This paper proposes a novel method of estimating the Fourier transform (FT) of deterministic, continuous-time signals, from a finite number N of their samples taken from a fixed-length observation window. It uses alias-free hybrid-stratified sampling to probe the processed signal at a mixture of deterministic and random time instants. The FT estimator, specifically designed to work with this sampling scheme, is unbiased, consistent and fast converging. It is shown that if the processed signal has continuous third derivative, then the estimator's rate of uniform convergence in mean square is N^{-5}. Therefore, in terms of frequency-independent upper bounds on the FT estimation error, the proposed approach significantly outperforms existing estimators that utilize alias-free sampling, such as total random, stratified sampling, and antithetical stratified whose rate of uniform convergence is N^{-1}. It is proven here that N^{-1} is a guaranteed minimum rate for all stratified-sampling-based estimators satisfying four weak conditions formulated in this paper. Owing to the alias-free nature of the sampling scheme, no constraints are imposed on the spectral support of the processed signal or the frequency ranges for which the Fourier Transform is estimated.