Alternative Control Topology for ISC

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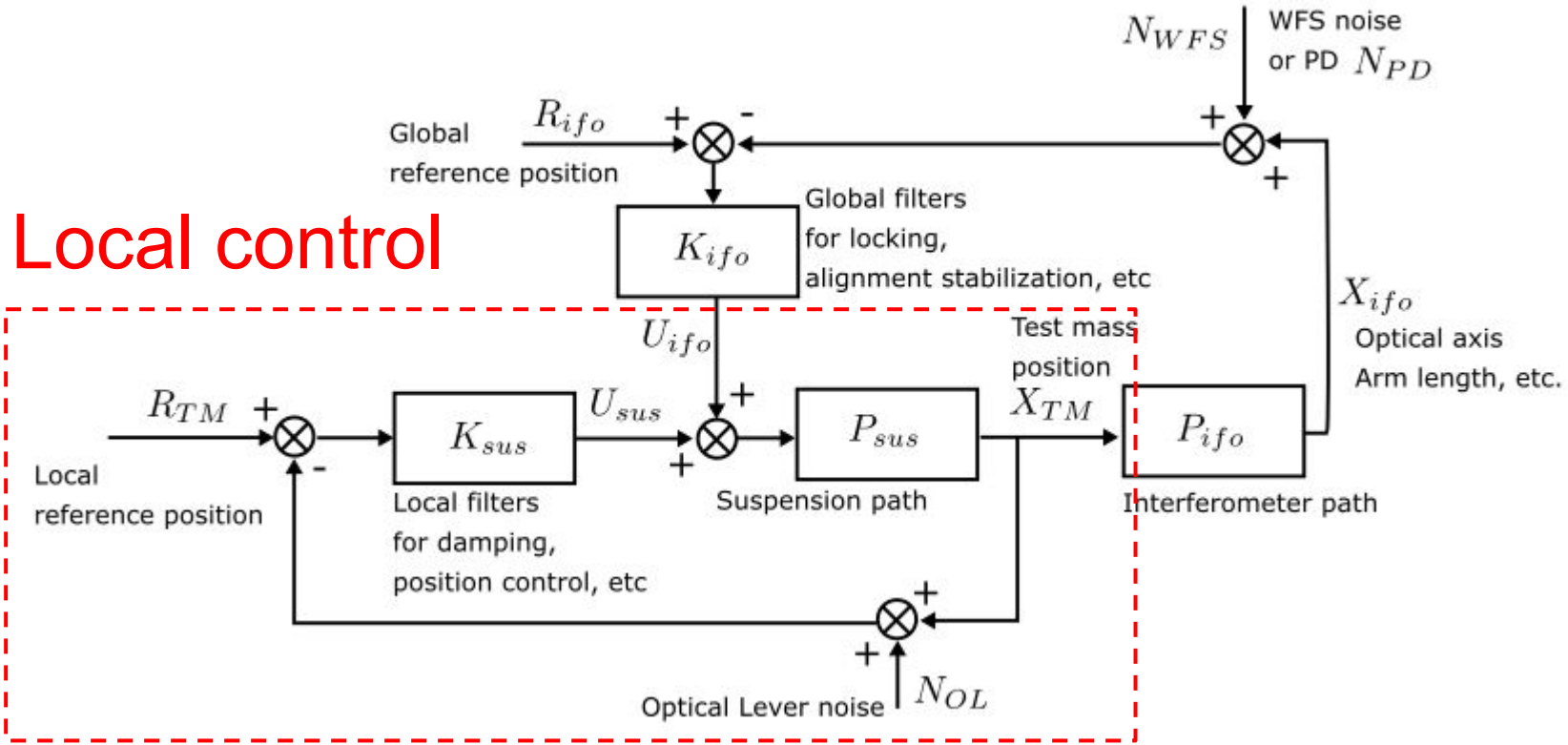
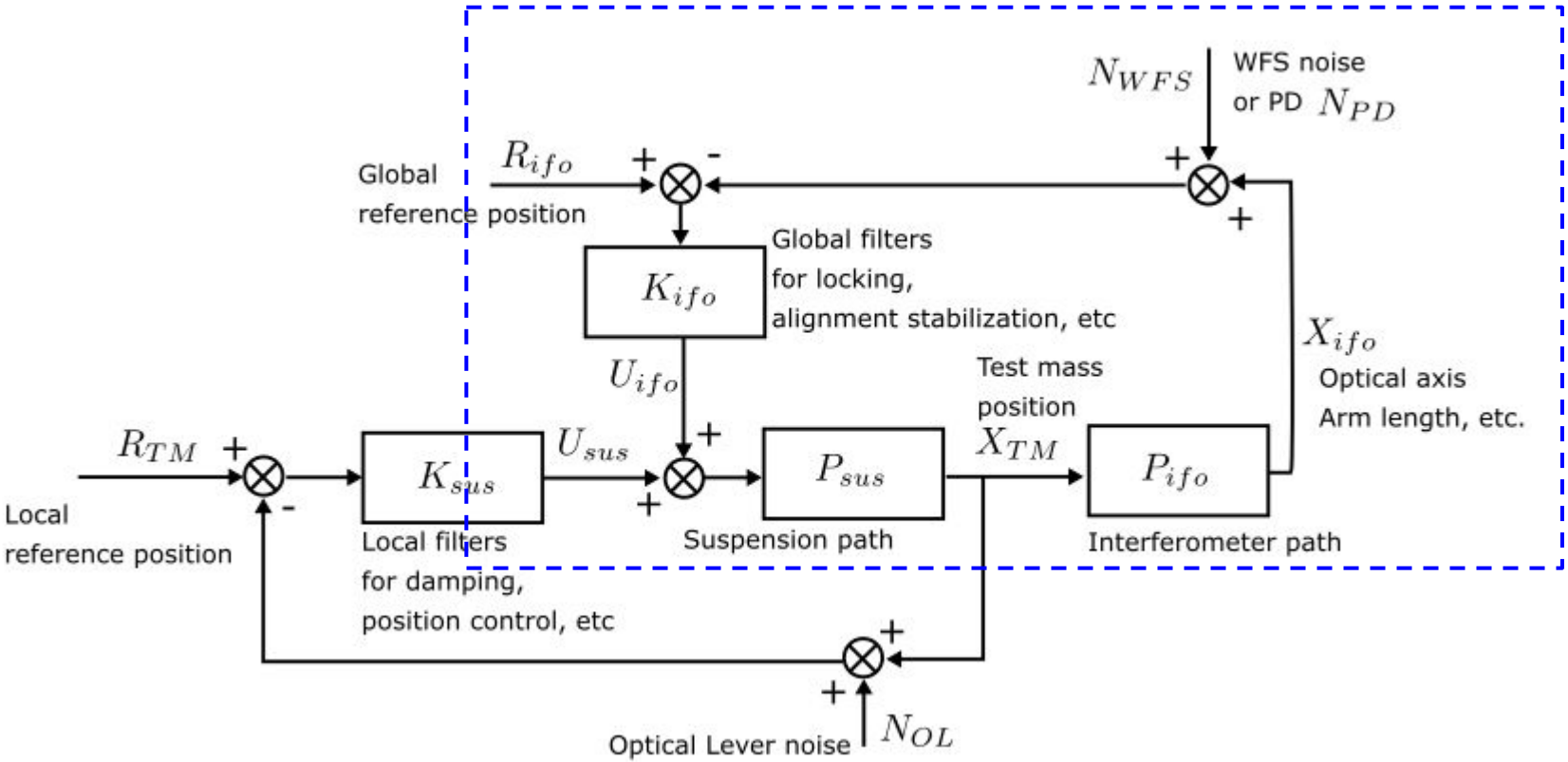
Current Control Topology



Current Control Topology

Global control

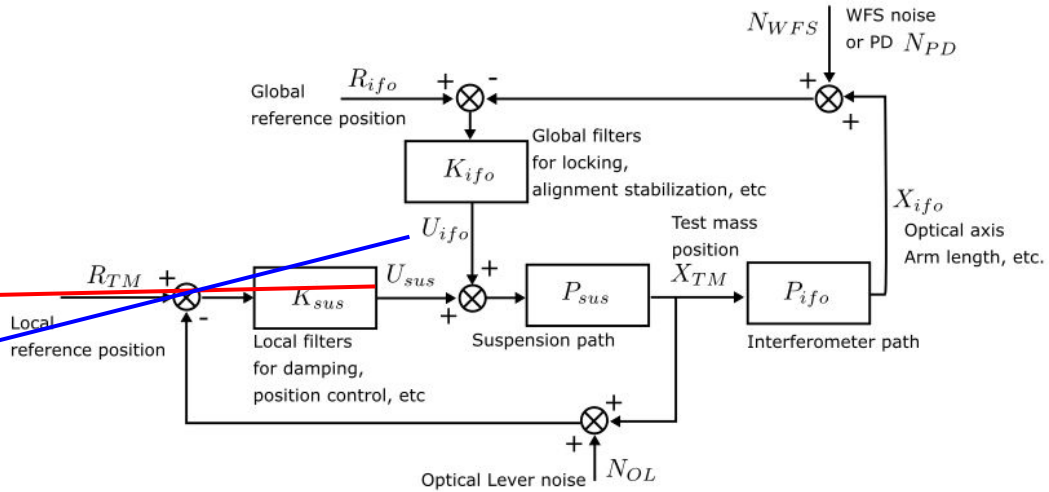


Potential Issues/limitations

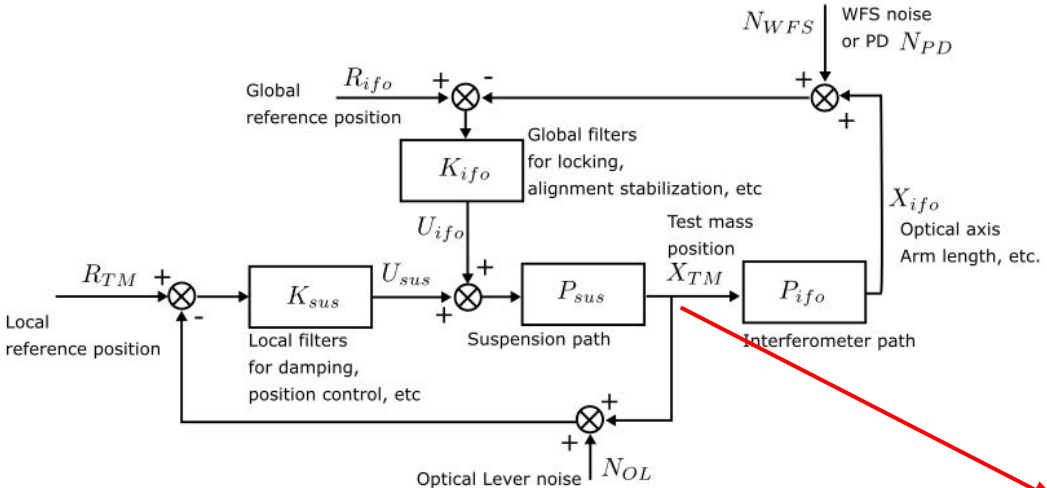
If the two controllers are integrators and the plants are constants (for demonstration), then the controller outputs will explode as the global loop closes, regardless of the stability.

$$\lim_{s\to 0} sU_{sus} = \lim_{s\to 0} s\,(K_{sus}/s)\,(R_{TM} - X_{TM})$$
$$= \lim_{s\to 0} \frac{K_{sus}}{s}\left(\frac{R_{TM}s + K_{ifo}P_{ifo}P_{sus}R_{TM} - K_{ifo}P_{sus}R_{ifo}/s}{1 + K_{sus}P_{sus}/s + K_{ifo}P_{ifo}P_{sus}/s}\right)$$
$$= -\infty,$$

$$\lim_{s\to 0} sU_{ifo} = \lim_{s\to 0} s\,(K_{ifo}/s)\,(R_{ifo} - X_{TM}P_{ifo})$$
$$= \lim_{s\to 0} \frac{K_{ifo}}{s}\left(\frac{R_{ifo} + K_{sus}P_{sus}R_{ifo}/s - K_{sus}P_{sus}R_{TM}P_{ifo}}{1 + K_{sus}P_{sus}/s + K_{ifo}P_{ifo}P_{sus}/s}\right)$$
$$= +\infty.$$



Potential Issues/limitations



$$\lim_{s\to 0} sX_{TM} = \lim_{s\to 0} \frac{K_{sus}P_{sus}R_{TM} + K_{ifo}P_{sus}R_{ifo}/s}{1 + K_{sus}P_{sus}/s + K_{ifo}P_{ifo}P_{sus}/s} = \frac{K_{ifo}P_{sus}R_{ifo}}{K_{sus}P_{sus} + K_{ifo}P_{ifo}P_{sus}},$$

Unwanted attenuation

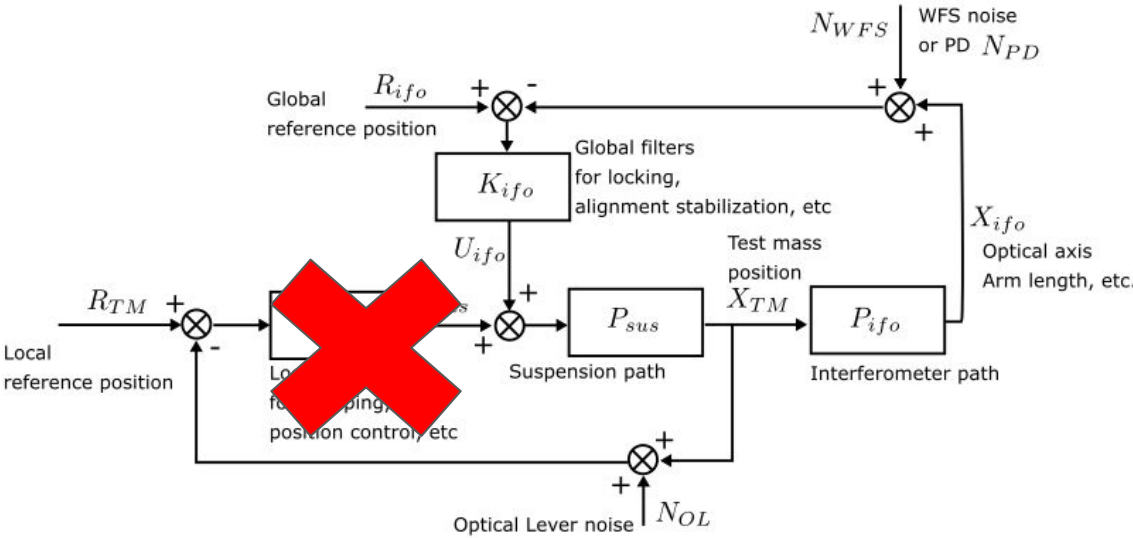
Even if we can handle those huge values of controller outputs, the control is still imperfect, as the interferometer degrees of freedom is cannot be controlled to the targeted position.

Potential Issues/limitations

As we can see, some local controls can be incompatible with the global control. So they have to be disabled during the take-over.

Since incompatible local filters have to be disabled during the take-over of the global control, this leaves a window where the suspension is susceptible to external disturbances which is a potential weakness of this scheme.

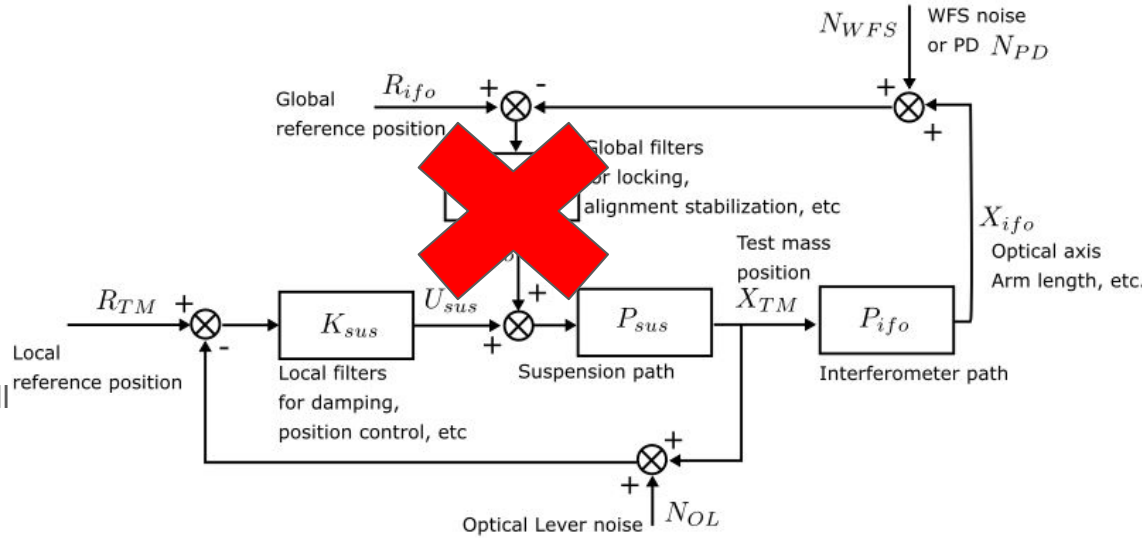
And because some local controls are disabled, the susceptibility may persists even after the take-over.



Potential Issues/limitations

As we can also see in the integrator example, the two control output signals complements (summed) to give an overall plausible actuation signal to the suspension which locks/aligns the interferometer.

However, if the global loop is, for some reason, suddenly disengaged or changed, the sudden change in the overall actuation signal will become a kick to the suspension which will cost additional calm down time.



Short summary

The current topology is prompt to at least four errors:

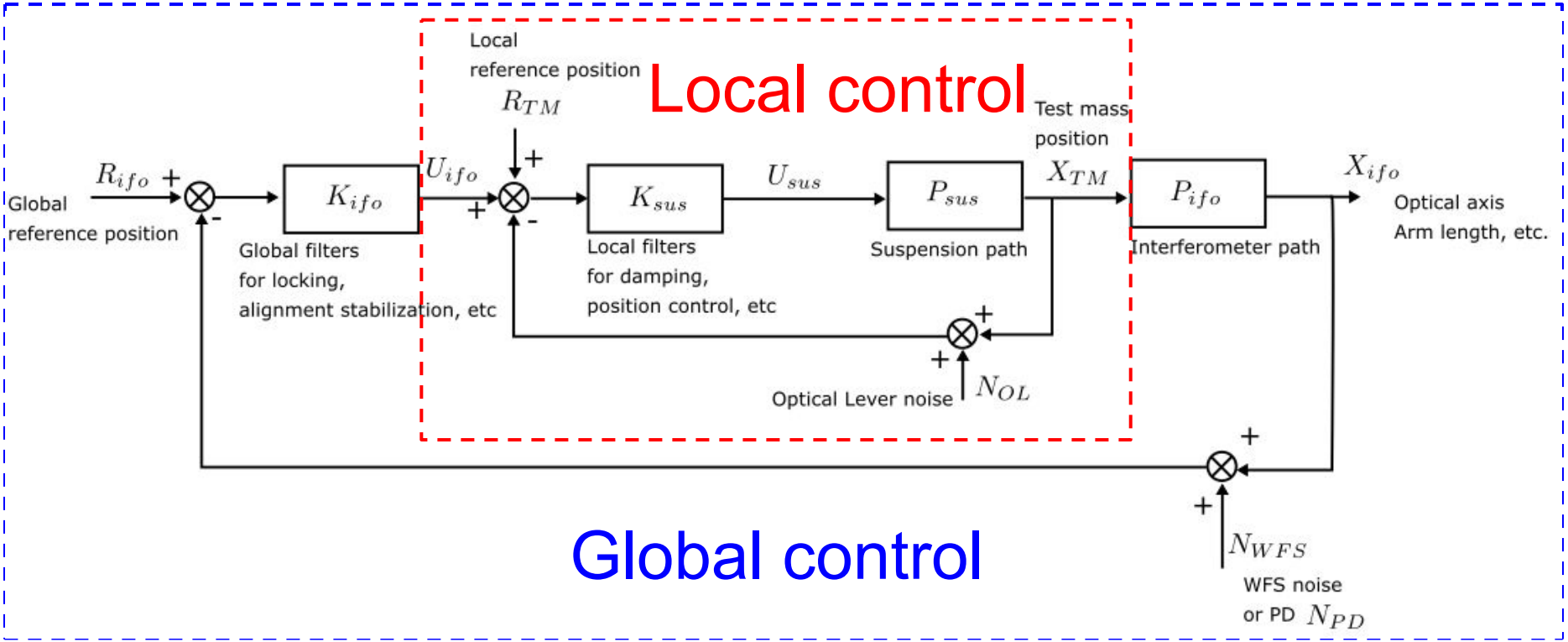
1. Individual controller outputs can be excessively high
2. Attenuated global/local control performance
3. Susceptible to additional disturbances due to disengaging local control
4. Kick of the suspension due to disengaging global control

Alternative topology

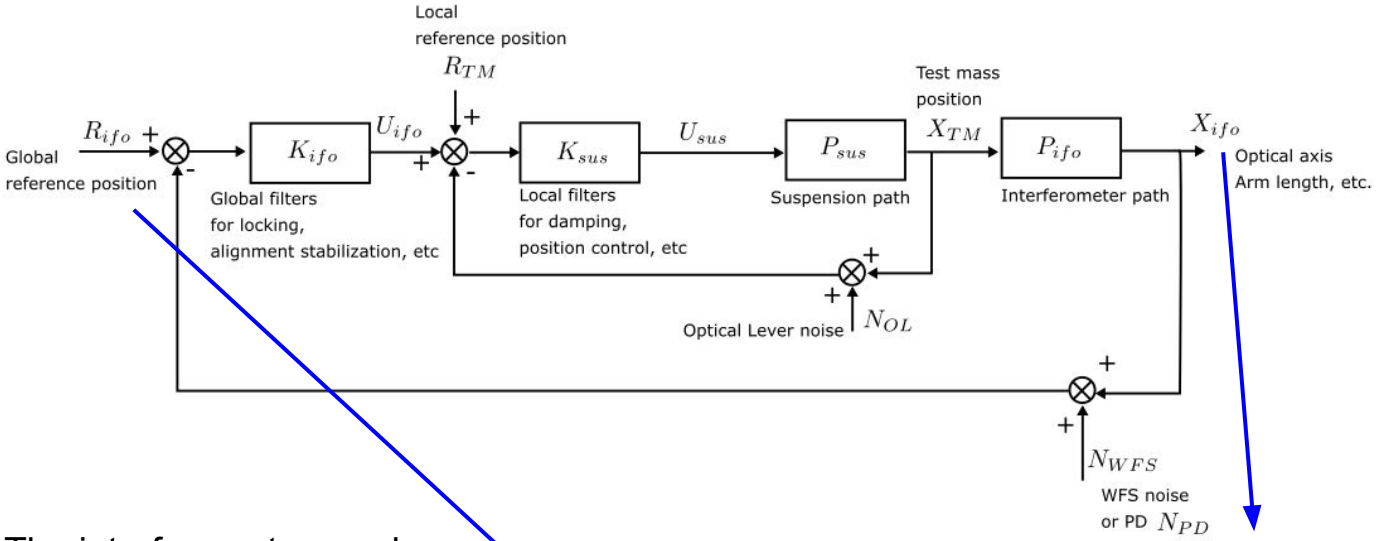
The causes for those adverse effects results from the fact that the local and global controllers are receiving conflicting tracking error, as in, they are trying to accomplish conflicting goals.

So, it would be nice if the controller objectives are synchronized and we can do so by feeding back the global controller output signal to the error signal of the local control.

Alternative topology



Alternative topology



Same analysis as before, double integrators, with plants as constants.

The interferometer can be controlled, regardless of the local reference.

$$\lim_{s\to 0} sX_{ifo} = \lim_{s\to 0} \frac{R_{ifo}K_{ifo}K_{sus}P_{sus}P_{ifo}/s^2 + R_{TM}K_{sus}P_{sus}P_{ifo}}{1 + K_{sus}P_{sus}/s + K_{sus}P_{sus}K_{ifo}P_{ifo}/s^2}$$

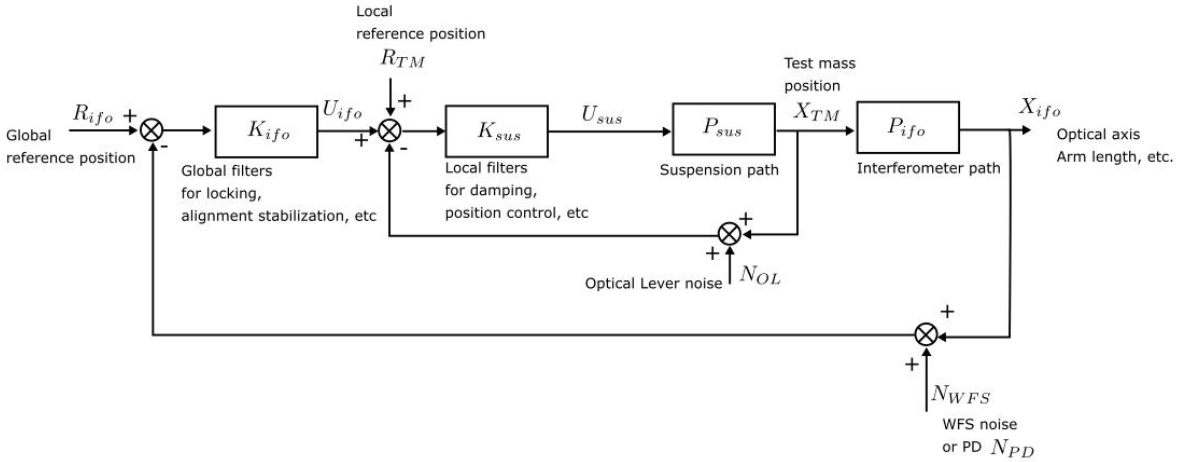
$$= R_{ifo},$$

Alternative topology

In this case, all process/manipulating variables are finite.

The errors signals are both minimized, i.e. the controllers are not in conflict.

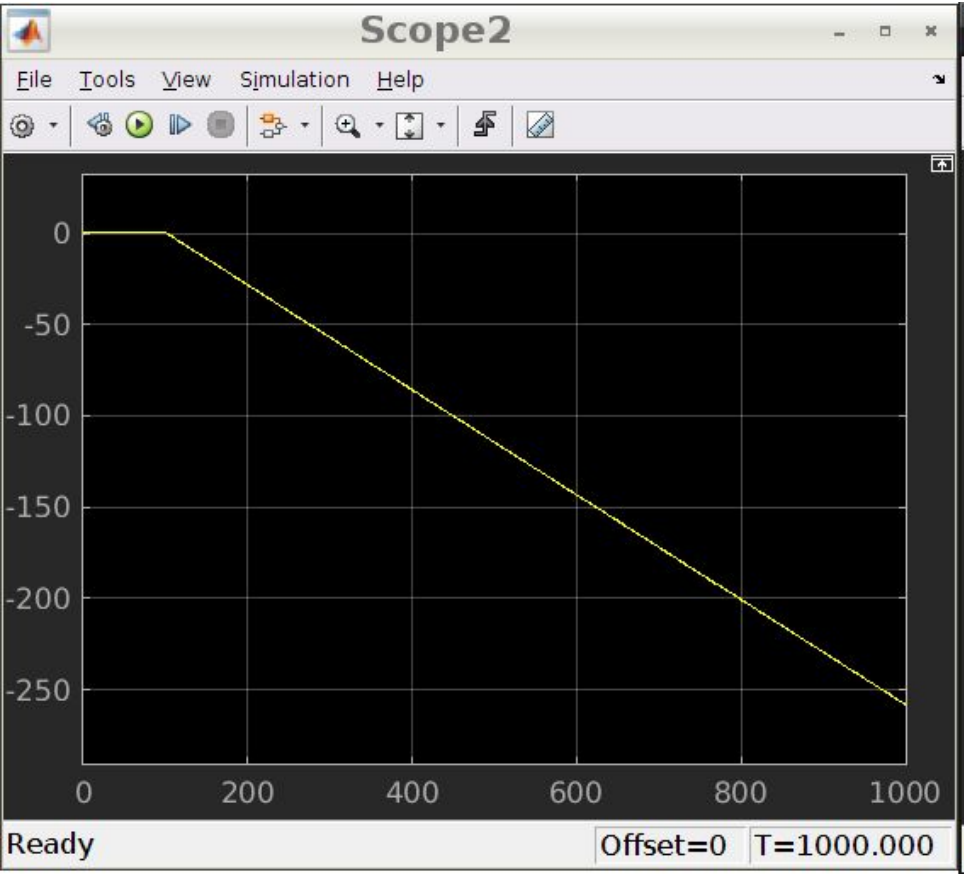
Transition between local and global control is smooth as the local controls are always closed, while the presents/absence of the global loop only changes the setpoint of the local loop.



Limitation

The only limitation of this approach is that the local control must have non-zero gain (high enough) at frequencies where global control is needed.

Questions, comments.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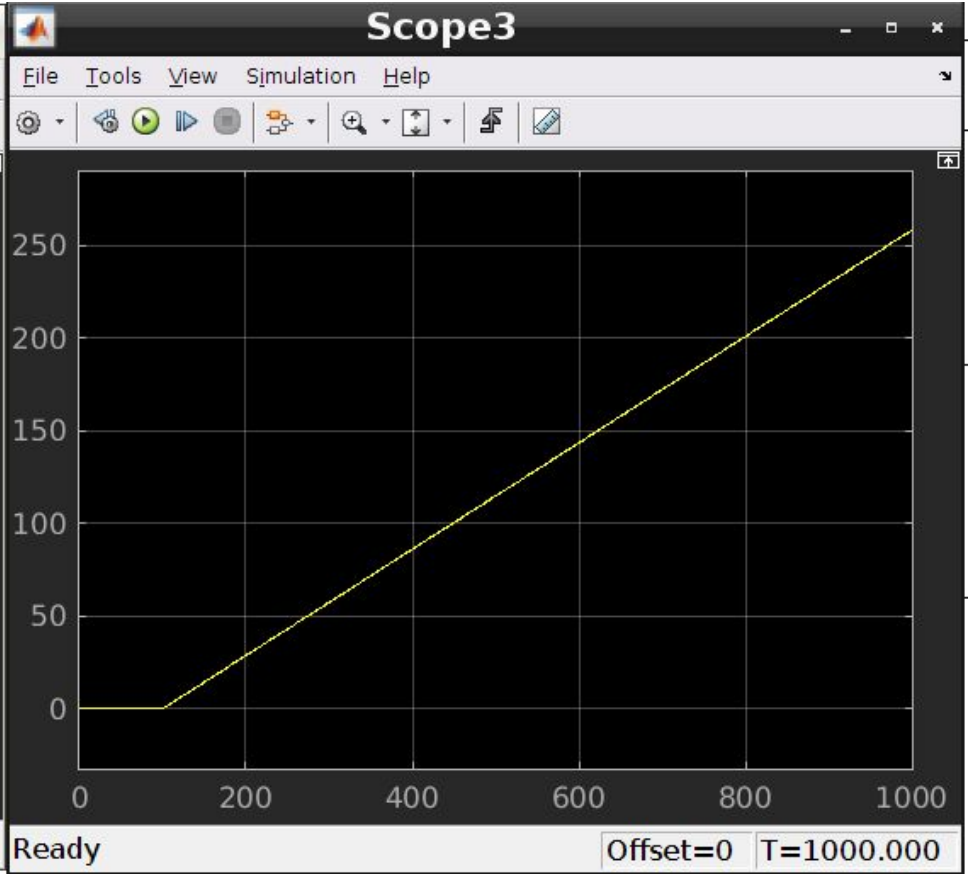
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