ACCEL LLRF Control Algorithm Design

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Custom Library for SLAC LLRF



- Custom block in Library Browser
- Testbench Simulink model
- Testbench Script
- Phase correction as an example
 - Set the desire phase value
 - Set the lower limit of the phase correction
 - Set the correction gain
 - Get the current phase value
 - Output the new set values for phase



Testbench for Custom Block

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Custom block

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- In and out gateways
 - Output type
 - Arithmetic types
 - Fixed point precision
 - Quantization
- Parameters
 - To and From the workspace
 - Save format

Testbench Script

SLAC

phase_corr_testbench.m x +
1 - clear all;

2 % General parameters

- 3 fsample=250e6;
- 4 period=1/fsample;
- 5 runcycle=10;
- 6 number_loop=30;
- 7 runtime=runcycle*period; 8

🎭 Custom parameters

- 10 p_int=0.1;
- 11 p_act=p_int;
- 12 p_des=1.5; 13 - p low lim=G
- 13 p_low_lim=0.1; 14 - p_gain=0.1;
- 14 p_gain=0.1; 15
- 16 17

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Simulation

- 18 <mark>figure;</mark>
- 19 pfor i=1:number_loop
- 20 %p_act=p_new;
- 21 sim('phase_corr_test.slx', runtime);
- 22 p_new_array=ans.p_new.signals.values;
- 23 p_new=p_new_array(end); 24 - p_act=p_new;
- 24 p_act=p_new; 25 - plog(i)=p_new;
- 25 plog(1)=p_new 26 - end
- 20 -
- 28 plog_i≡[p_int,plog]
- 29 30 - plot(
- 30 plot(plog_i,'o-'); hold on; 31 - xlabel('Number of Pulses');
- 32 vlabel('phase (rad)');
- 33 grid on;
- SLAC TID TECHNOLOGY INNOVATION DIRECTORATE

- Setup the general parameters
- Setup the customer parameters
- Call sim to simulate the firmware model
 - Use From Workspace to load data to Simulink model
 - Use To Workspace to read the output data back to workspace for verification and visualization
 - Plot the results

- Compare the results for fixed-point to floating point model
- Verify the function
- Goal: not see Simulink window open

Amplitude and Phase Control



- Amplitude and phase control flow performed after the RF frequency and flatness control
- The phase and amplitude of the klystron forward signal are precisely controlled to user defined values with a real-time compensating loop
- Implementation plan
 - User defined values set in software
 - The target phase and amplitude values set in software
 - User defined waveform corrected by flatness control flow
 - Average values calculated in firmware
 - Streaming IQ samples of the cavity reflection signal are converted to amplitude and phase values in firmware
 - New set of phase and amplitude values calculated based on user defined steps and targets
 - New set values converted back to IQ and then modulated with pulse waveform from software

Phase Control Block



- Take the phase value for each of the pulse
- User defined desired phase value
- Phase correction value calculated
 - Correction value based on the difference between desired value and measurement
 - Correction step controlled by phase control loop gain (user defined)
 - Correction value within lower limit (user defined)
 - "deadband" the phase no longer changes
- New set value as the output of the block



Phase Control Loop Firmware Simulation Results



 $p_act = 2*pi$ $p_des = 0.5$ $p_gain = 0.1 - 0.5$





p_act =0.1 p_des =1.5 p_gain = 0.1 - 0.5

Phase and Amplitude Control Blocks in SLAC LLRF

Simulink Library Browser		-	×
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SLAC LLRF			
 Fixed-Point Designer HDL Support Fuzzy Logic Toolbox HDL Coder HDL Verifier Image Acquisition Toolbox Mixed-Signal Blockset Model Predictive Control Toolbox Motor Control Blockset Model Predictive Control Toolbox Phased Array System Toolbox Phased Array System Toolbox Powertrain Blockset Radar Toolbox Reinforcement Learning Report Generator Rob System Toolbox Rob System Toolbox Rob System Toolbox Rob Toolbox Sersor Fusion and Tracking Toolbox Sernesr Fusion and Tracking Toolbox Simulink Control Design Simulink Control Design Simulink Design Optimization Simulink Test SLAC LLRF So C Blockset So C Blockset So C Blockset Vehicle Dynamics Blockset Vehicle Network Toolbox System Identification Toolbox Vehicle Network Toolbox Vehicle Network Toolbox Vehicle Network Toolbox Vision HDL Toolbox Xisina Toolbox Sinsen Blockset Vehicle Network Toolbox Vision HDL Toolbox Xisina Toolbox Xision HDL Toolbox Xisina Toolbox 	A_des A_des A_act B_act A_des A_		



Amplitude Control Block



- Take the amplitude value for each of the pulse
- User defined desired amplitude value
- New amplitude set value calculated
 - Correction value based on the difference between desired value and measurement $a_{cor} = (\frac{a_{des}}{a_{act}} - 1) \cdot a_{gain} \quad a_{set} = a_{act} \cdot a_{gain}$
 - Control step controlled by amplitude control loop gain (user defined)
 - Correction value within lower limit (user defined)
 "deadband" the amplitude no longer changes
- New set value as the output of the block
- Basic function realized, fine tunning and more simulation required for wrapping up the block



Amplitude Control Block

5 5 000000 gain 0.3 \cap gain 0.2 4.5 4.5 4 4 Amplitude 3.5 Amplitude 3.5 3 3 gain 0.3 2.5 2.5 gain 0.2 2 2 10 15 20 25 30 0 5 10 15 20 25 30 0 5 Number of Pulses Number of Pulses $a_act = 5$ $a_act = 2$ a des = 2a des = 5 $a_{gain} = 0.2 \text{ and } 0.3$ a_gain = 0.2 and 0.3

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Thank you!

