Exercise 7

Optimal disturbance rejection and tracking

1. Open the Sysquake file `ex7.sq` in Sysquake. The plots show closed-loop pole placements for the two systems

$$G_1 = \frac{\mathrm{q}^{-1}}{1-\mathrm{q}^{-1}} \qquad G_2 = \frac{1.1\mathrm{q}^{-1}}{1-0.9\mathrm{q}^{-1}}$$

   their output sensitivity functions and corresponding time responses. A sawtooth reference should be tracked, despite modeling error (both models should track the reference with the same controller). In the **settings** menu, it is possible to select fix factor R_f in the pole placement polynomial equation and D in the polynomial equation for the tracking design (T polynomial). By default, $R_f = 1$ and $D = 1 - \mathrm{q}^{-1}$ which means that a P-controller is used and T is adjusted to track step changes. Since the reference consists of piecewise ramps, the tracking design is not adequate. Change to $D = (1-\mathrm{q}^{-1})^2$, i.e. type in $[1, -2, 1]$ in the settings menu. Notice that if you click on the red or blue pole the T-design is made on the first or second model, respectively. Thus, either the red or the blue response will track without error.

2. Select, for example, the Sensitivity plot window and change in **Plots** to *Preview action*. Try different preview design to see how the transients can be smoothed.

3. Write in the command window

```
global d
d=5*ones(1,18);
```

   Then click in, for example, in the Closed-loop poles window which will now make d entering as an input disturbance. The tracking will now be biased since the controller is not designed for elimination of a constant disturbance. Change in the settings $R_f = 1 - \mathrm{q}^{-1}$ ($[1, -1]$). Is the bias error eliminated?

4. Change instead the disturbance to be a ramp as

```
d=1:18;
```

   Click in Closed-loop window to introduce the change. Verify that the ramp-like disturbance is eliminated (after transients) if $R_f = (1-\mathrm{q}^{-1})^2$, but not if $R_f = 1 - \mathrm{q}^{-1}$.

5. Remove the disturbance

```
d=zeros(1,18);
```

   Select Preview time to 1 and try repetitive design. Change D to $1 - q^{-18}$ ($[1, zeros(1, 17), -1]$). The reference should now be tracked without error (for the model the feedforward-design of T is based on).

6. Change also the feedback design for robust tracking, i.e. eliminate the model mismatch by choosing the fixed factor $R_f = 1 - q^{-18}$ ($[1, zeros(1, 17), -1]$). Change the *Preview action* plot back to the *Sensitivity* S_y which will be needed for robust pole placement. Move poles more inside the unit circle to achieve good damping at all frequencies and try to achieve as fast robust tracking as possible.

7. Add a periodic disturbance again and verify that this is removed by the repetitive design. Take e.g.

```
d=1:18;
```

   Click in Closed-loop window to introduce the change.