Thermodynamic Projection Theory (TPT)

VOLUME II: UNIFIED SYMBOL REGISTRY (v5.0)

Unified symbol registry and operational calculation blocks

Governing law: Thermodynamic Projection Equation (TPE) (TPE)

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1 Scope

This document is a strict symbol-and-equation registry for:

- the TPT v4 theory paper (conformed), and
- the TPT user manual v1.

It provides (i) a unified symbol table, (ii) an equation index keyed to operational meaning, (iii) compute-ready restart blocks, and (iv) a gap-audit listing missing or implicit definitions.

2 Unified symbol registry

Symbol	Meaning / Definition	Where used
$\rho(t)$	Reduced / observed open-system state (density operator). In the v4 paper, the macro `\rhoU` denotes this reduced state.	v4 eq. (TPE); manual
$H_{\text{eff}}(t)$	Effective Hamiltonian governing the unitary part of the reduced dynamics. Macro `\Heff`.	v4 eq. (TPE)
$\mathcal{K}(t,s)$	Non-Markovian memory kernel (superoperator). Macro `\Kmem`.	v4 eq. (TPE)
$\mathcal{D}$	Markovian dissipator (superoperator) in the δ-kernel limit. Macro `\Dsuper`.	v4 Markovian limit
$\mathcal{P}, \mathcal{Q}$	Projection superoperators in the Nakajima–Zwanzig schematic. Macros `\Pproj`, `\Qproj`.	v4 eq. (NZ)
$\mathcal{L}$	Liouvillian superoperator acting on states/operators (open-system generator used inside the NZ schematic).	v4 eq. (NZ)
$\mathrm{e}^{(\cdot)}$	Operator exponential. In NZ: $\mathrm{e}^{(t-s)\,\mathcal{QL}}$. (Here e denotes the exponential base; equivalently $\exp(\cdot)$.)	v4 eq. (NZ)
τ	Intrinsic / processing time. Macro `\tproc`.	v4 Jacobian bridge; manual
t	Geometric / observed time. Macro `\tgeom`.	v4 and manual
$J(t)$	Jacobian bridge: $J(t) \coloneqq d\tau/dt$. In v5.0, this acts as the global evolution multiplier for the TPE.	v4 eq. (Jacobian); manual
$\Gamma_{\text{eff}}(t)$	Effective dissipation / processing rate; identified with $J(t)$. Macro `\Geff`.	v4 eq. (JΓ); manual
$\mathrm{d}/\mathrm{d}t$	Geometric-time derivative operator.	v4, manual
$\mathrm{d}/\mathrm{d}\tau$	Processing-time derivative operator; related by chain rule via $J(t)$.	manual
$[\cdot,\cdot]$	Commutator: $[A,B] = AB - BA$.	v4 eq. (TPE), (GKSL)
$\{\cdot,\cdot\}$	Anticommutator: $\{A,B\} = AB + BA$.	v4 eq. (GKSL)

Symbol	Meaning / Definition	Where used
L_k	Lindblad (jump) operators in the GKSL limit.	v4 eq. (GKSL)
Γ	Universal Decay Constant (Entropy Tax). Represents fundamental manifold friction required for operational closure.	v5 eq. (TPE$_v$5)
γ_k	GKSL rates / weights multiplying each jump channel.	v4 eq. (GKSL)
y	Survival-factor / Yukawa-like amplitude in the ladder ansatz: $y \propto \exp(-\int \Gamma_{\text{eff}}\, dt)$.	manual ladder
n	Ladder rung / level index used in the quantized integral ansatz $\int J\, dt \approx n\, s$.	manual ladder
y_n	Discrete ladder amplitudes: $y_n \approx \exp(-n\, s)$.	manual ladder
R	Quantization radius parameter defining the step $s = 2\pi/R$.	manual ladder + CKM
s	Quantization step: $s \equiv 2\pi/R$; exponent increment.	manual ladder + CKM
v	Higgs vacuum expectation value (VEV) used in $m = yv/\sqrt{2}$ mapping.	manual ladder
m_f	Fermion mass mapped from y_f: $m_f = y_f\, v/\sqrt{2}$.	manual ladder
m_n	Discrete ladder masses: $m_n \approx (v/\sqrt{2})\, \exp(-n\, s)$.	manual ladder
λ	Wolfenstein parameter (manual sets $\lambda = s = \pi/14$).	manual CKM
α	Exponent prefactor (manual sets $\alpha = 1 - \frac{1}{2\pi}$).	manual CKM
$\lvert V_{cb}\rvert$	CKM magnitude anchored by $\lvert V_{cb}\rvert = \exp[-\alpha \cdot 17\, s]$.	manual CKM
$\lvert V_{ub}\rvert$	CKM magnitude anchored by $\lvert V_{ub}\rvert = \exp[-25\, s]$.	manual CKM
A	Wolfenstein parameter derived from $\lvert V_{cb}\rvert$: $A = \lvert V_{cb}\rvert/\lambda^2$.	manual CKM
$\bar{\rho}$	Barred Wolfenstein parameter (manual sets $\bar{\rho} = 1/(2\pi)$).	manual CKM
r	Derived ratio: $r = \lvert V_{ub}\rvert/(A\lambda^3)$ used to compute $\bar{\eta}$.	manual CKM
$\bar{\eta}$	Barred Wolfenstein parameter from $r^2 = \bar{\rho}^2 + \bar{\eta}^2$ with $\bar{\eta} > 0$.	manual CKM
β	Unitarity-triangle angle: $\tan\beta = \bar{\eta}/(1-\bar{\rho})$.	manual CKM
$\sin(2\beta)$	Observable computed by $\sin(2\beta) = \sin\Big(2\arctan\Big(\bar{\eta}/(1-\bar{\rho})\Big)\Big)$.	manual CKM
J_{model}	Model Jarlskog proxy: $J_{\text{model}} \approx A^2\lambda^6\bar{\eta}$.	manual CKM
δ	CP-violating phase extracted via $\sin\delta$ ratio.	manual CKM
s_{ij}, c_{ij}	Standard mixing-angle sines/cosines (PDG parameterization reconstruction).	manual CKM

3 Equation index (operational meaning)

3.1 Jacobian bridge

$$J(t) \coloneqq \frac{d\tau}{dt}, \qquad J(t) \equiv \Gamma_{\text{eff}}(t). \tag{1}$$

Operational role: converts between processing-frame derivatives and observed derivatives by the chain rule. In v5.0, this Jacobian is promoted to the global evolution multiplier for the TPE.

3.2 Thermodynamic Projection Equation (TPE)

$$\frac{d\rho(t)}{dt} = J(t)\left[-i\left[H_{\text{eff}}(t), \rho(t)\right] + \int_0^t \mathrm{d}s\ \left(\mathcal{K}(t,s) \pm \Gamma\right)\rho(s)\right] \tag{2}$$

Operational role: v5.0 Augmented reduced dynamics with global Jacobian multiplier and integrated entropy tax.

3.3 GKSL limit

$$\frac{d\rho}{dt} = -i[H_{\text{eff}}, \rho] + \sum_k \gamma_k\left(L_k\rho L_k^\dagger - \frac{1}{2}\{L_k^\dagger L_k, \rho\}\right). \tag{3}$$

Operational role: Markovian dissipation in jump-operator form.

3.4 Nakajima–Zwanzig schematic

$$\frac{d}{dt}\mathcal{P}\rho(t) = \mathcal{P}\mathcal{L}\mathcal{P}\rho(t) + \int_0^t \mathrm{d}s\, \mathcal{P}\mathcal{L}\, \mathrm{e}^{(t-s)\mathcal{Q}\mathcal{L}}\, \mathcal{Q}\mathcal{L}\mathcal{P}\rho(s). \tag{4}$$

Operational role: explicit projection-kernel structure.

4 Compute-ready restart blocks

4.1 Mass ladder block

$$s \equiv \frac{2\pi}{R}, \tag{5}$$

$$y \propto \exp\left(-\int \Gamma_{\text{eff}}(t)\, dt\right) = \exp\left(-\int J(t)\, dt\right), \tag{6}$$

$$\int J\, dt \approx n\, s, \tag{7}$$

$$y_n \approx \exp(-n\, s), \tag{8}$$

$$m_n \approx \frac{v}{\sqrt{2}}\, \exp(-n\, s). \tag{9}$$

Numeric constant used in the manual:

$$\frac{v}{\sqrt{2}} = 174.10383166375172 \text{ GeV}. \tag{10}$$

4.2 CKM restart block (exact manual constants)

Locked constants:

$$R = 28, \quad s = \frac{2\pi}{R} = \frac{\pi}{14}, \quad \lambda = s, \quad \alpha = 1 - \frac{1}{2\pi}, \quad \bar{\rho} = \frac{1}{2\pi}. \tag{11}$$

Anchor magnitudes:

$$|V_{cb}| = \exp[-\alpha \cdot 17\, s]\,, \qquad |V_{ub}| = \exp[-25\, s]\,. \tag{12}$$

Derived Wolfenstein quantities:

$$A = \frac{|V_{cb}|}{\lambda^2}, \qquad r = \frac{|V_{ub}|}{A\lambda^3}, \qquad \bar{\eta} = \sqrt{r^2 - \bar{\rho}^2} \quad (\bar{\eta} > 0). \tag{13}$$

Target observable:

$$\tan\beta = \frac{\bar{\eta}}{1-\bar{\rho}}, \qquad \sin(2\beta) = \sin\left(2\arctan\left(\frac{\bar{\eta}}{1-\bar{\rho}}\right)\right). \tag{14}$$

Exact PDG extraction step:

$$s_{12} = \lambda, \quad s_{13} = |V_{ub}|, \quad c_{13} = \sqrt{1 - s_{13}^2}, \quad s_{23} = \frac{|V_{cb}|}{c_{13}}. \tag{15}$$

CP-phase extraction:

$$J_{\text{model}} \approx A^2\lambda^6\bar{\eta}, \qquad \sin\delta = \frac{J_{\text{model}}}{c_{12}c_{23}c_{13}^2\, s_{12}s_{23}s_{13}}. \tag{16}$$

5 Gap audit (strict coverage)

This registry is fit for purpose if and only if every symbol that appears in the governing equations and compute blocks is defined in the table above. The remaining gaps that are present in the source documents themselves are:

- The symbol $\mathcal{L}$ is used in the NZ schematic but is not expanded in the v4 paper beyond "Liouvillian". If an explicit form is intended (Hamiltonian + dissipator, etc.), it must be stated.
- The exponential base e is introduced in the v4 paper via `\newcommand{\e}{\mathrm{e}}`; operationally it is the standard exponential function. If the document should exclusively use $\exp(\cdot)$, standardize this choice.
- The normalization of survival factor y is formally specified by the Universal Decay Constant Γ (the Entropy Tax), providing the friction term required for operational closure.