



AD FALCON API Manual

Implicit Time Integration

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1 Implicit Time Integration

This page documents **implicit** time integration in FALCON (the default path that runs a coupled **Newton** solve per increment). It applies to:

- **Uncoupled** analyses (solid only)
- **Coupled** analyses (solid + water pressure PW)
- **Fully coupled** analyses (solid + water/air pressures PW/PA)

For non-Newton time integration used mainly with adaptive substepping, see [Explicit and IMEX Time Integration](#).

1.1 What “Implicit” Means in FALCON

When `@@TimeIntegration: Implicit` is selected, FALCON advances the step with a **monolithic** nonlinear solve:

- Unknowns include the active **displacement DOFs** (e.g., DisX, DisY, DisZ) and, when present, **pressure DOFs** (PW, PA).
- Each increment is solved by Newton iterations until the (scaled) unbalanced force measure is below the target.

Even though the solve is monolithic, FALCON uses *two different time-discretization building blocks* inside that Newton system:

1. **Solid (displacements):** Newmark family in generalized- α form
2. **Flow (pressures):** one-step θ -method

1.2 Syntax

Time integration is configured per step inside `% Step Definitions`.

Minimal implicit step:

```
% Step Definitions
@Step 1:
  @@StartStep: 0
  @@SimMode: Dynamic
  @@TimeIntegration: Implicit
  @@StepTime: 1.0
  @@NumberSteps: 100
%%%
```

1.3 Implicit Time-Integration Parameters (Step Keys)

These keys are read inside a step block:

Key	Meaning	Allowed values	Default
<code>@@TimeIntegration:</code> / <code>@@TimeIntegrator:</code>	Select time integration mode	Implicit	Implicit
<code>@@RhoInf:</code>	Generalized- α spectral radius at infinity (solid time integration)	$\rho_\infty \in [0, 1]$	Not set \rightarrow classic Newmark ($\alpha_f = \alpha_m = 0$)
<code>@@Theta:</code> / <code>@@FlowTheta:</code>	Flow θ -method parameter (pressures)	$\theta \in [0.5, 1]$	0.6
<code>@@EnforceBackward:</code>	Consolidation-only shortcut that forces backward Euler for flow	Yes / No	No

Notes:

- `@@AlphaF:` / `@@AlphaM:` are intentionally **not supported**; use `@@RhoInf:` only.
- When `@@EnforceBackward: Yes` is used with `@@SimMode: Consolidation`, FALCON forces $\theta = 1$ for flow (backward Euler), regardless of `@@Theta` / `@@FlowTheta`.

1.4 Applicability by Analysis Type and Simulation Mode

Analysis type	<code>@@SimMode: Static</code>	<code>@@SimMode: Consolidation</code>	<code>@@SimMode: Dynamic</code>
Uncoupled (solid only)	Nonlinear equilibrium (no inertia)	Not applicable	Newmark (with inertia)
Coupled (solid + PW)	Steady coupled solve (no inertia, no transients)	Quasi-static coupled transient (no inertia, flow active)	Fully coupled dynamics (inertia + flow)
Fully coupled (solid + PW + PA)	Steady coupled solve (no inertia, no transients)	Quasi-static coupled transient (no inertia, flow active)	Fully coupled dynamics (inertia + flow)

Notes:

- **Consolidation** is allowed only for coupled / fully coupled analyses.
- In **Static** mode, inertia is deactivated. The intent is a steady equilibrium solve (and, for coupled problems, a steady pressure field when rate terms are not active).
- In **Consolidation** mode, inertia is deactivated but time-dependent flow terms are active.

1.5 Solid Time Integration: Newmark (Generalized- α Form)

FALCON computes Newmark-like parameters using generalized- α algorithmic weights:

$$\gamma = 0.5 + \alpha_f - \alpha_m, \quad \beta = 0.25 (1 + \alpha_f - \alpha_m)^2 \quad (1)$$

1.5.1 Default behavior (most runs)

By default, FALCON uses:

- **No @@RhoInf: specified** (default implicit setting)
- Equivalent generalized- α weights: $\alpha_f = \alpha_m = 0$

This yields standard **Newmark average-acceleration**:

- $\gamma = 0.5$
- $\beta = 0.25$

1.5.2 User control

FALCON exposes generalized- α control **only** via the spectral radius at infinity:

- **@@RhoInf**: sets the spectral radius at infinity $\rho_\infty \in [0, 1]$ and maps it to α_m, α_f using Chung–Hulbert (1993):

$$\alpha_m = \frac{2\rho_\infty - 1}{\rho_\infty + 1}, \quad \alpha_f = \frac{\rho_\infty}{\rho_\infty + 1} \quad (2)$$

1.6 Flow Time Integration: One-Step θ -Method (Coupled/Fully Coupled)

For pressure DOFs (PW and, when present, PA), FALCON uses a one-step θ -method with:

- Valid range: $\theta \in [0.5, 1.0]$
- Default: $\theta = 0.6$

Interpretation:

- $\theta = 1.0 \rightarrow$ **Backward Euler** (most dissipative, most robust)
- $\theta = 0.5 \rightarrow$ **Crank–Nicolson** (less dissipative, can oscillate without enough damping)

1.6.1 Input keys

Use either of these keys inside a step block:

- `@@Theta`: <value>
- `@@FlowTheta`: <value>

1.6.2 Consolidation shortcut: enforce backward Euler

With `@@SimMode`: Consolidation, you may set:

- `@@EnforceBackward`: Yes

This forces $\theta = 1.0$ for the step (backward Euler for flow).

1.7 Minimal Examples

1.7.1 Uncoupled dynamic (implicit)

```
% Step Definitions
@Step 1:
  @@StartStep: 0
  @@SimMode: Dynamic
  @@TimeIntegration: Implicit
  @@StepTime: 1.0
  @@NumberSteps: 100
%%%
```

1.7.2 Coupled consolidation (implicit + default $\theta = 0.6$)

```
% Step Definitions
@Step 1:
  @@StartStep: 0
  @@SimMode: Consolidation
  @@TimeIntegration: Implicit
  @@FlowTheta: 0.6
  @@StepTime: 1000.0
  @@NumberSteps: 100
%%%
```

1.7.3 Coupled consolidation (force backward Euler for flow)

```
% Step Definitions
@Step 1:
  @@StartStep: 0
  @@SimMode: Consolidation
  @@TimeIntegration: Implicit
  @@EnforceBackward: Yes
  @@StepTime: 1000.0
  @@NumberSteps: 100
%%%
```

1.8 Related Pages

- Step syntax and simulation modes: [Steps](#)
- Automatic stepping (Newton-based): [Automatic time incrementation](#)
- Non-Newton dynamic options: [Explicit and IMEX Time Integration](#)