-1}(J_{\mathrm{GK}} - J_{\mathrm{PFK}})$$

$$d\mathrm{FBP}/dt = (1 + k_{\mathrm{LG}})^{-1}(J_{\mathrm{PFK}} - J_{\mathrm{PDH}})$$

$$J_{\mathrm{GLUT}} = V_{\mathrm{GLUT}}\left(\frac{G_e}{G_e + k_{\mathrm{GLUT}}^{\mathrm{GLC}}} - \frac{G_i}{G_i + k_{\mathrm{GLUT}}^{\mathrm{GLC}}}\right)$$

$$J_{\mathrm{GK}} = V_{\mathrm{GK}}\frac{G_i^{h_{\mathrm{GK}}^{\mathrm{GLC}}}}{G_i^{h_{\mathrm{GK}}^{\mathrm{GLC}}} + k_{\mathrm{GK}}^{h_{\mathrm{GK}}^{\mathrm{GLC}}}}$$

$$J_{\mathrm{PFK}} = V_{\mathrm{PFK}}\frac{(1 - k_{\mathrm{PFK}})w_{1110} + k_{\mathrm{PFK}}\sum_{i,j,l\in\{0,1\}} w_{ij1l}}{\sum_{i,j,k,l\in\{0,1\}} w_{ijkl}}$$

$$w_{ijkl} = \frac{\left(\frac{\mathrm{AMP}}{K_{\mathrm{PFK}}^{\mathrm{AMP}}}\right)^i \left(\frac{\mathrm{FBP}}{K_{\mathrm{PFK}}^{\mathrm{FBP}}}\right)^j \left(\frac{\mathrm{F6P}^2}{K_{\mathrm{PFK}}^{\mathrm{F6P}}}\right)^k \left(\frac{\mathrm{ATP}^2}{K_{\mathrm{PFK}}^{\mathrm{ATP}}}\right)^l}{f_{\mathrm{AMP}}^{ik} f_{\mathrm{FBP}}^{jk} f_{\mathrm{MT}}^{il} f_{\mathrm{BT}}^{jl} f_{\mathrm{ATP}}^{kl}}$$

$$J_{\mathrm{PDH}} = k_{\mathrm{PDH}}\sqrt{\mathrm{FBP}}$$

ATP Production/Hydrolysis:

$$d\mathrm{ATP}/dt = J_{\mathrm{ANT}} - J_{hyd}$$

$$J_{\mathrm{ANT}} = V_{\mathrm{ANT}}\mathrm{ADP}\exp\left[\left(k_{\mathrm{ANT}} + k_{\mathrm{ANT}}^{\mathrm{PDH}}\frac{J_{\mathrm{PDH}}}{J_{\mathrm{PDH}} + V_{\mathrm{ANT}}^{\mathrm{PDH}}}\right)\left(1 - \frac{Ca_c}{k_{\mathrm{ANT}}^{Ca}}\right)\right]$$

$$J_{hyd} = (k_{hyd,bas} + k_{hyd}^{Ca}Ca_c)\mathrm{ATP}$$

$$\mathrm{AMP} = \mathrm{ADP}^2/\mathrm{ATP}$$

$$\mathrm{ATP} + \mathrm{ADP} + \mathrm{AMP} = A_{tot}$$

Membrane Potential and Calcium Concentrations:

$$dV/dt = -(I_{Ca(V)} + I_{K(V)} + I_{K(Ca)} + I_{K(\text{ATP})})/C_m$$

$$dn_{K(V)}/dt = (n_{K(V),\infty} - n_{K(V)})/\tau_{K(V)}$$

$$dCa_c/dt = k_{cyt}^{Ca}(J_{\text{PM}} - J_{\text{ER}})$$

$$dCa_{\text{ER}}/dt = k_{\text{ER}}^{Ca} J_{\text{ER}}$$

$$I_{i(s)} = g_{i(s)} n_{i(s)} \cdot (V - V_i), \quad i(s) \in \{Ca(V), K(V), K(Ca), K(\text{ATP})\}$$

$$n_{i(s),\infty} = [1 + (k_{i(s)}/r(s))^{h_{i(s)}}]^{-1}, \quad i(s) \in \{Ca(V), K(V), K(Ca)\}$$

$$n_{i(s)} = n_{i(s),\infty} \text{ for } i(s) \in \{Ca(V), K(V)\}$$

$$r(s) = \begin{cases} e^s & \text{if } s = V \\ s & \text{otherwise} \end{cases}$$

$$n_{K(\text{ATP})} = \frac{0.08\left(1 + 2\frac{\text{MgADP}^-}{kdd}\right) + 0.89\left(\frac{\text{MgADP}^-}{kdd}\right)^2}{\left(1 + \frac{\text{MgADP}^-}{kdd}\right)^2\left(1 + \frac{\text{ADP}^{3-}}{ktd} + \frac{\text{ATP}^{4-}}{ktt}\right)}$$

$$\text{MgADP}^- = 0.0165\text{ADP}$$

$$\text{ADP}^{3-} = 0.135\text{ADP}$$

$$\text{ADP}^{4-} = 0.05\text{ATP}$$

$$J_{\text{PM}} = -[I_{Ca(V)}/(2F) + k_{\text{PM}}Ca_c]$$

$$J_{\text{ER}} = k_{\text{ER},in}Ca_c - k_{\text{ER},out}(Ca_{\text{ER}} - Ca_c)$$

**S1 Text. Model Equations.**
Equations for the Dual Oscillator Model.