LLRF Fill-in topics

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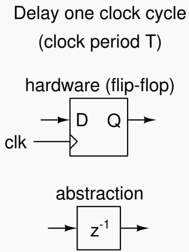
Topics

- Definition of z transform
- Relationship between z and s transforms
- Integrator wind-up
- Detune calculation
- Quench waveforms
- Block diagram

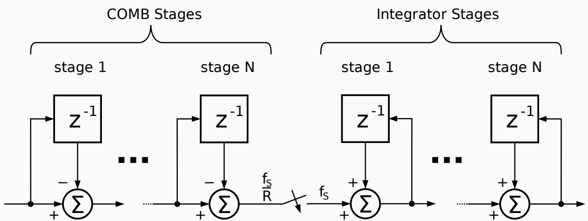
Definition of z transform

Dynamics in DSP (Digital Signal Processing) captured with a 1-clock-cycle delay called z^{-1}



Example of use

CIC Interpolator (Hogenauer, non-piplined)



Relationship between z and s transforms

Laplace transform of time shift

$$\mathcal{L}(f(t-a)u(t-a) = e^{-as}F(s)$$

where $u(a)$ is the Heaviside step function

z^{-1} represents delay of T seconds

$$z = e^{sT}$$

Integrator wind-up

https://en.wikipedia.org/wiki/Integral_windup

Excess overshoot in a PI controller

Fixed by making sure that the controller integrator clips *before* (or at least at similar signal level) to the point where the plant response saturates.

http://brettbeauregard.com/blog/2011/04/improving-the-beginner%e2%80%99s-pid-reset-windup/

Detune calculation

Transfer function from drive through cavity to probe

$$A(\omega) = \frac{1}{1 + j\chi(\omega)} = \frac{1}{1 + j\frac{\omega - \omega_0}{\omega_{\mathrm{3dB}}}}$$

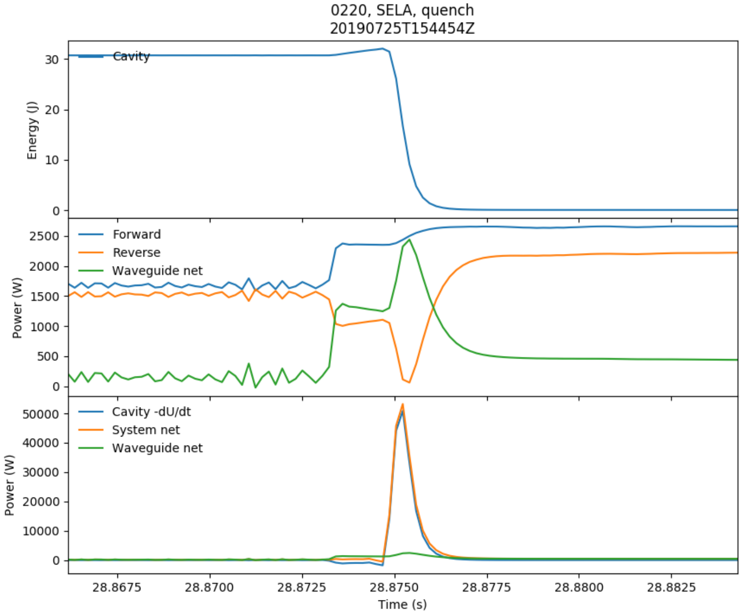
If ω_0 drifts, the phase of A changes. Detune frequency easily estimated as

$$\Delta f = \Delta\phi \cdot \frac{\omega_{\mathrm{3dB}}}{2\pi}$$

Trick is how to realistically measure $\Delta\phi$, even in the presence of large (and practically unknown) phase shifts from cables.

Easy when RF is pulsed: curve-fit the phase of the decay waveform.
In many cases, can use that technique to *calibrate* the on-resonance ϕ.

Quench Waveforms



(without interlocks)

Abstract block diagram of LLRF