Normal form of your dynamical system

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6:16am, September 8, 2014

Specified dynamical system

$\dot{x}_1 = \varepsilon^2(-x_1^3 + x_1) + \varepsilon y_1 a$

$\dot{y}_1 = \varepsilon(-\frac{\mathrm{d}\,y_1}{\mathrm{d}\,t} y_1^2 + w_1 y_1^2 \sigma) + w_1\sigma - y_1$

Time dependent coordinate transform

$y_1 = \varepsilon^2(7/8e^{3t}\star w_1\, Y_1^4\sigma + 9/4e^{t}\star w_1\, Y_1^4\sigma + 25/8e^{-1t}\star w_1\, Y_1^4\sigma + 5/8Y_1^5) + \varepsilon(-3/2e^{t}\star w_1\, Y_1^2\sigma - 3/2e^{-1t}\star w_1\, Y_1^2\sigma - 1/2Y_1^3) + e^{-1t}\star w_1\,\sigma + Y_1$

$x_1 = \varepsilon^2(-e^{2t}\star w_1\, Y_1^2 a\sigma + 3/2e^{t}\star w_1\, Y_1^2 a\sigma + 1/2e^{-1t}\star w_1\, Y_1^2 a\sigma + 1/6Y_1^3 a) + \varepsilon(-e^{-1t}\star w_1\, a\sigma - Y_1 a) + X_1$

Result normal form DEs

$\dot{Y}_1 = 3\varepsilon e^{-1t}\star w_1\, w_1 Y_1\sigma^2 - Y_1$

$\dot{X}_1 = \varepsilon^3(3w_1 X_1^2 a\sigma - w_1 a\sigma) + \varepsilon^2(-X_1^3 + X_1) + \varepsilon w_1 a\sigma$