We propose a stochastic model for the continuous-time dynamics of a limit order book. The model strikes a balance between two desirable features: it captures key empirical properties of order book dynamics and its analytical tractability allows for fast computation of various quantities of interest without resorting to simulation. We describe a simple parameter estimation procedure based on high-frequency observations of the order book and illustrate the results on data from the Tokyo stock exchange. Using Laplace transform methods, we are able to efficiently compute probabilities of various events, conditional on the state of the order book: an increase in the mid-price, execution of an order at the bid before the ask quote moves, and execution of both a buy and a sell order at the best quotes before the price moves. Comparison with high-frequency data shows that our model can capture accurately the short term dynamics of the limit order book.