Smooth Ramp for Isolation Turnoff

Dane Stocks
Brian Lantz

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1 Summary

This document explains the function and implementation of the library part CUSHION_DOF in both the isihammaster and isi2stagemaster models. The library part uses a smooth polynomial function to ramp the isolation loop signal to zero when the watchdog trips. For a derivation of the ramping function this part uses in modified form, see technical note LIGO-T1300510-v2. An image of the library part appears in Figure 1.

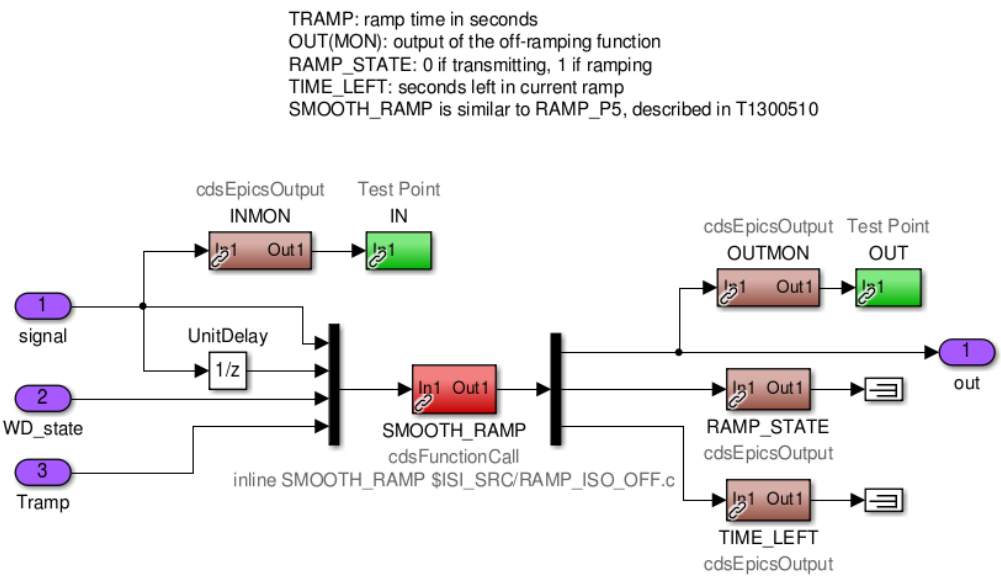


Figure 1: Simulink diagram of CUSHION_DOF.

The loop signal from a specific DOF, the integer state of the watchdog system, and a user-specified ramping time called TRAMP are read in by the part. The only out value of the part is the output of the ramping function, but it keeps track of when it is ramping through the RAMP_STATE variable, as well as how much time is left in a single rampdown through TIME_LEFT. This information is read out to the user through associated MEDM screens.

The C code of this part uses the following logic:

1. The ramping function checks to see if a ramp is currently running. If this is true, the ramp increments until TRAMP elapses and the loop signal reaches zero.

2. If a ramp is not running, then the function checks to see if the watchdog state variable has changed from 1 to 2 over the last cycle.

   (a) If this is the case, a new ramp is started; based on the user-specified TRAMP (with the enforced condition that this value is between 0 and 20 seconds), the ramp coefficients are calculated and RAMP_STATE is changed to RAMPING.

   (b) If the watchdog state variable has not changed from 1 to 2 in the last cycle, then the ramping function sets its output to the input signal it received. In other words, it acts as a wire.

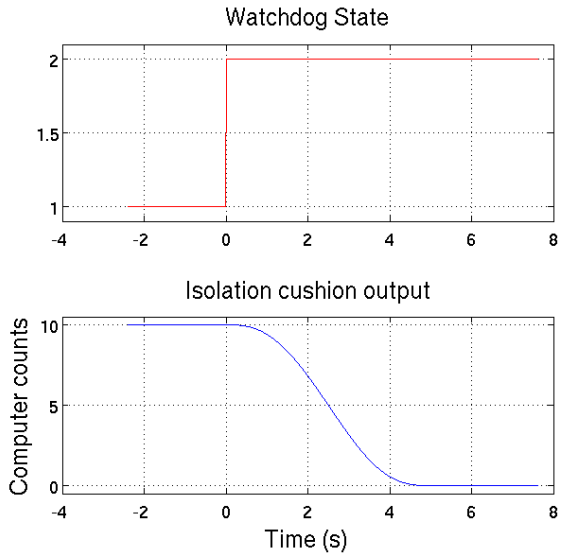
3. The cycle ends and the logical process begins again. Note here that if a rampdown has completed and the watchdog has not been reset, a new ramp will not begin. The watchdog system must be manually reset (state 1) to allow for a trip to begin a new ramp.

Letting the ramp begin with the velocity of the actuator signal when it trips is not advisable since, when the actuator trips the watchdog as shown in Figure 5, the drive signal is increasing rapidly, which is not good and has prompted the watchdog trip. Instead, we start the ramp with the current actuator force and bring it smoothly to zero. A sharp change in the slope of the actuator signal does not equate to a sharp "impulse" felt by the stages, as the actuator signal represents a "force" and this value is not changing when the ramp begins.

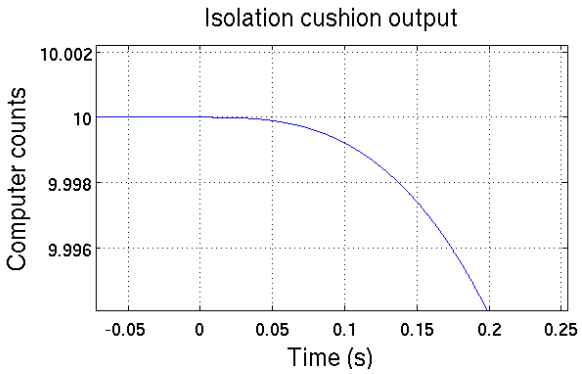
2 Testing

2.1 Manual test

A brief example demonstrates how CUSHION_DOF works. In this test, the input signal from one isolation loop DOF was fixed at 10 arbitrary computer counts. With TRAMP chosen to be 5 seconds, the watchdog state variable was manually changed from 1 to 2 at time $t_0 = 0$. Figure 2 shows SMOOTH_RAMP using the polynomial spline to ramp the signal down from 10 to 0 in a period of 5 seconds. (Note that the reason the output value stays at 0 is because the constant input value was changed to 0 during the rampdown.)



(a) The rampdown begins the same cycle the WD trips.



(b) A zoomed-in view of the beginning of rampdown.

Figure 2: Results of a manual test of CUSHION_DOF. TRAMP was chosen to be 5 seconds, and the WD state variable was changed from 1 to 2 at $t_0 = 0$, creating a rampdown.

2.2 Test in s1isihamx

After the manual test, a new sub-block was created in the s1isihamx Simulink model to apply the smooth ramp function to each of the six DOFs contained in the isolation pathway. This sub-block is named ISORAMP and Figure 3 shows its place in the larger flow of the s1isihamx model. To test whether the ramp functions as expected in practice, we examined the behavior of the X DOF isolation signal in the event of a watchdog trip. The signal was set to a constant 10 computer counts, and TRAMP was set to 10 seconds. Instead of manually changing the WD state variable, we tripped the HAMX WD system from the main isolation controller MEDM screen. The results, shown in Figure 4, confirm that CUSHION_DOF functions as expected.

2.3 Test using H1 trip data

The idea of low-passing the actuator signal before beginning the rampdown was suggested, but this approach is not ideal. We found that low-passing can generate a large change in the signal value before the ramp begins—this produces an unwanted impulse on the stages. Figure 5 shows results of testing both a low-passed ramp and the original ramp. We conclude it is best to not low-pass the drive signal before ramping down.

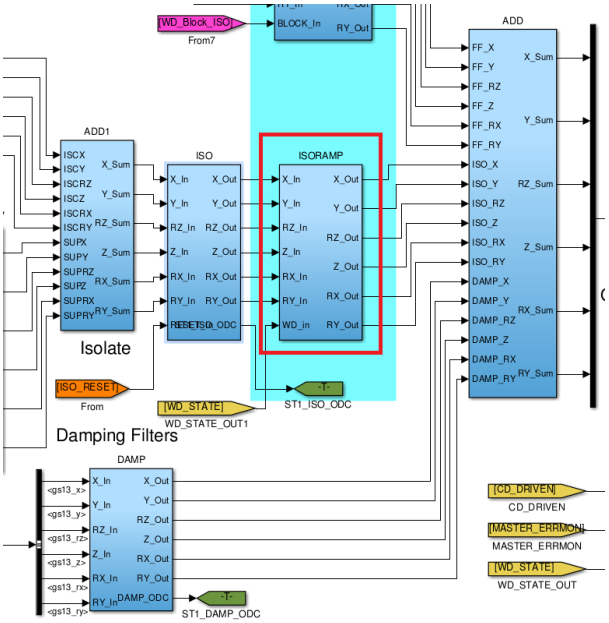


Figure 3: View of flow within the s1isihamx model. ISORAMP (boxed in red) uses six copies of CUSHION_DOF to rampdown each DOF. The WD state variable is fed into the sub-block and distributed to each DOF. Likewise, the user-specified TRAMP is fed into each part so they ramp down in unison.

3 Implementation

After ensuring that CUSHION_DOF functions as expected, sub-blocks were generated in the (common) isihammaster and isi2stagemaster models to implement the smooth rampdown. In the Stage 1 path of isi2stagemaster, the blocks ISOBLOCK and ST2_COMP_BLOCK were replaced with blocks named ISORAMP and ST2_COMP_RAMP, respectively. These new sub-blocks implement the library part CUSHION_DOF. A view of the new Stage 1 model flow appears in Figure 6, while the changes made to the Stage 2 model are shown in Figure 7. The replacement of ISOBLOCK in isihammaster with ISORAMP exactly emulates the change seen in Figure 3, and is not explicitly shown in this document.

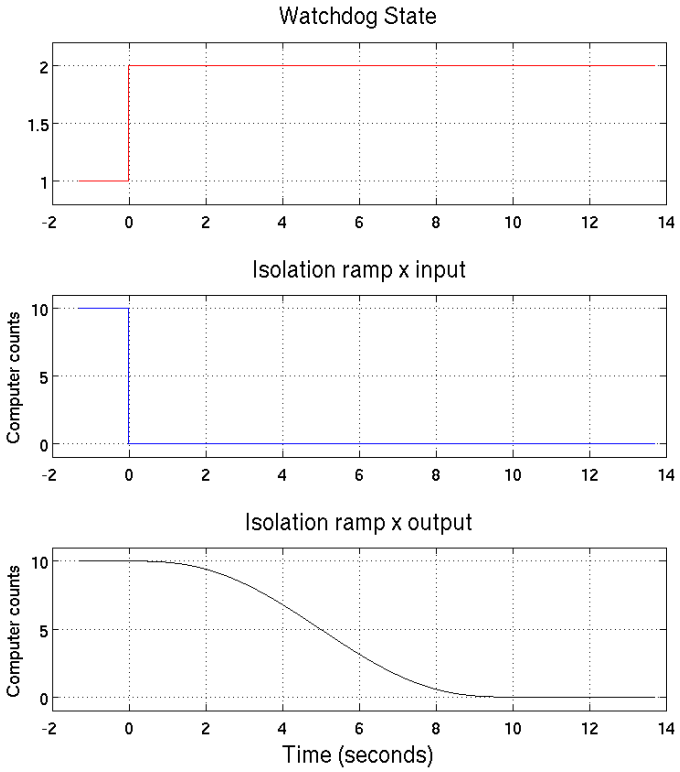
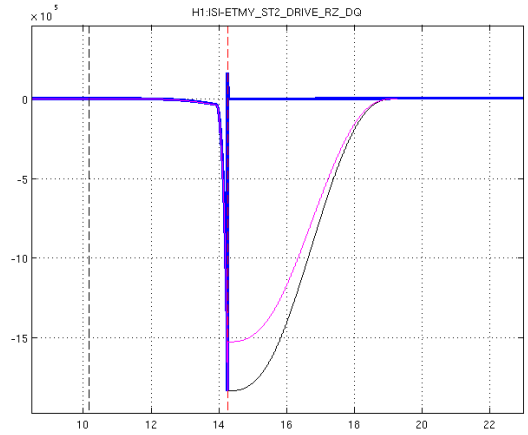
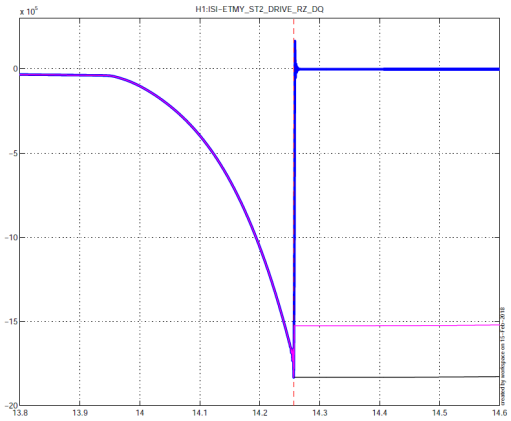


Figure 4: Rampdown of X DOF isolation signal in the event of a watchdog trip in s1isihamx. (Top): the WD system is tripped at time $t_0 = 0$, (Middle): the isolation loop signal immediately drops to 0 at $t_0 = 0$, (Bottom): After the trip, CUSHION_DOF smoothly ramps down the isolation loop signal from its previous value to 0 over 10 seconds. This is highly desirable, as a smooth rampdown reduces impulsive forces experienced by the isolation tables.



(a) Overview of drive signal response with standard ramp (black) and low-passed ramp (magenta).



(b) Zoomed-in view of discontinuity in low-passed signal, which generates an unwanted impulse.

Figure 5: Graphs showing response of ETMY RZ drive during a WD trip on H1. The dashed red vertical line indicates the time of the WD trip. The blue line corresponds to the (real) drive signal, the black line shows the what the drive's response would have been had CUSHION_DOF been installed, and the magenta line shows what the rampdown would have been if the drive signal was low-passed after the WD trips.

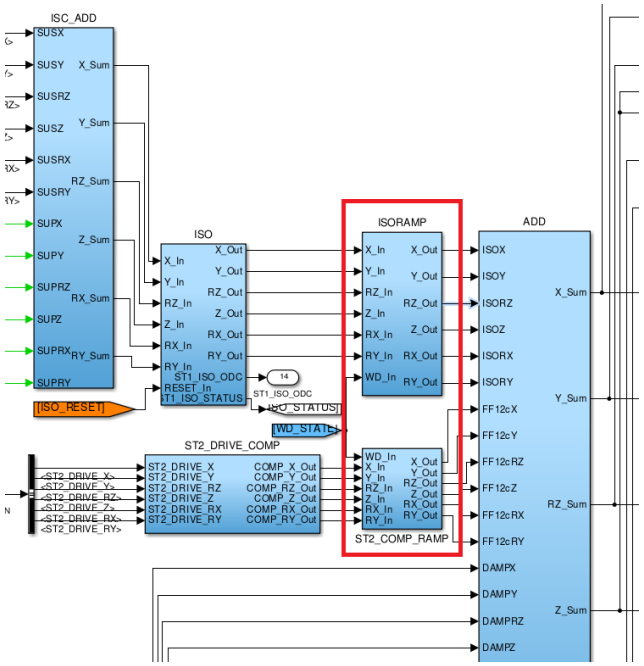


Figure 6: View of the ISORAMP and ST2_COMP_RAMP sub-blocks within the ISI2STAGE_ST1 path of isi2stagemaster.

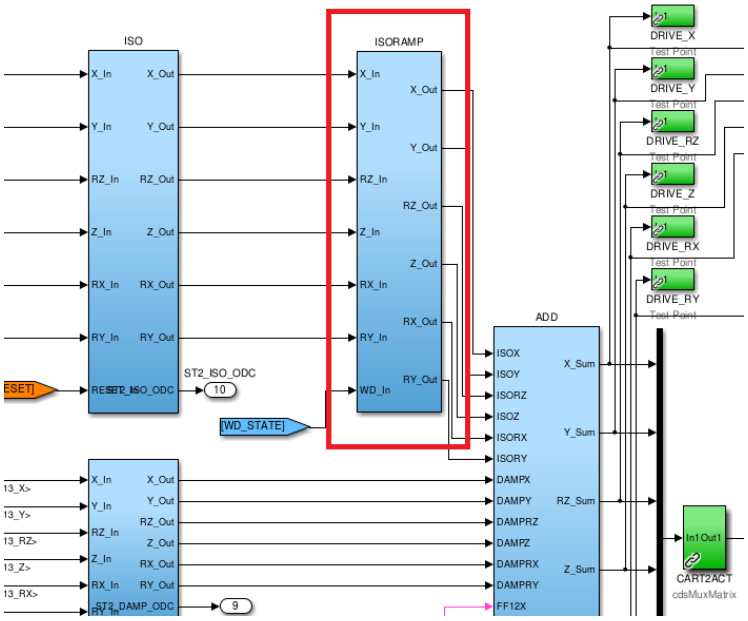


Figure 7: View of the ISORAMP sub-block within the ISI2STAGE_ST2 path of isi2stagemaster.