MRO Delay Line

Delay Line Trolley Limit Handling

The Cambridge Delay Line Team

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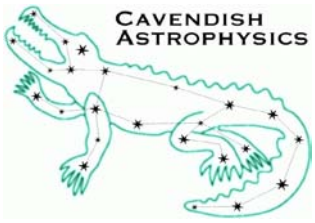

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Change Record

Revision	Date	Authors	Changes
0.3	2007-07-11	MF	First released version

Objectives

To describe in one document the handling of limits of the delay line trolley and its mechanisms.

Scope

This document describes the handling of limits, hardware, firmware and software, on the delay line trolley and its mechanisms. The limit sensors that apply to trolley motion are mounted on the trolley while the activation mechanism is mounted within the delay line pipe. This document describes the functionality of limits and not the specific hardware details of any particular implementation.

Reference Documents

These documents provide further detailed information about the trolley and delay line:

- "Trolley Electronics Design Description"
  This provides a description of how the trolley mechanisms are controlled.
- "Trolley Mechanical Design Description"
  This describes the mechanical design of the trolley.

- "Metrology System and VME Hardware Design Description"
  This describes the hardware used to measure the cat's eye position.

- "Delay Line Pipes and Supports Design Description"
  This describes the design of the delay line pipes in which the trolley runs.

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Introduction

Some mechanisms on the trolley have inherent limits beyond which a mechanism cannot be driven, one is able to rotate continuously and others do not have specific limits that require hardware to protect them. The trolley itself however does need to be protected from over-travel by use of limit switches and mechanical stops. The information presented here describes the requirements and rationality for the provision or otherwise of protective measures.

The mechanisms are listed in the table below together with any identified limits.

Table 1 Summary of limit types

Mechanism	Software limits	Firmware limits	Hardware limits
Trolley drive	On-board register and External VME.	PMAC range-warning PMAC limits: trolley switches triggered by pipe hardware.	Trolley switches triggered by pipe hardware followed by mechanical buffer.
Steering	CPU	PMAC ranges.	None
Focus	CPU	-	None
Tip-tilt	CPU	-	Limited by voltage driver.
Cats-eye	CPU monitor.	Electronic locking at around ±2mm and also a current limit.	Passive bump stops.

1 Operation of specific mechanisms

1.1 Focus mechanism

There are no position limits on the assembly and therefore the software relies on the position indicated by the LVDT. If a fault develops the drive is protected by a time-out feature which shuts down the drive if the position is not reached and flags a warning.

1.2 Tip-tilt mechanism

There are no hardware limits for this mechanism. The range is limited by the piezo voltage driver (software limits may be imposed in the trolley CPU?)

1.3 Steering mechanism

The steering angle is obtained by action of an eccentric bearing on a linkage system connected to the steering axis. The bearing is driven by a stepper motor which is fitted with an absolute analogue rotary sensor. There are no limit switches and so continuous rotation is possible, causing the steering angle to change between positive and negative maxima. To prevent this firmware limits are imposed by PMAC and software limits are applied in the trolley CPU which calculates the steering demand.

1.4 Cat's Eye

There are no limit switches for this mechanism but there is a compliant motion stop at either end of the travel. A linear sensor measures the differential position between the

carriage and the cat's eye and this can be monitored to indicate if either stop has been reached. The pre-amplifier circuitry is arranged such this signal also causes the cat's eye to be held with a ~2mm deflection if the signal from the metrology channel causes the Cats eye to be deflected by this amount. If the metrology is lost the VME system requests a trolley slew condition with zero velocity. This automatically switches the cat's eye circuit to local loop mode which locks the cat's eye in the central position.

1.5 Trolley Drive

There are a number of limits or markers associated with the trolley drive. All are based on sensors or switches mounted on the trolley which are actuated by 'targets' mounted on the delay line pipe. These are described below and the action illustrated in the diagram which does not imply any particular scale but indicates qualitative spacing of the limits.

1.5.1 Speed Limit

Located near both ends of the delay line, this is the first limit detected and, if the trolley is travelling faster than it should be at this point the PMAC attempts to decelerate the trolley to a low velocity until the pre-limit switch is actuated. The pre-limit is at a position which would be just beyond the datum position and therefore the trolley would be ready to drive out of the pre-limit to the datum switch.
This action specifically covers the case where both the metrology and on-board position information is incorrect.

1.5.2 Datum

The datum sensor is fitted to the 'near' end of the delay line (i.e. the end closest to the metrology bench) but beyond the speed limit and just before the pre-limit. When driving the trolley to the datum in order to initialise the metrology count, the pre-limit switch first indicates that the datum position has been passed. Then, with the trolley under velocity control from the VME system, the datum activates the metrology initialise function.

1.5.3 Pre-limit

The pre-limit is positioned a little bit beyond the datum limit and is meant to inform that the end of the delay line is near and the trolley should stop. If this limit is actuated then the firmware on the PMAC automatically brings the trolley to a controlled stop. The PMAC then prevents any further motion commanded in the same direction but allows motion commanded in the reverse direction, enabling the trolley to be driven out of the pre-limit condition to the datum position.

1.5.4 Final Limit

The final limit is the last opportunity to remove drive from the trolley. Activation of this limit removes power from the motor drive amplifier through the action of the limit switch. If the STOP input of the Maxon amplifier is used then the action causes maximum deceleration of the motor. If the ENABLE input is used instead the action causes the removal of the voltage to the motor windings and the power output stage will be high impedance.

While the limit is actuated there is no means to drive the trolley out of the limit condition unless a by-pass circuit is made through manual intervention. However, if

the function being provided by the final limit is to protect against power amplifier failure or faulty command voltage then it is feasible for PMAC to control the STOP input of the amplifier through the use of a fault flag input. Removal of the fault condition can then be handled by human intervention in setting the appropriate control bits in PMAC, using the trolley microprocessor via the network.

1.5.5 Amplifier Fault

The fault output of the Maxon amplifier is connected to the amplifier fault input of the PMAC so that PMAC can remove the drive demand and flag the condition in status returns.

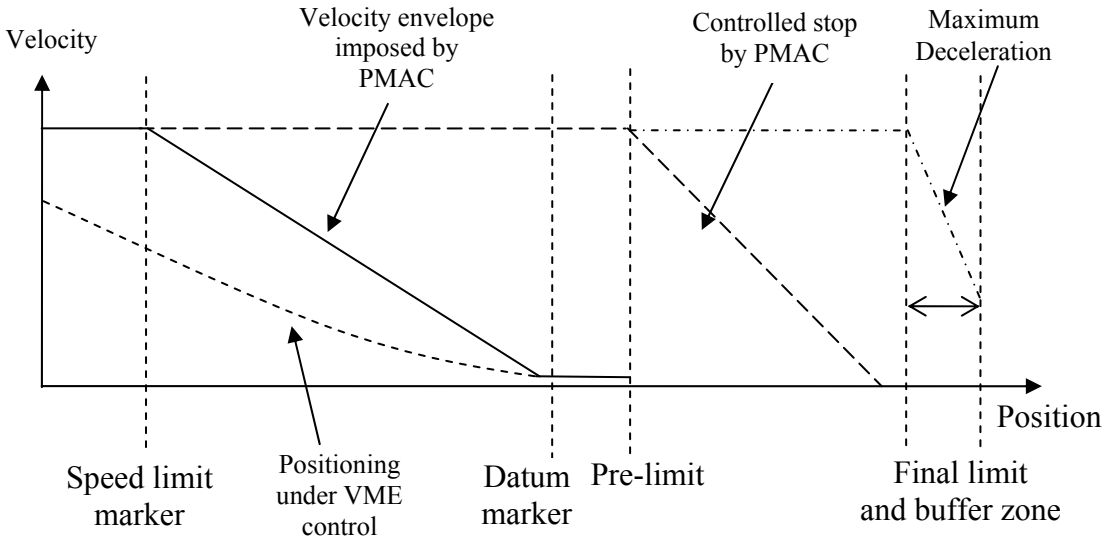

Figure 1. This diagram indicates the arrangement for limits and datum at the end of the delay line pipe closest to the metrology bench. The speed limit and datum operate only over discrete local zones whereas the pre-limit and the final limit are both continuous zones. See text for an explanation of the sequencing of actions.

1.6 Operation of Trolley Drive Limits

1.6.1 Position limits

The aim of the control software is to never allow the trolley to enter the final limit zone. There are three conditions under which the pre-limit is triggered

1. Seeking datum
2. Command failure: The Workstation, VME, trolley CPU or input demand to PMAC has failed in a way which produces an uncontrolled velocity demand.
3. Drive amplifier failure

1.6.2 Datum seeking

If it is required to re-datum the trolley then it is assumed that metrology is lost and the trolley is slewed under VME command towards the datum. When the speed limit

marker is sensed by the trolley the PMAC starts to bring the trolley to a controlled stop just beyond the pre-limit but leaving a small velocity to ensure the pre-limit is reached. When the trolley passes the datum the VME detects this and starts its datum procedure which takes effect once control is released by the PMAC on reaching the pre-limit. The trolley is revered at low speed towards the datum switch.

1.6.3 Command failure

Under normal operation the trolley is being positioned under control of the VME system (which uses the metrology system for position measurement). The VME system may position the trolley anywhere but not beyond the pre-limit and not with a velocity that exceeds the velocity profile imposed by PMAC. If the velocity profile is exceeded then PMAC brings the trolley to a controlled stop between the datum and the pre-limit. If the metrology system is incorrect then it may try to position the trolley beyond the pre-limit but this would be captured by the velocity profile imposed by PMAC and the trolley should drive slowly into the pre-limit. If the speed limit signal is not sensed for some reason then the trolley will continue to drive into the pre-limit. The firmware on board PMAC will then bring the trolley to a controlled stop at a defined deceleration. PMAC will allow motion of the trolley only in the reverse direction.

1.6.4 Failure condition

If the sensing of the pre-limit has failed or if PMAC has failed in a way which does not shut down all drive functions (which is very unlikely) or the drive amplifier has failed in a way that produces continuous drive into the limit then the final limit is activated if it is reached and power is removed from the drive motor by direct action on the power amplifier. Three types of action could be considered:

1. The final limit causes a STOP signal at the Maxon Amplifier. This produces maximum deceleration according to the current limit set in the amplifier and would stop the trolley soonest.
2. The final limit causes the ENABLE signal to be removed from the amplifier. This removes the motor voltage from the windings and the amplifier output goes high impedance. By itself, this allows the trolley to coast to a stop due mostly to friction in the drive and is therefore not satisfactory. However it could be accompanied by shorting of the motor windings through operation of a relay controlled by the enable signal.
3. The final limit causes the trolley drive power to be cut. Power cannot be restored until the trolley is re-positioned away from the final limit zone or a by-pass circuit is allowed to be made though external intervention.

When the final limit is reached it is likely that the trolley would be travelling at sufficient velocity to rebound off the buffers and thus releasing the limit condition. If the fault still persists and drives the trolley to the limit again then eventually the trolley will sit against the limit with the amplifier in a STOP condition and some recovery action will be needed. In the event of a failure which still produces continual drive the amplifier is protected by over-current and over-temperature limits which flag an amplifier fault condition and shuts down the output drive stage.

1.7 Recovery

1.7.1 Remote intervention

If the final limit is still activated then some means of temporarily overriding it is required to see if the fault condition still exists after examining status and attempting to reverse the drive after overriding the amplifier STOP control in PMAC or resetting the amplifier, PMAC or trolley microcomputer as necessary.
If the fault condition persists but is not due to the drive amplifier then it should be possible to configure the amplifier for velocity mode operation through hardware switching and place an appropriate demand on the amplifier to drive the trolley to the service end of the delay line.
If the drive amplifier proves faulty in a way which is not indicated by the amplifier fault flag then overriding the final limit switch within PMAC may cause an increase in motor current and a small amount of motion against the buffer which would be obvious by monitoring the trolley status. In this case the override can be cancelled and an alternative means of recovering the trolley embarked upon.

1.7.2 Direct Intervention

If it proves impossible to drive the trolley out of the final limit or away from the buffer then, in the case that the failure has occurred at the end of the pipe close to the metrology table, it will be necessary to pull the trolley down the pipe to the other end and remove it. To achieve this, the pipe must be brought up to atmosphere so that a towing wire can be attached to the inductive power cable which is then pulled through the length of the pipe until the wire appears. A lug on the far end of the wire then engages safely on the trolley and the wire can be used to pull the trolley backwards through the pipe.