

## Timescale Tutorial, by Demetrios Matsakis, U.S. Naval Observatory

Timescales are weighted averages of clock data, which are intended to be optimal according to specific criteria, such as frequency precision, time accuracy, or robustness with respect to component changes. The basic time scale equation and considerations for clock weighting and editing will be discussed, along with examples of timescale algorithms used by different timekeeping institutions, including GPS. Similarities and differences between Auto-regressive Integrated Moving Average (ARIMA), Kalman filter, Exponential Filter, and Bang-Bang algorithms will be shown. Clock steering will be discussed from the point of view of control theory. Linear-Quadratic Gaussian and pole placement approaches will be described. For all of the above, examples using real clock data will be shown.