Motor / Heater Deck

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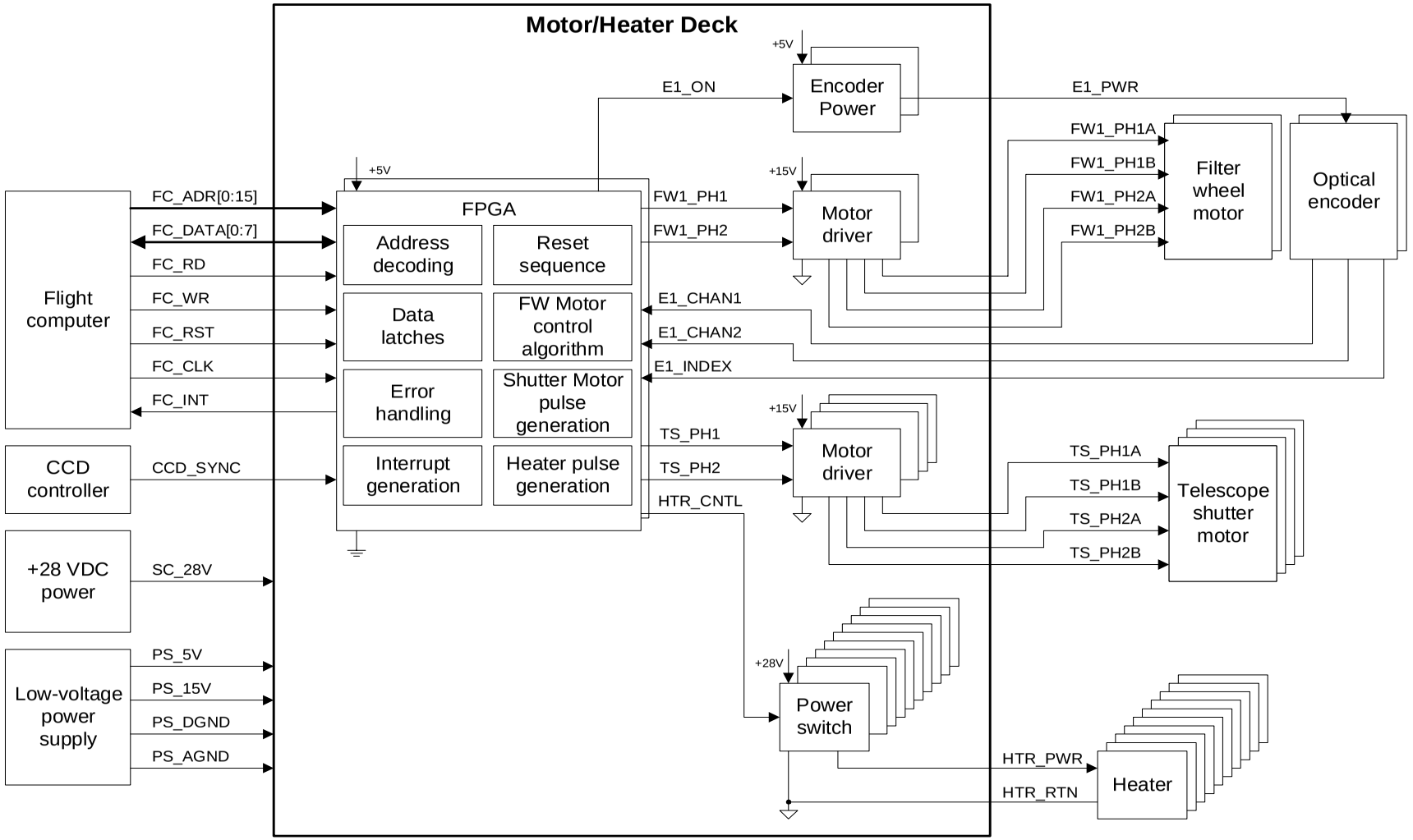
Motor / Heater Deck Requirements Summary

- **Control position of 2 filter wheels, inertia 15 oz-in^2 each**
  - **8 filters per wheel, spaced 45 degrees apart**
  - **use closed-loop control algorithm to minimize time to index**
- **Control 4 step motors for telescope shutters**
  - **use open-loop control algorithm**
  - **motors driven into physical endstops**
- **Provide opto-isolated pulse width modulated power for 10 heaters**
  - **4 telescope operational heaters**
  - **3 profiler heaters**
  - **1 filter wheel heater**
  - **1 CCD heater**
  - **1 CCD window heater**
- **Inhibit PWM switching when CCD is taking data**

Motor / Heater Deck Block Diagram



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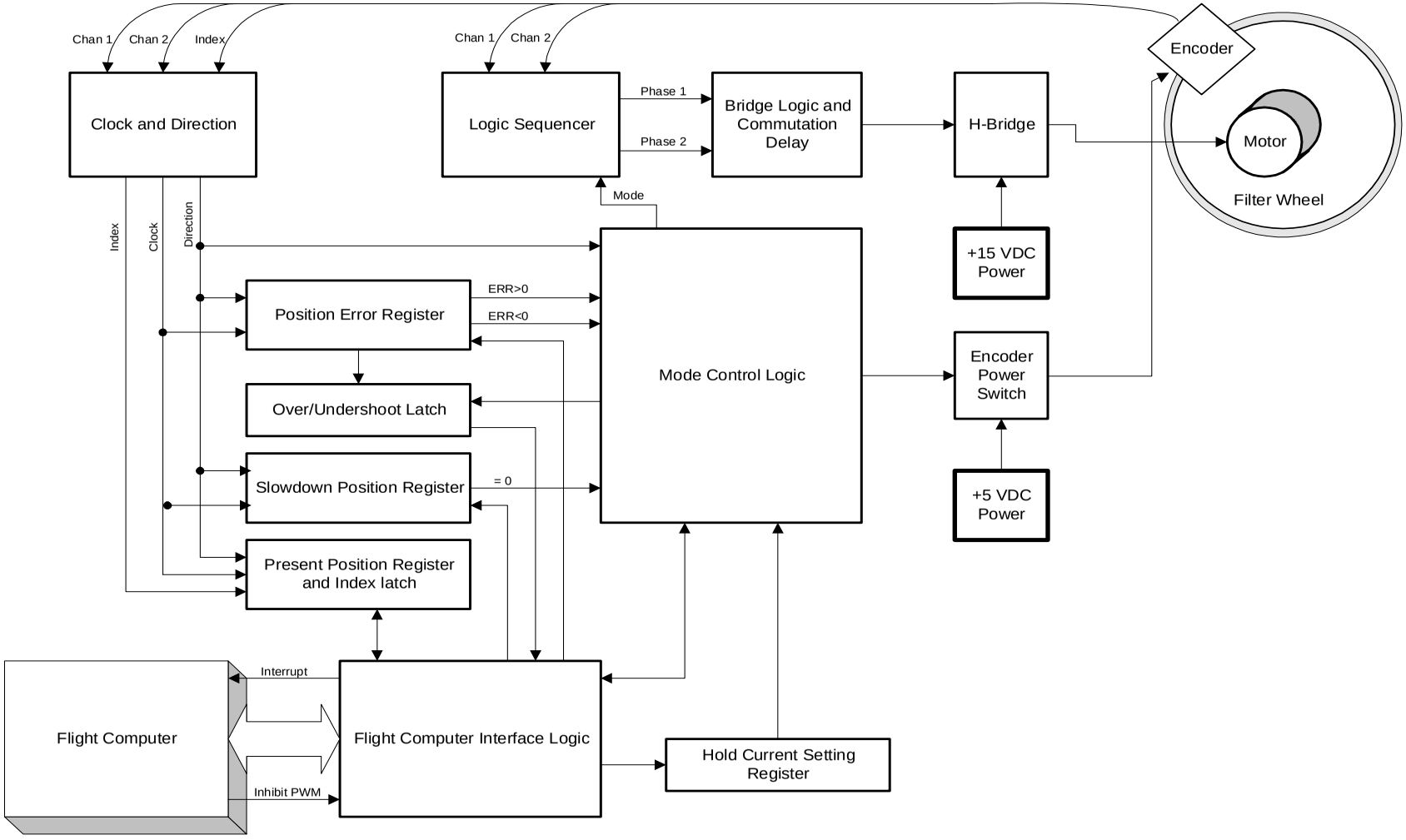
Motor / Heater Deck Subsystem Overview

- **Field Programmable Gate Arrays, FPGA for digital logic (2 req'd)**
  - Flight computer interface, address decoding and data latches
  - Pulse generation for motors and heaters
  - Filter wheel closed-loop motion control
  - Each of 2 FPGA's will control one filter wheel motor, two telescope shutters, and 5 heaters
  - Switching delays in logic to prevent H-bridge cross-conduction
  - Use combinatorial logic for H-bridge signal generation to prevent SEU from causing cross-conduction
- **Motor drivers for control of stepper motors**
  - H-bridges use discrete JANTXV2N7336 N and P channel MOSFETS
  - Level shifters convert logic signals to gate drives

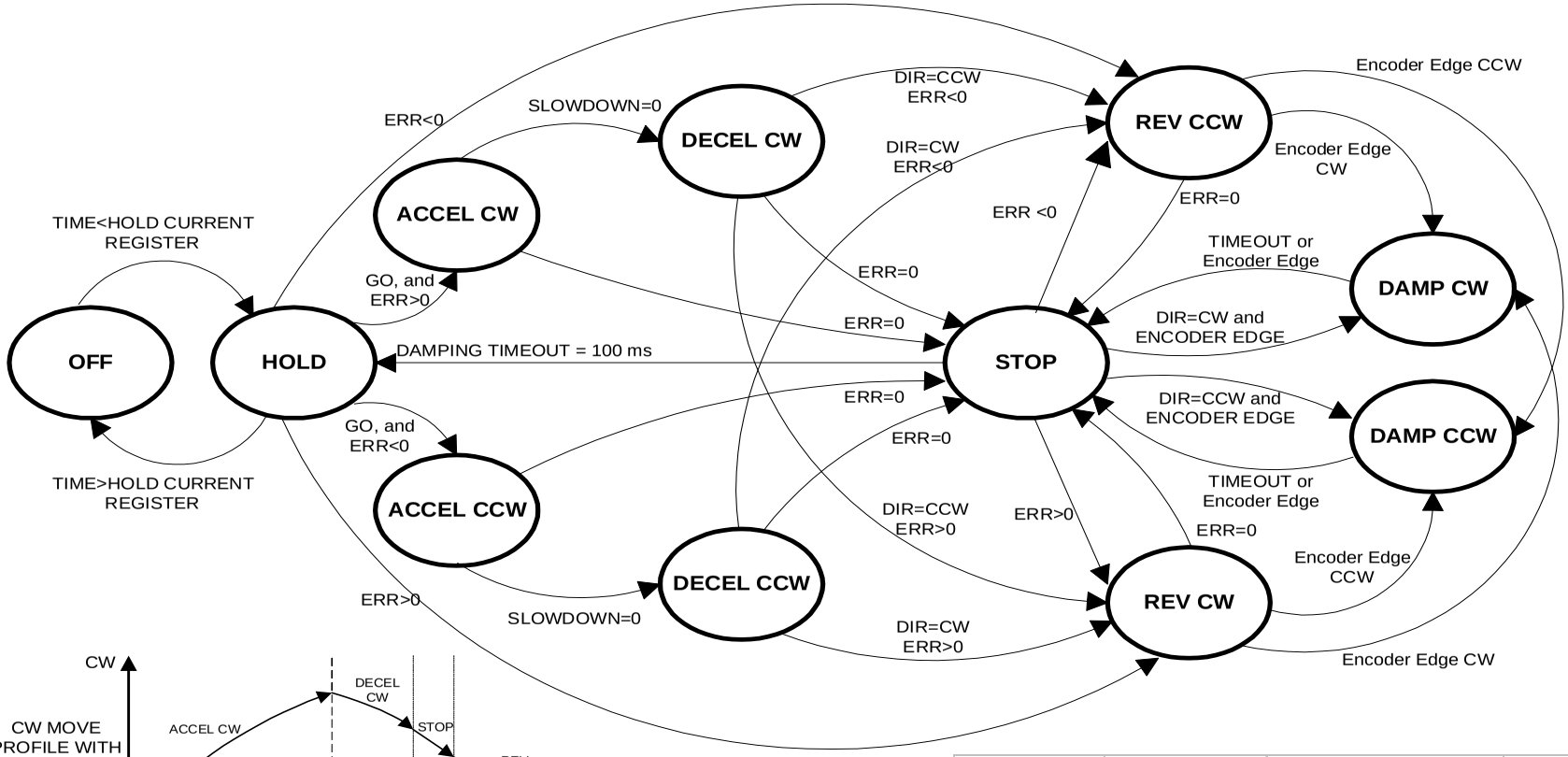
Motor / Heater Deck Subsystem Overview - cont

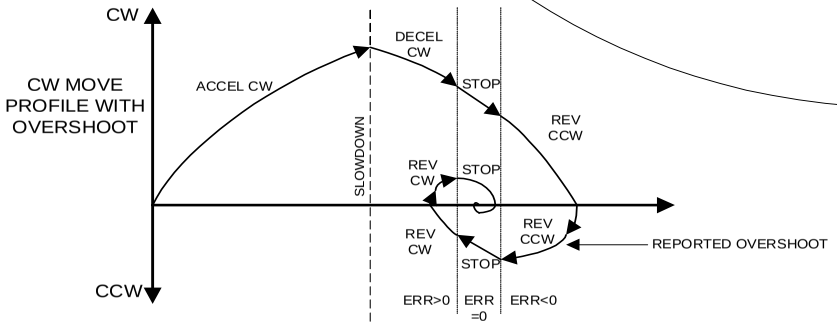
- **Power switches for control of heaters**
  - Heaters powered from 28 volt bus
  - Optoisolation required, use 6N140A quad optocoupler
  - High side drivers for ground referenced loads
  - Use discrete P-channel MOSFETs, quad JANTXV2N7335
- **Filter wheel encoders**
  - Preamplifiers located in profiler
  - 200 ppr matches step motor
  - 2 channels with 90 degree quadrature
  - Index channel
  - Encoders individually powered-down by Motor / Heater Deck when not moving to conserve power

Motor / Heater Deck
FW Motor Control



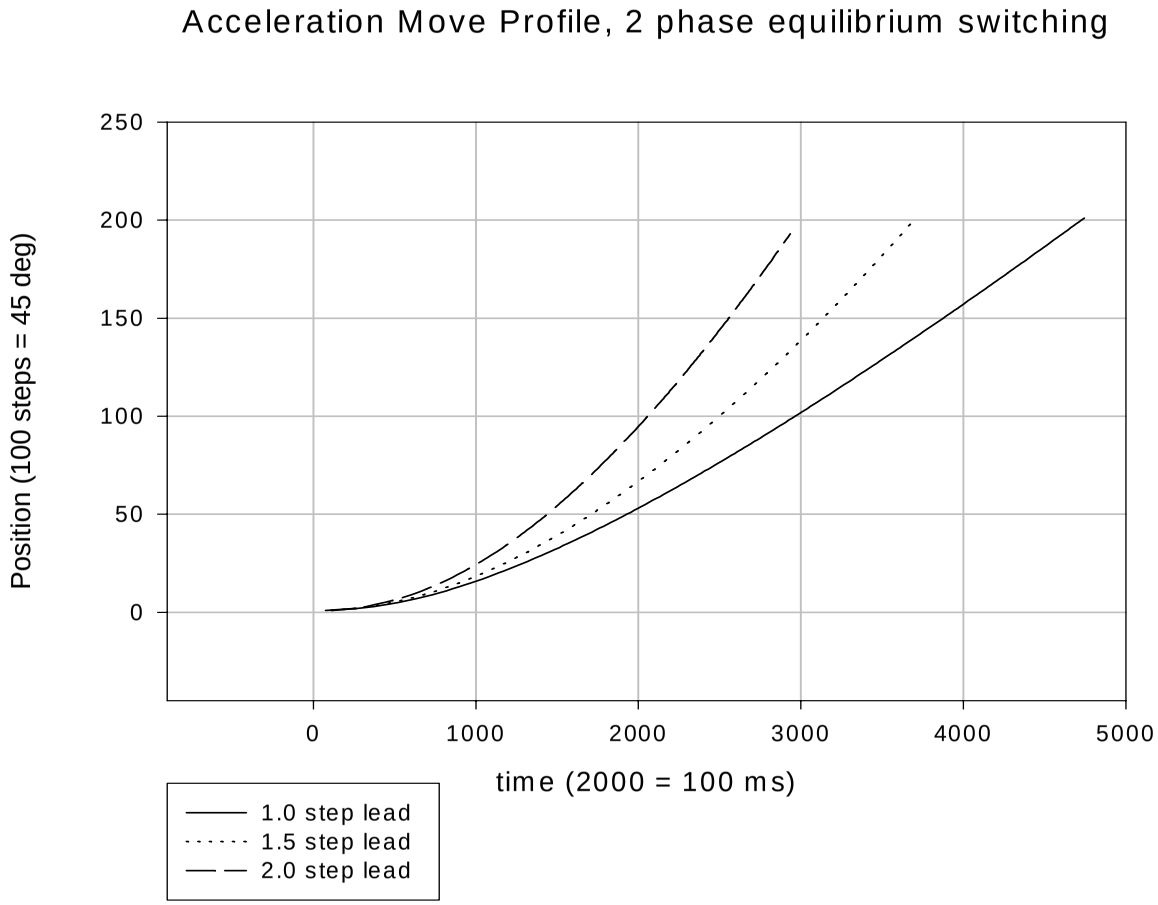
Motor / Heater Deck
FW Motor Mode State Diagram





MODE CW	MODE CCW	Lead in Motor Steps	Phases
STOP	STOP	0.5	1
DAMPCW	DAMPCCW	1	2
REVCW	REVCCW	1.5	1
ACCELCW	ACCELCCW	2	2
DECELCW	DECELCCW	-0.5	1

Motor / Heater Deck
FW Motor Control



Motor / Heater Deck
FW Motor Control Description

- **Motor phase currents are switched at 2-phase equilibrium points.**
  - **1-phase equilibrium was tested and total move times were similar, but 2 motor windings must be energized to hold position.**
  - **Encoder position is phase adjusted to match motor.**
- **Use 2.0 phase lead acceleration.**
  - **Provides greater torque than 1.0 or 1.5 phase lead modes.**
- **Use 3.5 (-0.5) phase lead deceleration.**
  - **Mode 0 phase lead decel provides slightly faster deceleration, but does not ensure direction reversal and uses twice the power.**
  - **Adequate deceleration and direction reversal is automatic.**

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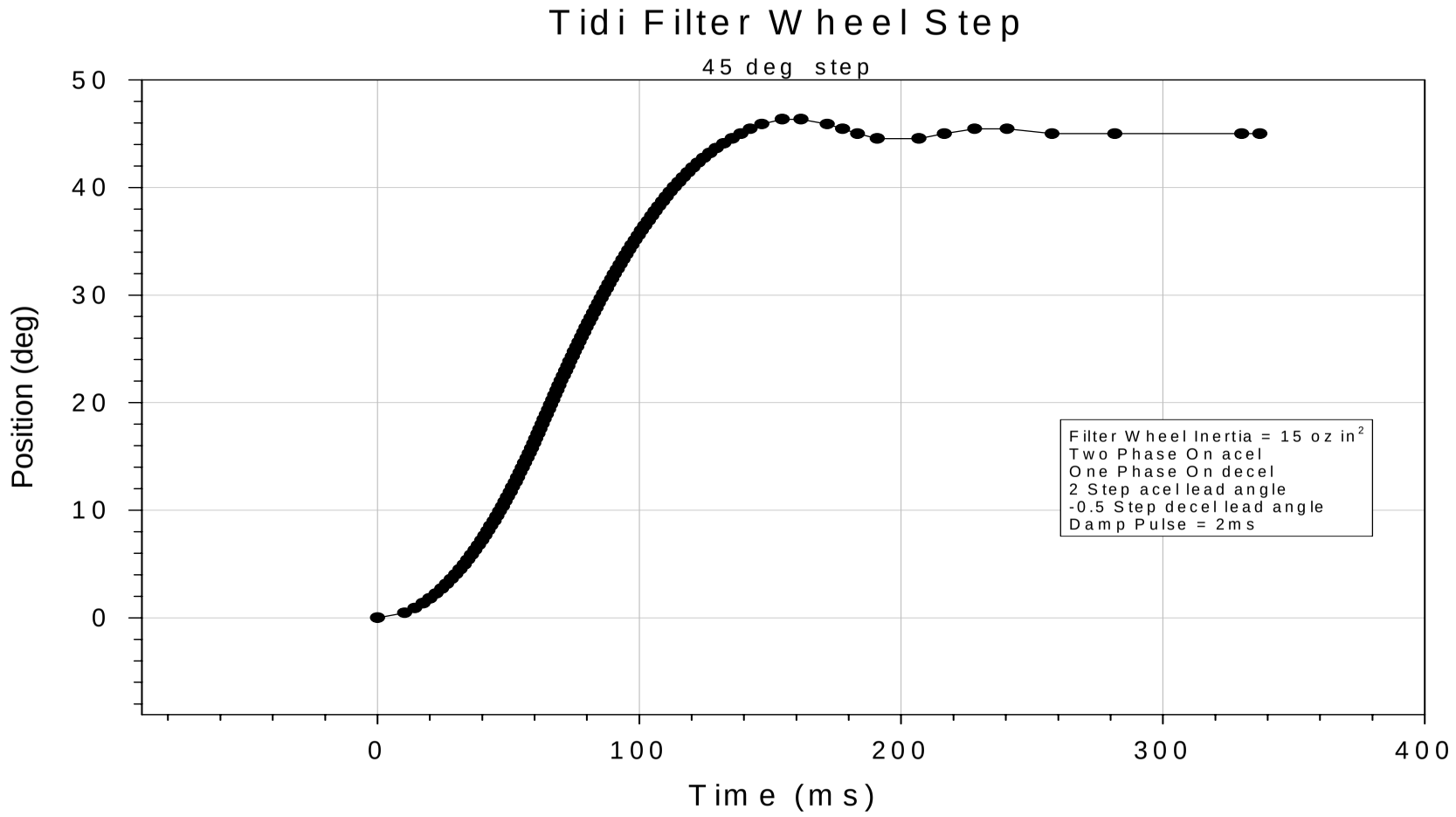
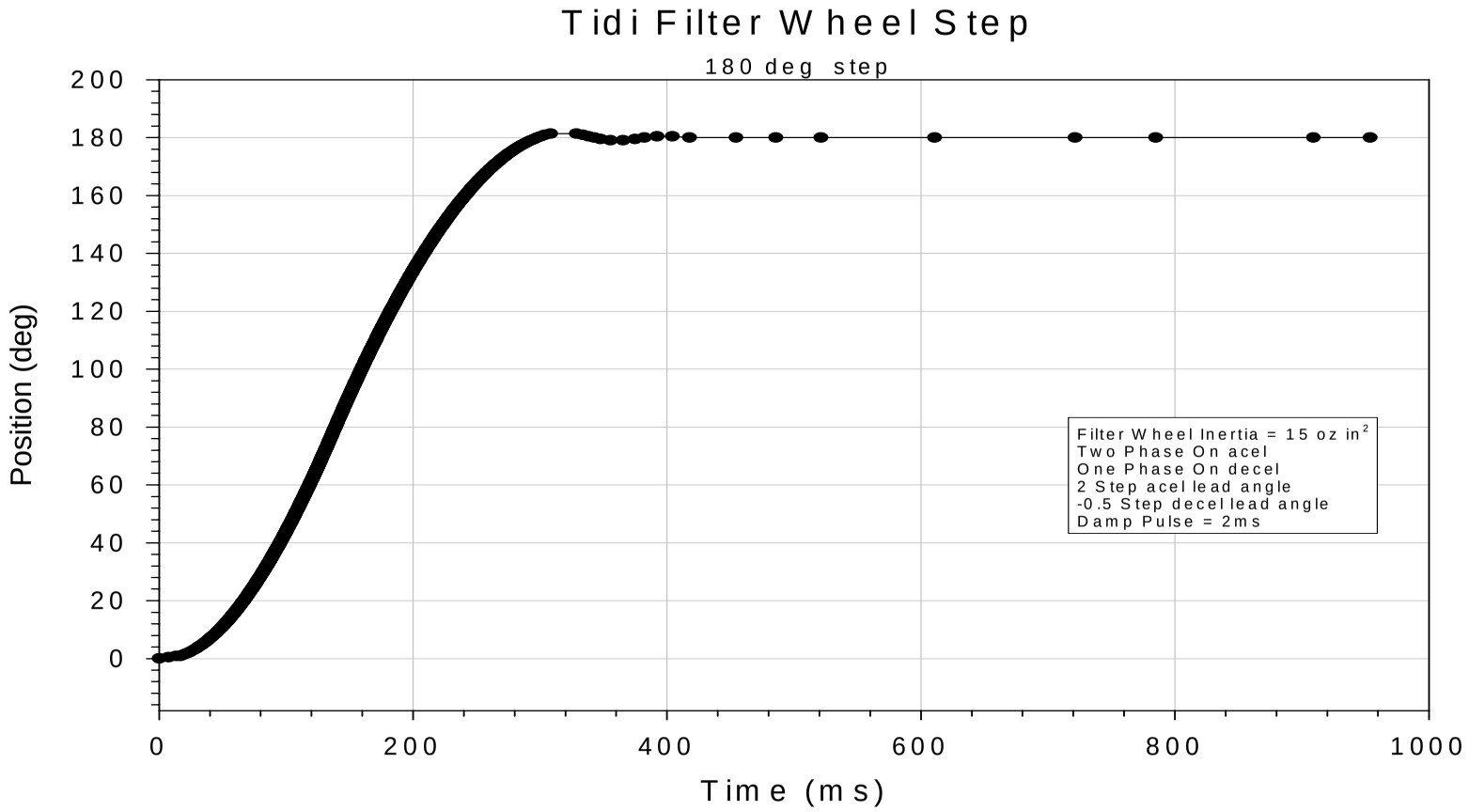
FW Motor Control Description

- **Active damping pulses are used to speed settling time**
  - **Used in STOP mode with decreasing amplitude during 100 ms damping interval.**
  - **Used in REVCW and REVCCW to provide rate limiting.**
- **Slowdown position is specified to 1/800 rev**
  - **1/200 rev does not provide enough resolution for optimal move profile**
  - **The optimal slowdown point is variable for different moves, but consistent for a particular move.**
  - **The desired endpoint will be reached even if the slowdown position is not optimal. Move time will be increased.**

Motor / Heater Deck
Filter Wheel 45 deg Move Profile



Motor / Heater Deck
Filter Wheel 180 deg Move Profile



Motor / Heater Deck Operational Description

- **Move Filter Wheel**
  1. The FC writes to the mtr_ena register to enable the filter wheel motor.
  2. The FC writes values to fwx_accel and fwx_move to specify acceleration distance and incremental movement parameters.
  3. The FC writes to fwx_cntl to initiate motion.
  4. The MH turns on power to the encoder and loads the position error register to begin motion, then clears the fwx_hold bit in fw_stat to indicate that motor power is on.
  5. The MH sets the fwx_move bit in fwx_stat to indicate that the position error is greater than zero.
  6. The MH generates signals to operate the filter wheel motor according to the parameters set by the FC and to drive the position error register to zero. Even if the deceleration point is not optimal, the desired position will be reached.

Motor / Heater Deck Operational Description - cont

7. The initial over or undershoot is latched at the point of first direction reversal. Whenever position error is zero, the fwx_move bit is set to zero.

8. When the position error is zero for at least 100 ms, the MH turns on a holding current as set by the fwx_holdpw register to one phase of the motor to maintain the present position. Power to the encoder is turned off and the the fwx_hold bit is set.

9. If the int_ena bit was set in the mtr_ena register by the FC, The MH sends an interrupt to the FC when the position error first becomes zero. With a reasonable deceleration point, further motion will be minimal.

10. The FC reads the fwx_err bit in fw_stat to determine whether an error occurred.

11. The FC reads the fwx_over register and if greater than 1, or -1, adjusts the length of acceleration for the next move. The absolute position register, fwx_posn may be read at any time.

12. Motor holding currents are turned off while the CCD read signal is active.

Motor / Heater Deck Operational Description - cont

- **Move Shutter Motor**

1. The FC writes to mtr_ena to enable the telescope shutter motor.
2. The FC writes to ts_step to specify the number of steps to move the motor.
3. The FC writes to ts_cntl to specify the direction of movement of the shutter and to start the motor.
4. The MH turns on power to the motor and sets the ts_move bit in ts_stat to indicate that motor power is on.
5. The MH generates signals to move the motor as specified by the FC.
6. The MH turns off power to the motor and clears the tsx_move bit in ts_stat and, if enabled, sends an interrupt to the FC to indicate that movement has stopped and power is off.

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Motor / Heater Deck Operational Description - cont

- **Set Heater Power**

  1. The FC loads the zzz_pw registers to indicate the heater duty cycles as an 8 bit value.

  2. The MH generates pulses to operate the heater.

  3. The FC monitors temperatures through other channels and updates the zzz_pw registers every second. If a value of zero is loaded, that heater is off.

  4. Heater currents are turned off while the CCD read signal is active.

- **Find Index**

  1. The FC writes to the mtr_ena register and clears the filter wheel index bit.

  2. The FC commands either a 200 step move or a series of smaller moves.

  3. After each move, the FC checks the fwx_index bit in the fw_stat register. If set, the index pulse was detected and the position register is set to the absolute position.

Motor / Heater Deck Control and Status Register List

Telescope shutter motors

Address	R/W	Byte name	Bit no.	Bit name	Comments
base+30H	W	ts1_step	0-7		TS no. of steps to move
base+31H	W	ts1_cntl	0	ts_go	TS start movement: 0 = stop 1 = start
			1	ts_dir	TS direction: 0 = open 1 = close
			2-7		Not used

Heaters

Address	R/W	Byte name	Bit no.	Bit name	Comments
base+40H	W	th1_pw	0-7		TH1 byte for pulse width
base+42H	W	th2_pw	0-7		TH2 byte for pulse width
base+44H	W	th3_pw	0-7		TH3 byte for pulse width
base+46H	W	th4_pw	0-7		TH4 byte for pulse width
base+48H	W	ph1_pw	0-7		PH1 byte for pulse width
base+4AH	W	ph2_pw	0-7		PH2 byte for pulse width
base+4CH	W	ph3_pw	0-7		PH3 byte for pulse width
base+4EH	W	fwh_pw	0-7		FWH byte for pulse width
base+50H	W	ccdh_pw	0-7		CCDH byte for pulse width
base+52H	W	shh_pw	0-7		SHH byte for pulse width

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Motor / Heater Deck Control and Status Register List

Master control and status

Address	R/W	Byte Name	Bit no.	Bit name	Comments
base+00H	W	mtr_ena	0-2		3-bit value for selecting motor: 0 = FW 1 1 = FW 2 2 = TS 1 3 = TS 2 4 = TS 3 5 = TS 4 6 = Clear fw1_index bit 7 = Clear fw2_index bit
			3	int_ena	interrupt generation 0 = disable 1 = enable
			4-7		Not used
base+01H	R	fw_stat	0	fw1_move	FW 1 movement: 0 = in progress 1 = done
			1	fw1_hold	FW 1 hold current: 0 = on 1 = off
			2	fw1_err	FW 1 error: 0 = no error 1 = error
			3	fw1_index	FW 1 index pulse 0 = not detected 1 = detected
			4	fw2_move	FW 2 movement
			5	fw2_hold	FW 2 hold current
			6	fw2_err	FW 2 error
			7	fw2_index	FW 2 index pulse 0 = not detected 1 = detected

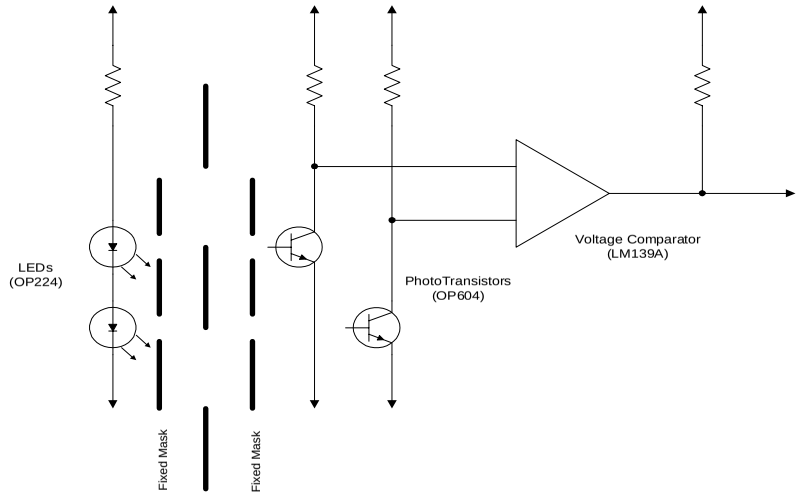
Motor / Heater Deck Control and Status Register List

Filter wheel motors

Address	R/W	Byte name	Bit no.	Bit name	Comments
base+10H	W	fw1_move	0-7		FW 1 no. of steps to move (signed 2's complement)
base+11H	W	fw1_holdpw	0-7		Pulse width for hold current
base+12H	W	fw1_accel	0-7		FW 1 no. of steps to accelerate (signed 2's complement)
base+13H	W	fw1_cntl	0	fw1_go	FW 1 start movement: 0 = stop 1 = start
			1-7		Not used
base+14H	R	fw1_posn	0-7		FW 1 actual motor position
base+15H	R	fw1_over	0-7		FW 1 maximum overshoot or undershoot for last move (signed 2's complement)

Address	R/W	Byte name	Bit no.	Bit name	Comments
base+20H	W	fw2_move	0-7		FW 2 no. of steps to move (signed 2's complement)
base+21H	W	fw2_holdpw	0-7		Pulse width for hold current
base+22H	W	fw2_accel	0-7		FW 2 no. of steps to accelerate (signed 2's complement)
base+23H	W	fw2_cntl	0	fw2_go	FW 2 start movement: 0 = stop 1 = start
			1-7		Not used
base+24H	R	fw2_posn	0-7		FW 2 actual motor position
base+25H	R	fw2_over	0-7		FW 2 maximum overshoot or undershoot for last move (signed 2's complement)

Motor / Heater Deck
Filter Wheel Encoder



- **Preamplifier for each filter wheel located in profiler.**
- **Differential design reduces sensitivity to opto-coupler degradation.**
- **200 ppr for non-ambiguous step-motor commutation.**
- **Opto components shielded for 5 krad exposure.**
- **50% light/dark ratio for encoder disk, 2 stationary masks**

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Motor / Heater Deck Status

- Filter wheel encoder design finalized
- Filter Wheel stepper motor control algorithm is determined
- Interface specification document has been revised
- Electrical schematic is 30% complete
- FPGA design is 20% complete
- All major component parts identified

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Changes in filter wheel encoder design since last review

- **Analysis of the single-ended design**
  - Expect large CTR degradation due to radiation effects and aging
  - Change in output duty cycle could lead to loss of quadrature
- **Use a differential design**
  - two emitters and detectors per channel to reduce the sensitivity to degradation.
  - Requires 50% more power than original design.
- **Use 200 ppr rather than 400 ppr**
  - No commutation ambiguity on power-up
  - Adequate resolution for motion control and damping
  - Increased reliability, less sensitive to phase shift
  - Will be powered-down when not moving

Changes in filter wheel motor control since last review

- **Litton motor is determined to be acceptable**
- **Motion algorithm has been finalized**
  - **The motor has 50 power-off detents per revolution and may move off the desired position when powered down. A holding current of approximately 10 mA through a single motor phase overcomes the detent torque and maintains position, allowing the encoder to be powered down when not moving. This holding current is controlled using PWM on the H-bridge and does not require additional hardware to implement.**
  - **Active damping is used to reduce the settling time**
- **Power profiles have been updated**
- **Interface document has been revised**