

# Multirate control for high accuracy and low cost: dual-stage experiments

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# Multirate control for high accuracy and low cost: dual-stage experiments

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## Motivation: balancing performance versus cost

Dual-stage systems are commonly used in industry to achieve a high position accuracy over a large range. The different performance requirements of the stages (e.g.,  $\mu\text{m}$  vs  $\text{nm}$ : order  $10^3$ ) result in different control bandwidths which naturally leads to a multirate design.

Multirate designs balance performance versus cost through use of different sampling frequencies. This enables reduction of implementation cost in terms of hardware, e.g., sensors, actuators, AD/DA converters. This is a clear advantage over traditional single-rate designs in which the sampling frequency for all control loops is determined by the control loop with the most stringent performance requirements.

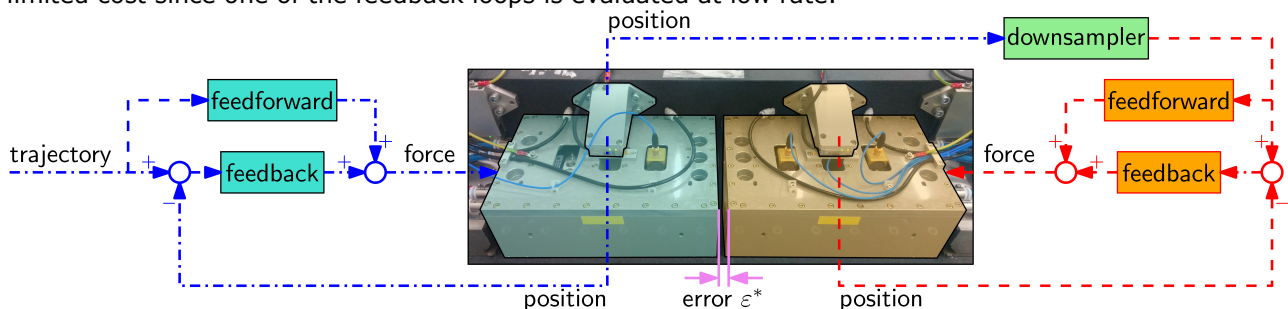
## Contribution: experimental validation of multirate control design framework

Although multirate control has many potential, at present its deployment is hampered by a lack of control design techniques. The main reason is linear periodically time-varying (LPTV) behavior for which well-known control designs based on Bode plots and Nyquist diagrams are not directly applicable.

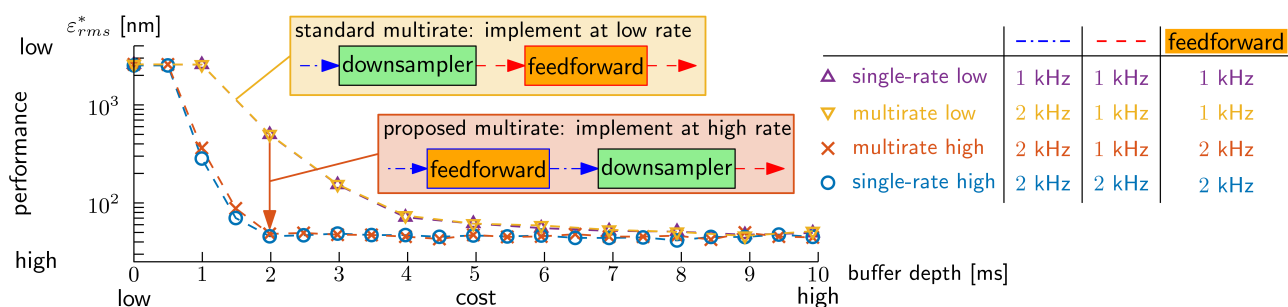
In this work, the design framework for multirate feedforward control [1] is validated through experiments on a dual-stage system. Recent developments in feedback control for LPTV systems are presented in [2].

## Experiments on a dual-stage system

The experimental setup of the dual-stage system is shown in Figure 1. Figure 2 shows the experimental results. The proposed approach *multirate high*, achieves high performance (similar to *single-rate high*) with limited cost since one of the feedback loops is evaluated at low rate.



**Figure 1** Experimental multirate dual-stage system with the part in blue at high rate (---) and the part in red at low rate (- - -). The objective is to minimize error  $\varepsilon^*$  through design of the **feedforward** controller.



**Figure 2** Experimental results showing performance versus cost and the advantages of multirate control.

## Conclusion

Multirate control may substantially contribute to improved performance and reduced implementation cost for systems with multiple control loops. The presented experimental results confirm this potential.

## References

- [1] J.C.D. van Zundert, J.L.C. Verhaegh, W.H.T.M. Aangenent, T. Oomen, D. Antunes and W.P.M.H. Heemels, "Feedforward for Multi-Rate Motion Control: Enhanced Performance and Cost-Effectiveness," In *Proceedings of the 2015 American Control Conference*, pp. 2831–2836, Chicago, 2015.
- [2] J. van Zundert and T. Oomen. "LPTV Loop-Shaping with Application to Non-Equidistantly Sampled Precision Mechatronics," *15th Int. Workshop on Advanced Motion Control*, pp. 467–472, Tokyo, 2018.