Automation of the ISS second loop: issues and mitigations

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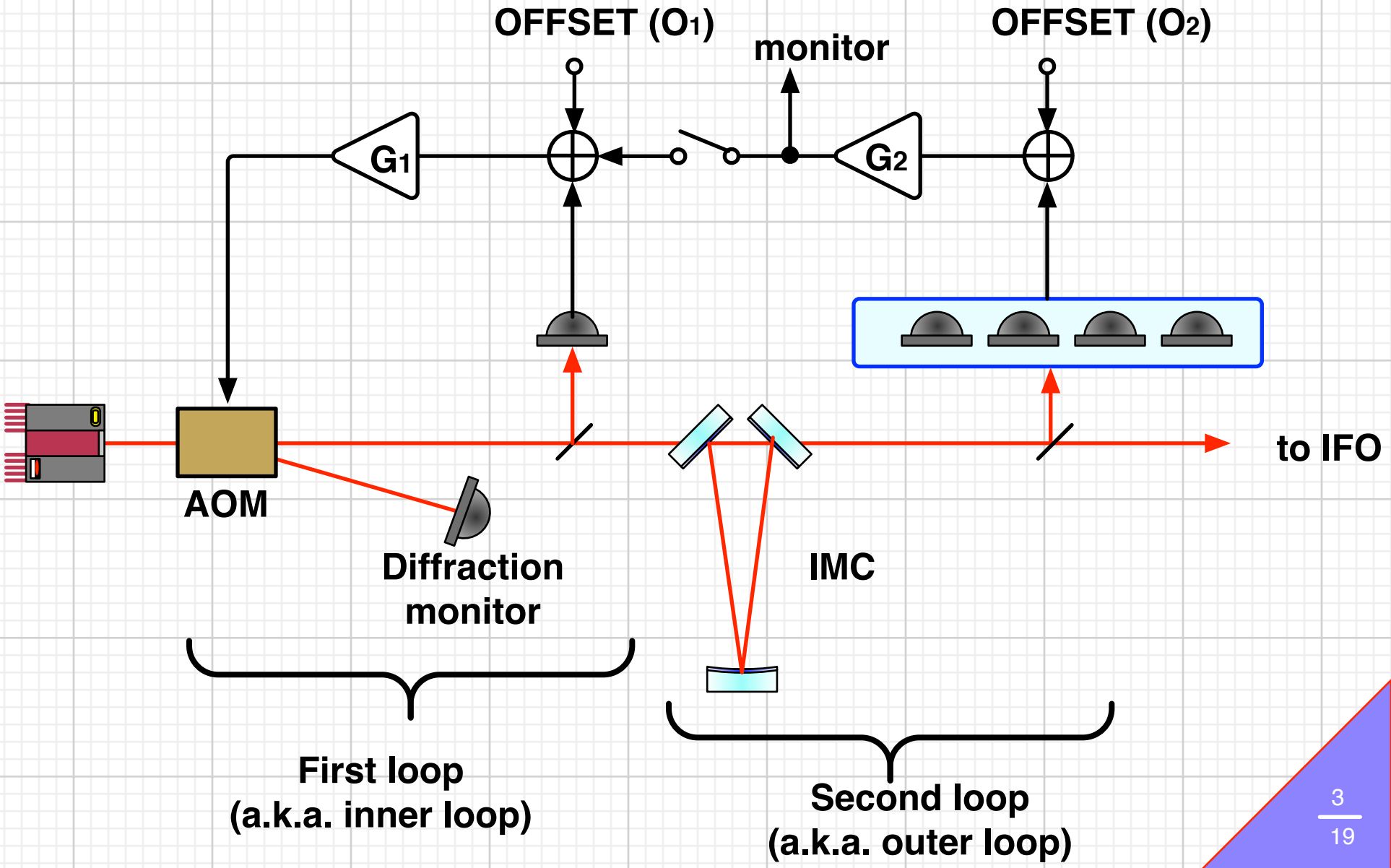
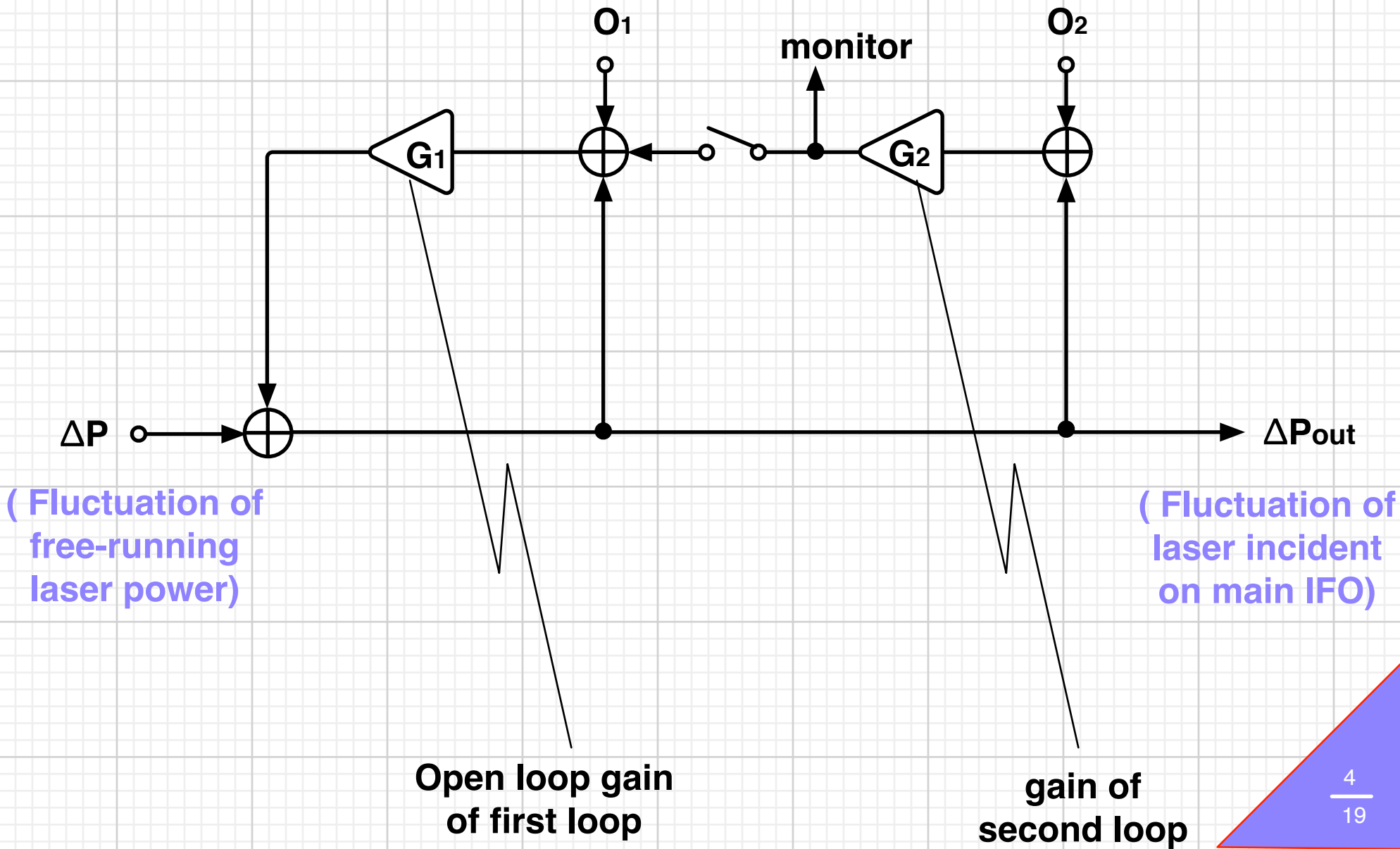
Some basics

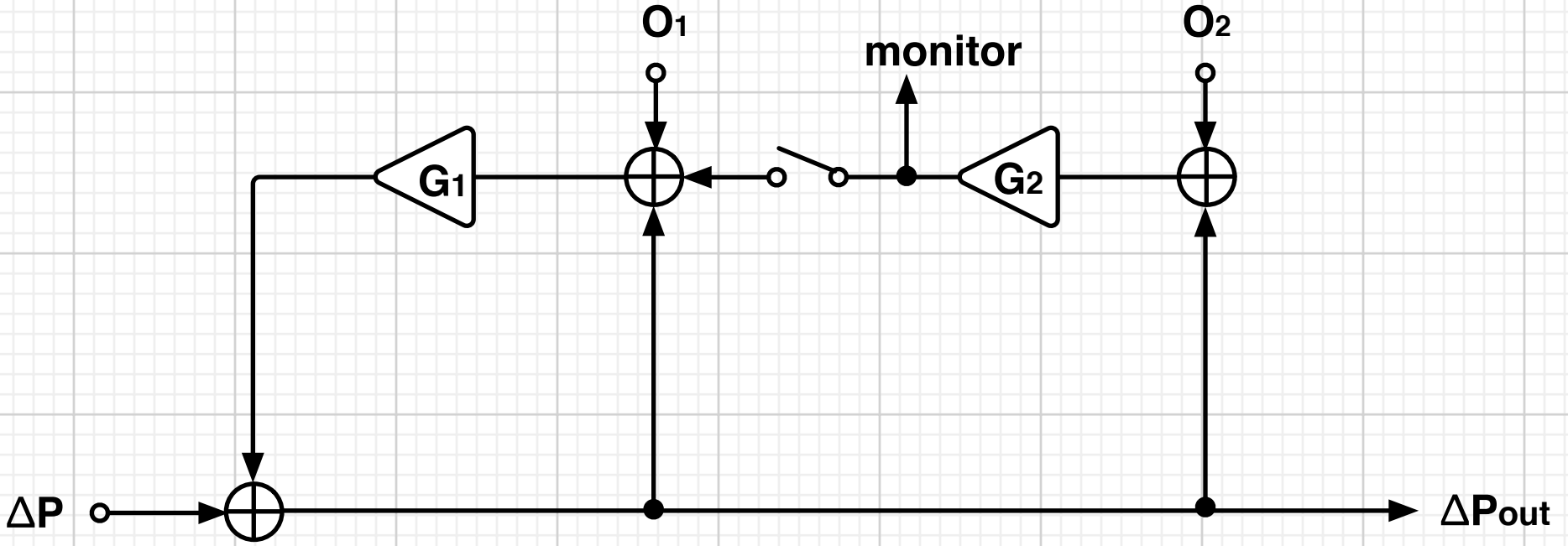
Experimental layout



in Block diagram



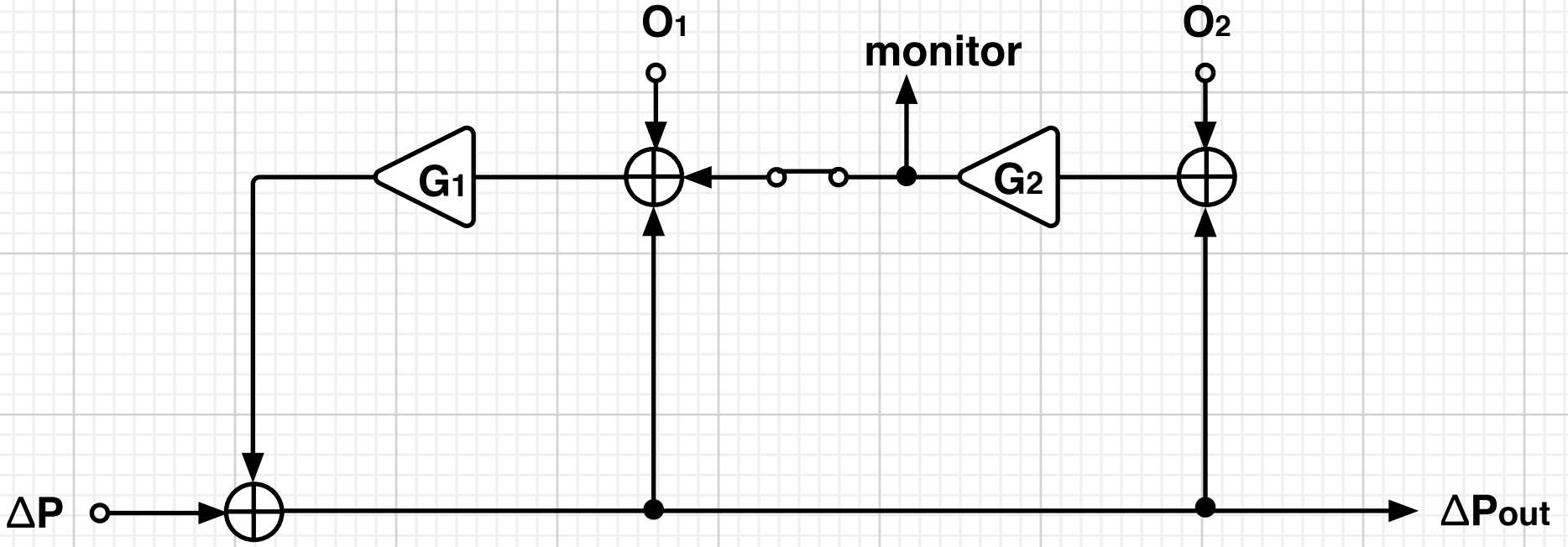
Only with first loop



$$\Delta P_{out} = \frac{\Delta P}{1+G_1} - \frac{G_1}{1+G_1} O_1 \approx -O_1$$

This means:
one can change the amount of the DC power incident on PRM by changing O1 (the artificial offset). No surprise.

With second loop



$$\Delta P_{out} = \frac{\Delta P}{1 + G_1 + G_1 G_2} - \frac{G_1}{1 + G_1 + G_1 G_2}(O_1 + G_2 O_2) \approx -O_2$$

This means:
once second loop is closed, O2 takes over the control of the DC offset (assuming G2 >> 1).

Trick

√ **Closing second loop changes the offset of the output laser from O1 to O2.**

=> introduces a transient. If too large, it unlocks the main IFO.

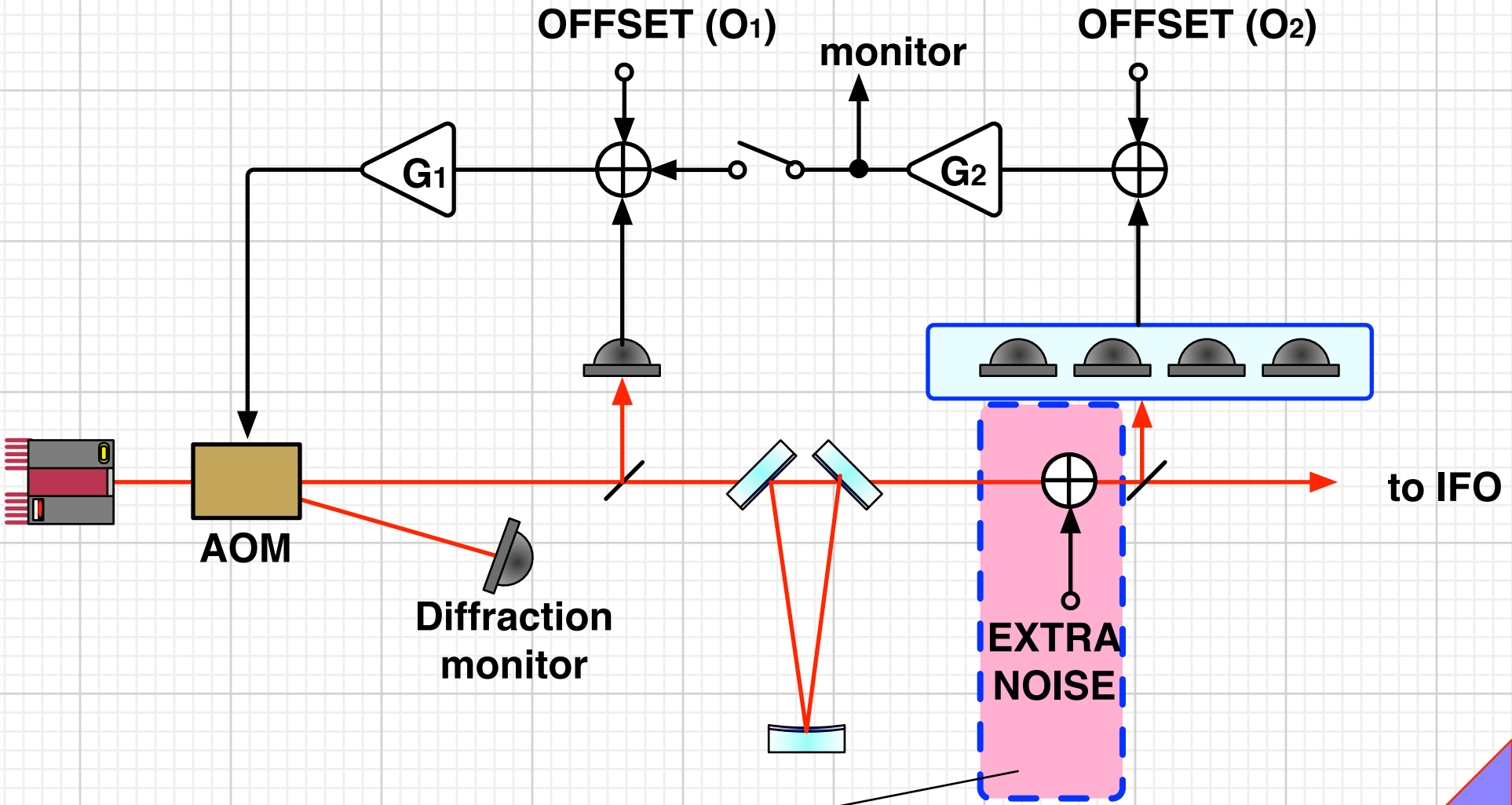
√ **To reduce the size of transient, O2 needs to be set properly before closing second loop.**

√ **Rule of thumb for reducing transient:**
Set O2 without closing second loop so that the monitor reads near zero.

√ **This works fine in an ideal situation.**

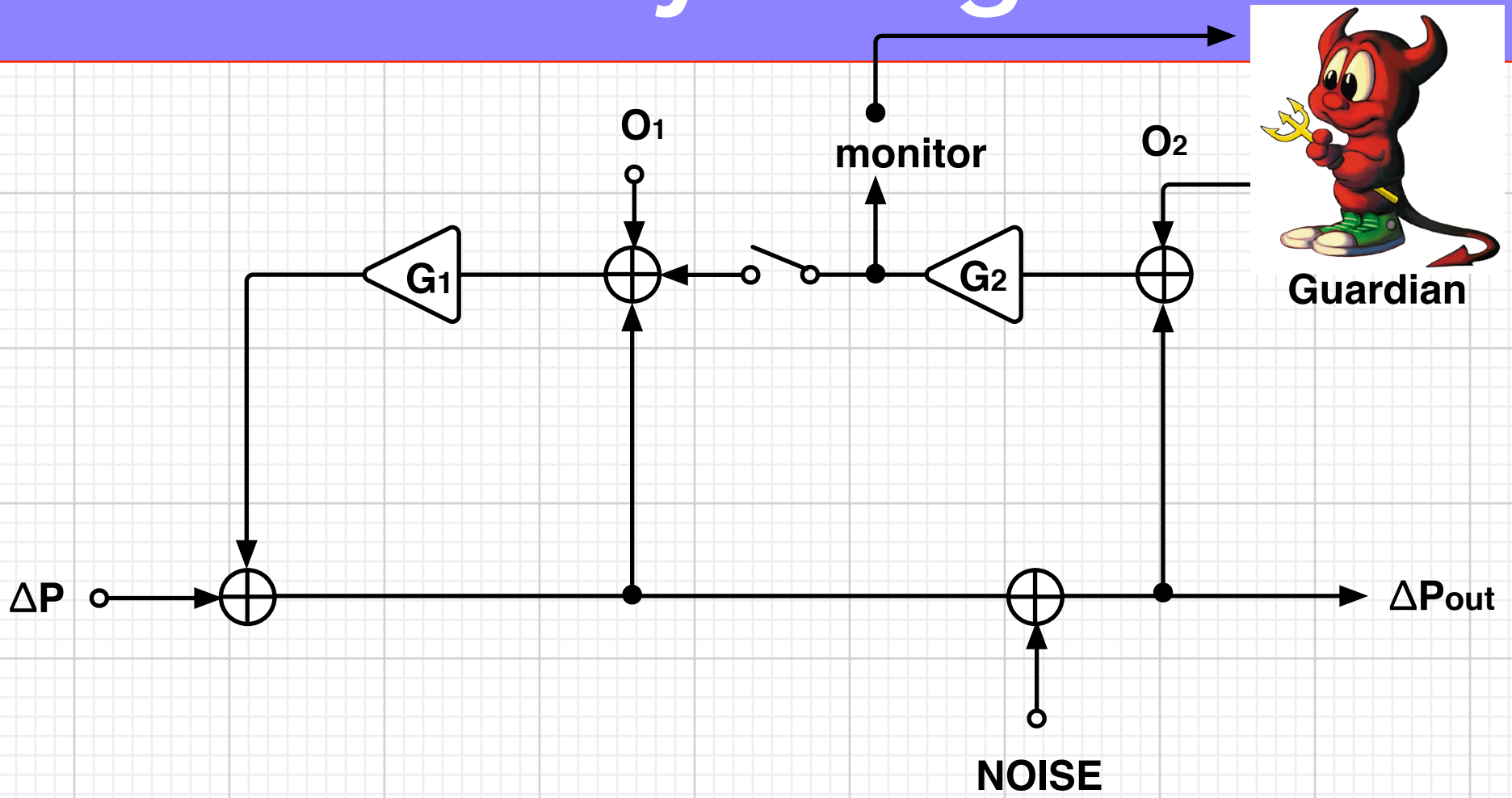
Issue (at LHO)

In reality



Due to angle-to-power coupling of the IMC mirrors.
Significant below 1 Hz.

Preliminary mitigation



A guardian code continuously updates O2 in order to keep up with the IMC noise when closing second loop. This worked fine when seismicity was low.

Guardian was not sufficient

When high seismic, guardian was not able to properly set O2.
It could not keep up with fast deviation by the extra noise.

√ **Guardian is not a fast process (limited control speed)**

√ **Designing and implementing multiple poles and zeros as a control filter in guardian is not straightforward.**

During the first observation run:
Operators manually closed second loop by pressing a button when the monitor signal momentarily read near zero [1]. Sad.

[1] LHO alog 22449 https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=22449

Recent mitigations

Help from fast digital system

We proposed using the digital front end system which can overcome the weak points of the guardian.

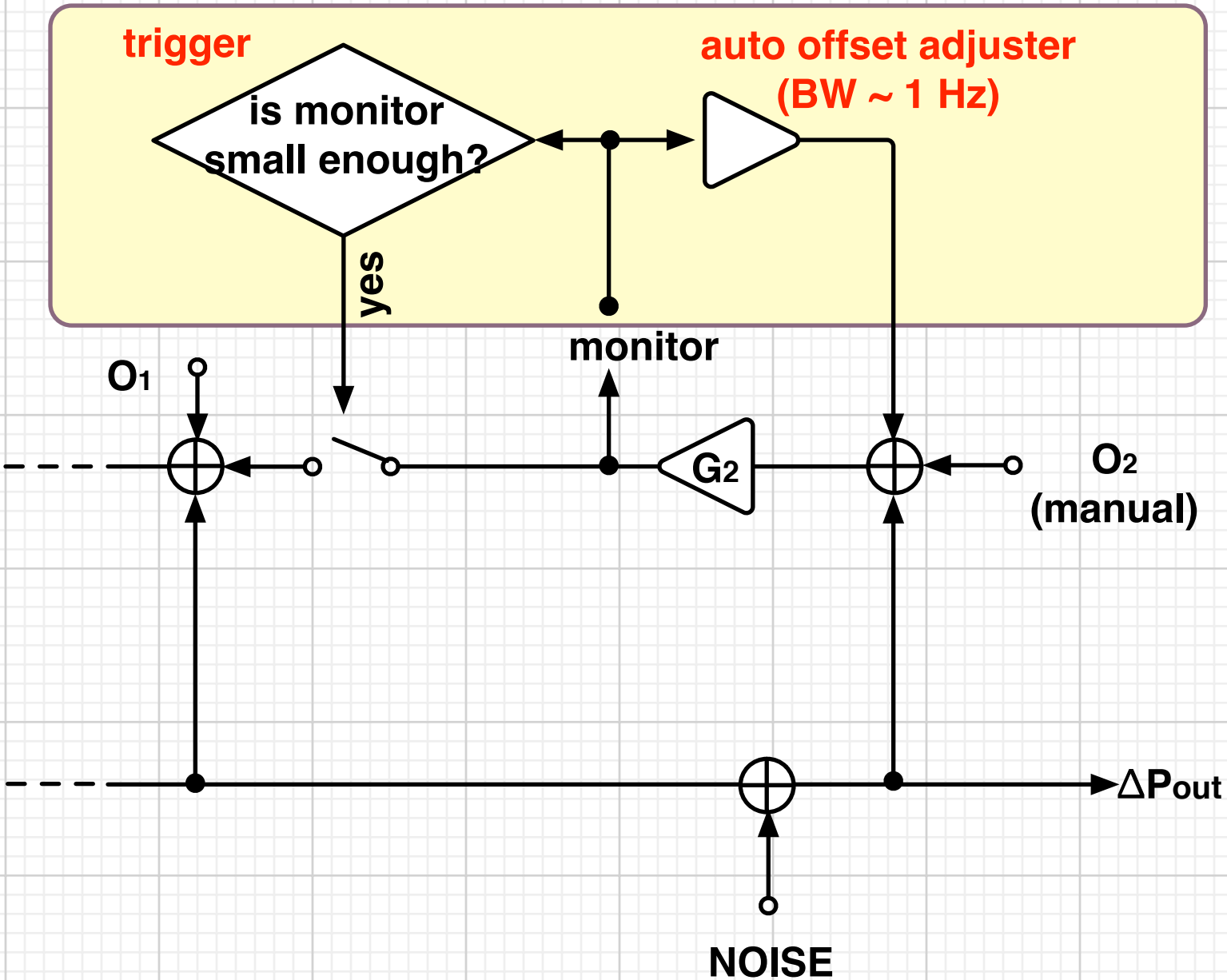
With the digital system, we should be able to....

√ **Implement a fast control**
(we wanted achieve a UGF higher than ~ 1 Hz or so).

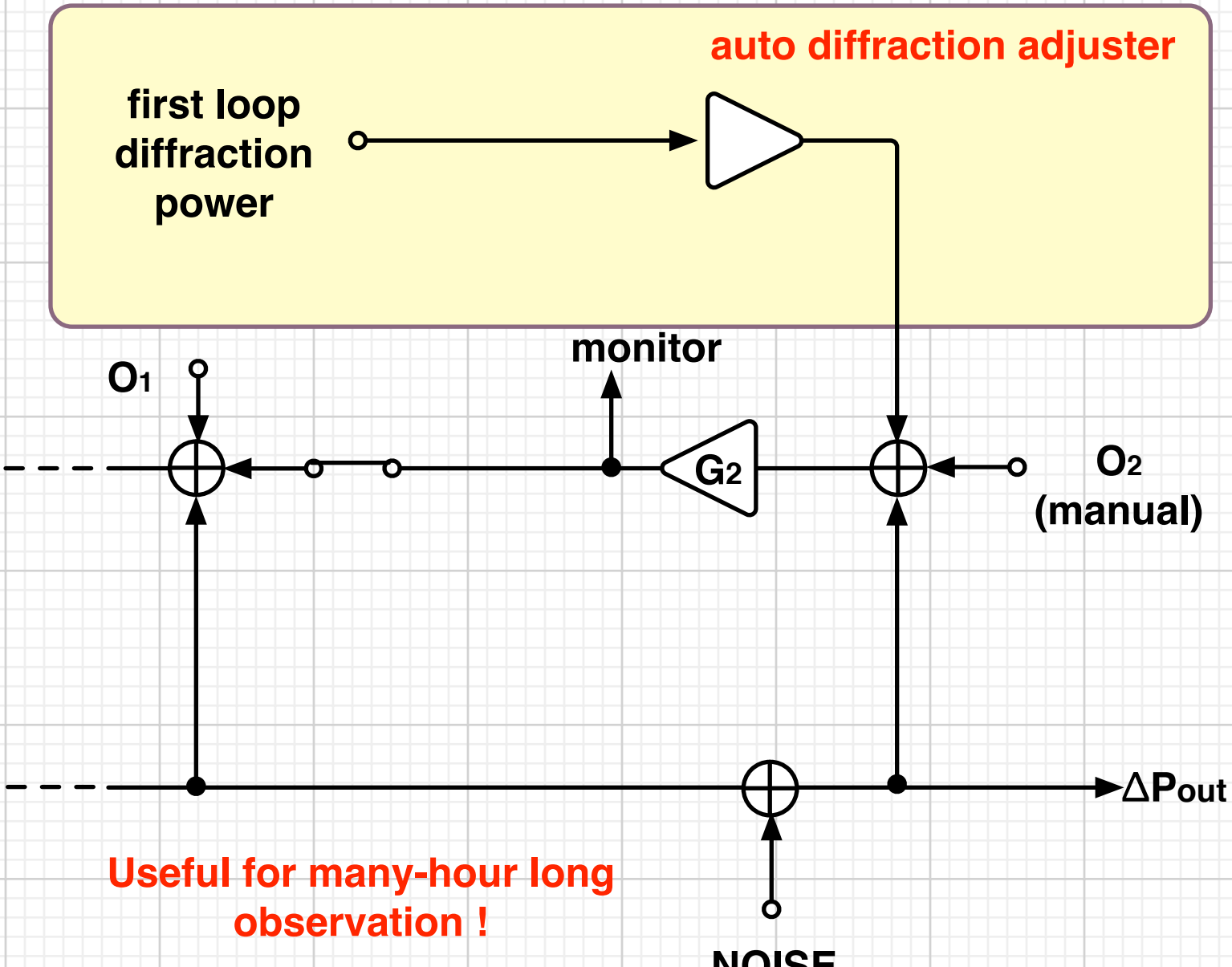
√ **Design and implement complicated frequency response.**

√ **Close second loop with an automatic trigger logic.**

The implementation

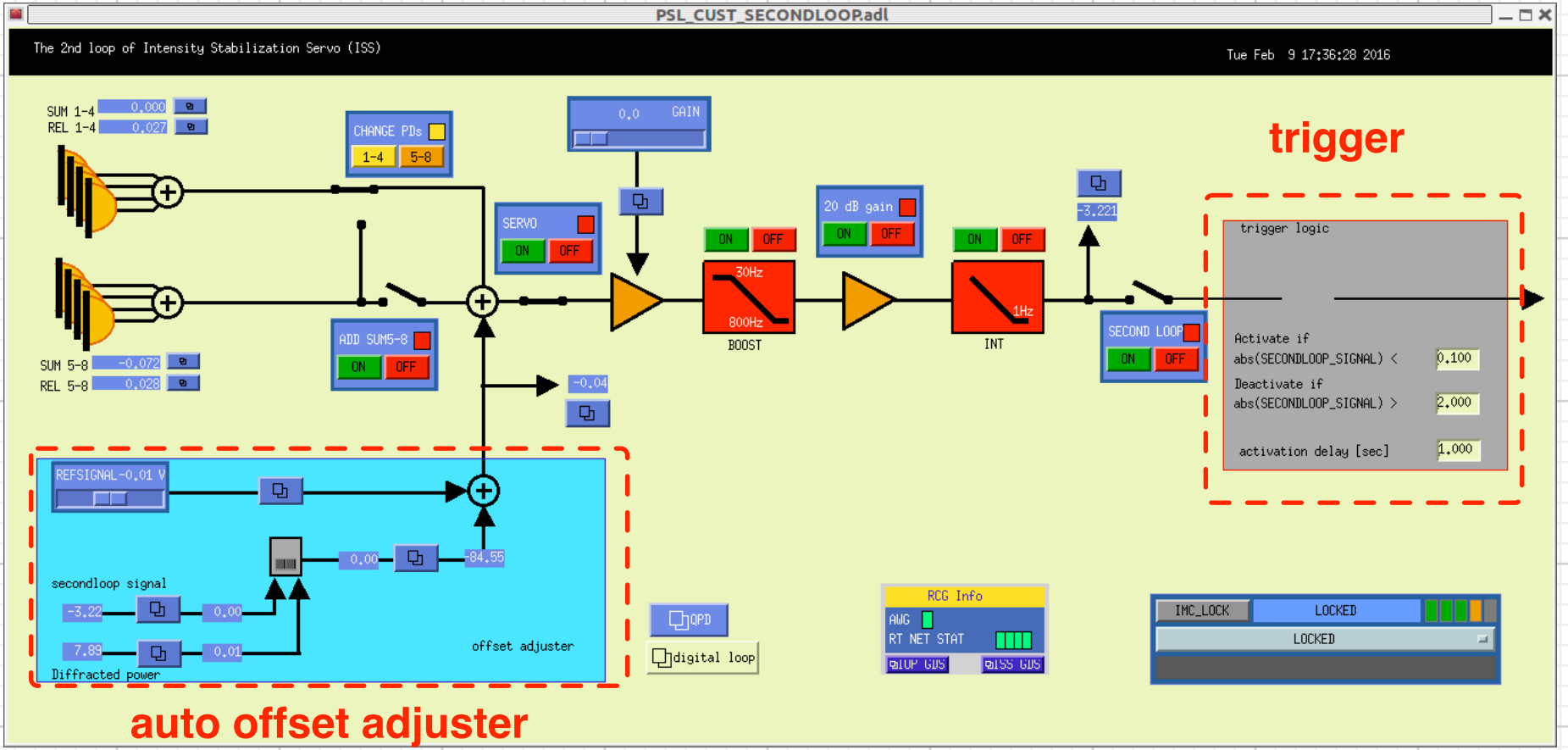


A bonus: when closed



Useful for many-hour long observation !

New screen



[1] LHO alog 25473 https://alog.ligo-wa.caltech.edu/aLOG/index.php?callRep=25473

An issue

√ **Auto adjuster's parameters are set specifically for 20 W PSL power.**

=> may not properly work when low-power commissioning mode

A solution:

A smart normalization, for example using the PSL output power.

Summary

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- √ **Closing ISS introduces transient**
- √ **The offset in second loop (O2) needs to be adjusted before closing the loop.**
- √ **Guardian was not sufficient to automatically and continuously adjust the offset.**
- √ **LHO implemented the fast servo and trigger logic in the digital front end system.**
- √ **So far it seems much better.**
  The loop closes automatically and therefore no more human intervention is required.