

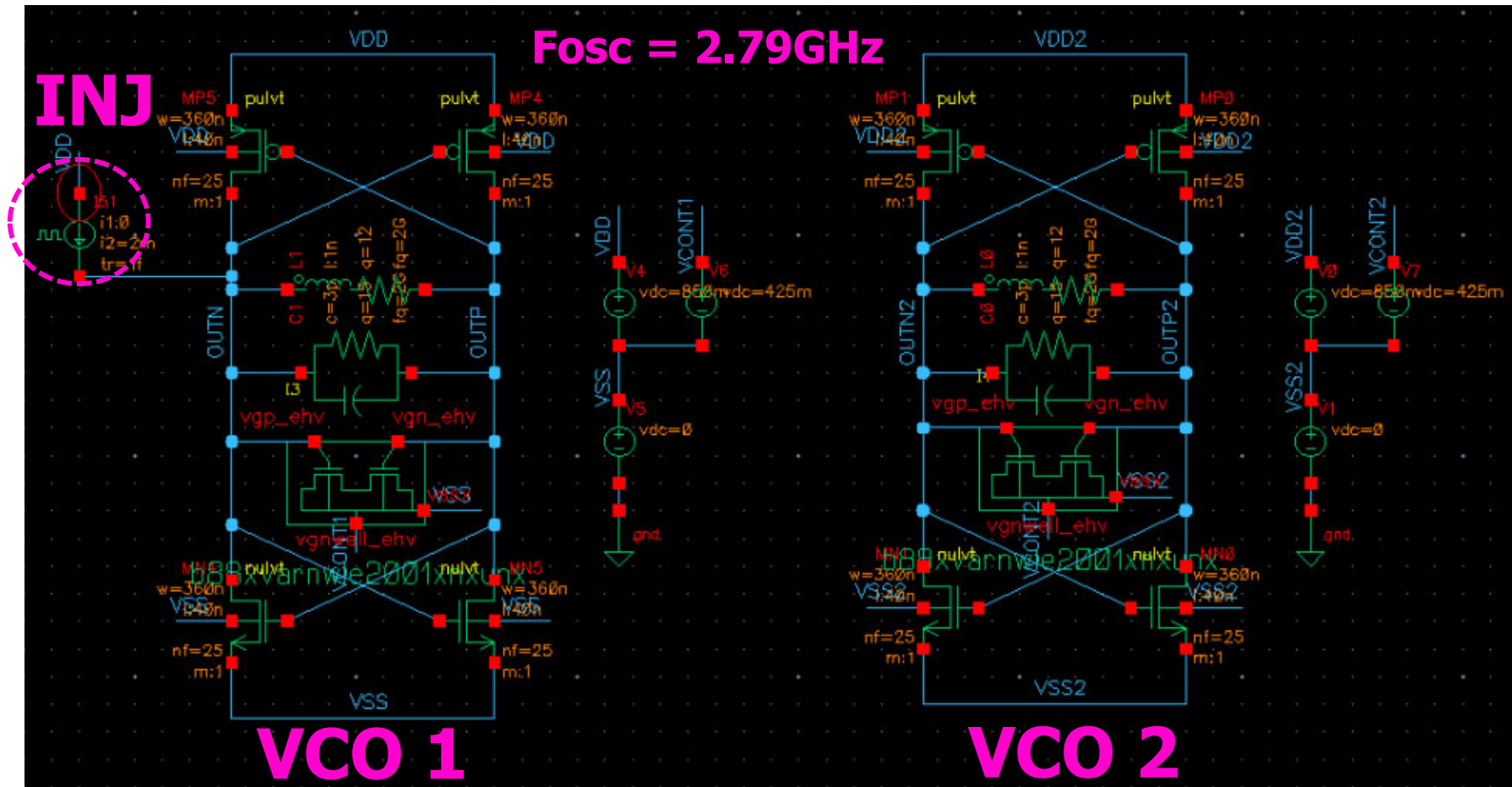
VCO ISF Simulation

October 2023



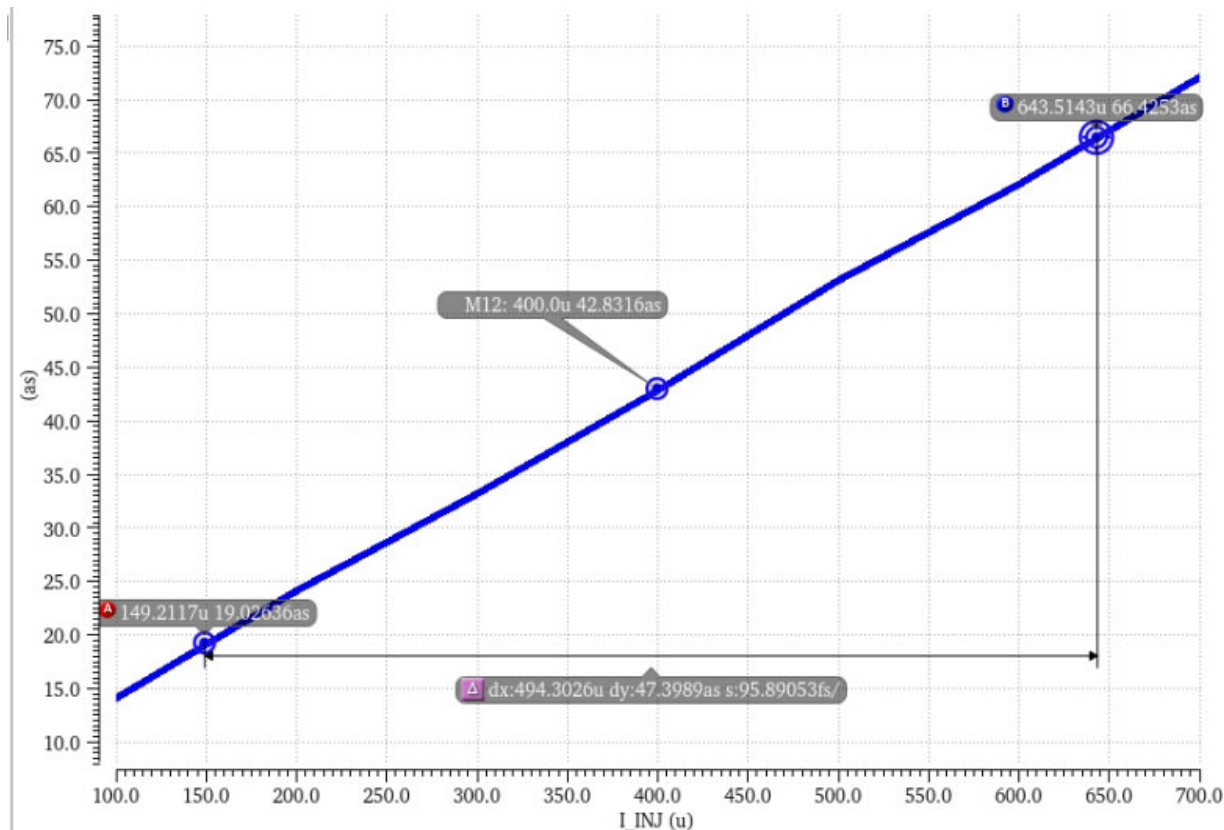
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ISF Simulation Setup



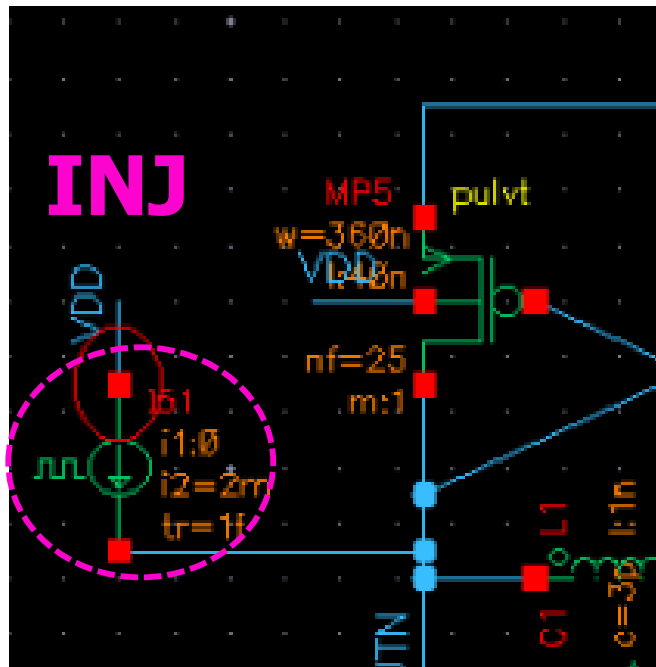
- Create a test bench with your VCO (VCO 1) for injection and a replica VCO (VCO 2) which will be used for phase comparison
- Separate VDD, VSS and VCONTROL for the two VCOs
- Add the injection source to VCO 1
- Give the same initial conditions to both VCOs and make sure that they startup properly and have the same phase and frequency

Oscillator Injection Linearity



- Set the injection point and sweep the injected current amplitude and plot the resulting phase shift
- The resulting phase shift should be linearly proportional to the magnitude of the injection as is shown above
- For ISF analysis use an injection current in the linear range

Injection Source Configuration

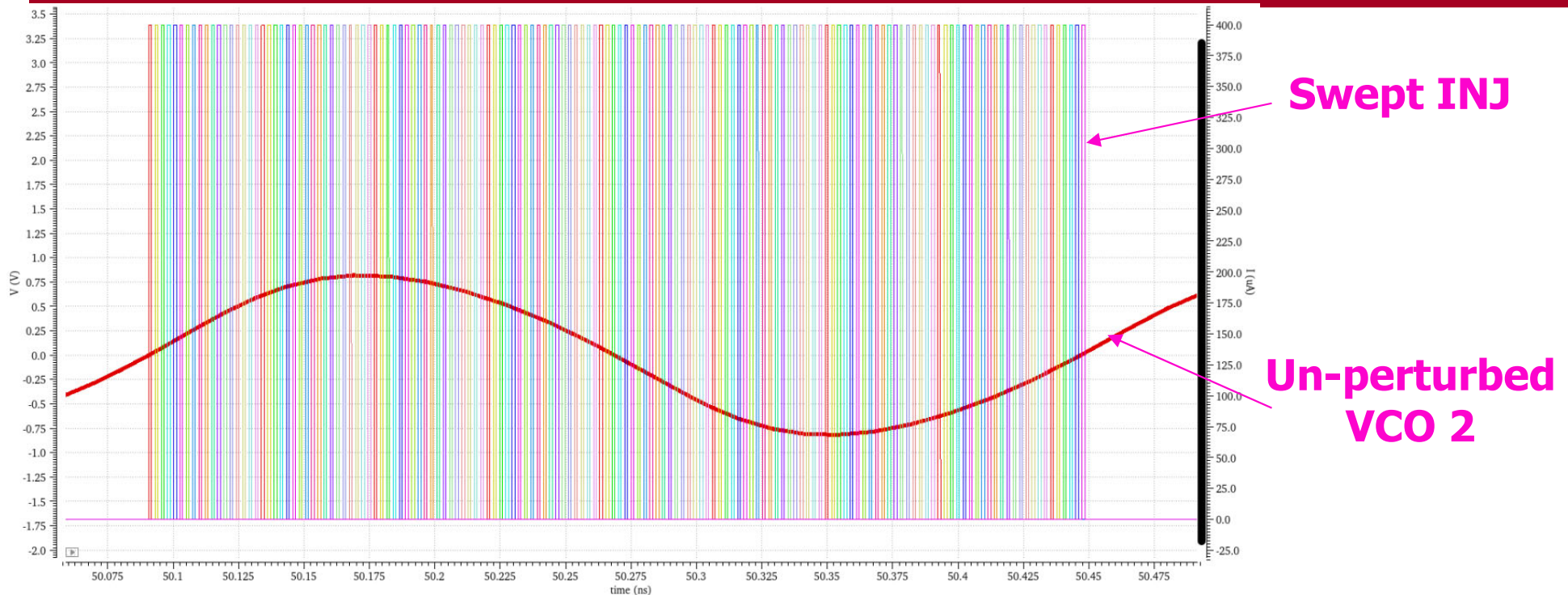


INJ Source Parameters

Current 1	0 A
Current 2	I_INJ A
Period	1 s
Delay time	DELAY_TIME s
Rise time	1f s
Fall time	1f s
Pulse width	1p s

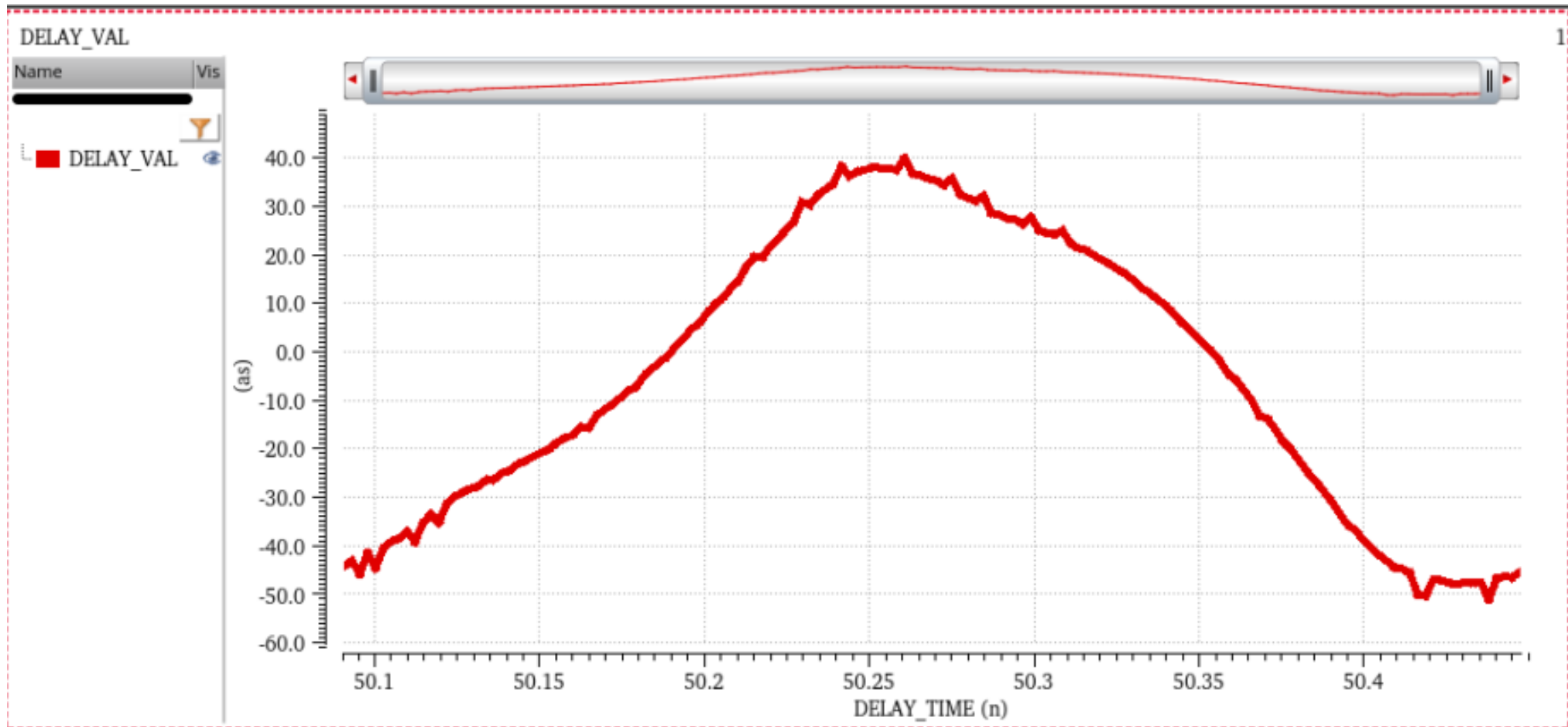
- The delay should be set to a variable which will be swept over the period of the oscillator
- Overall the injected amplitude can be change as well as the pulse width if more charge is needed to get a larger phase step
- Choose an injection current that maintains oscillator linearity

ISF Extraction



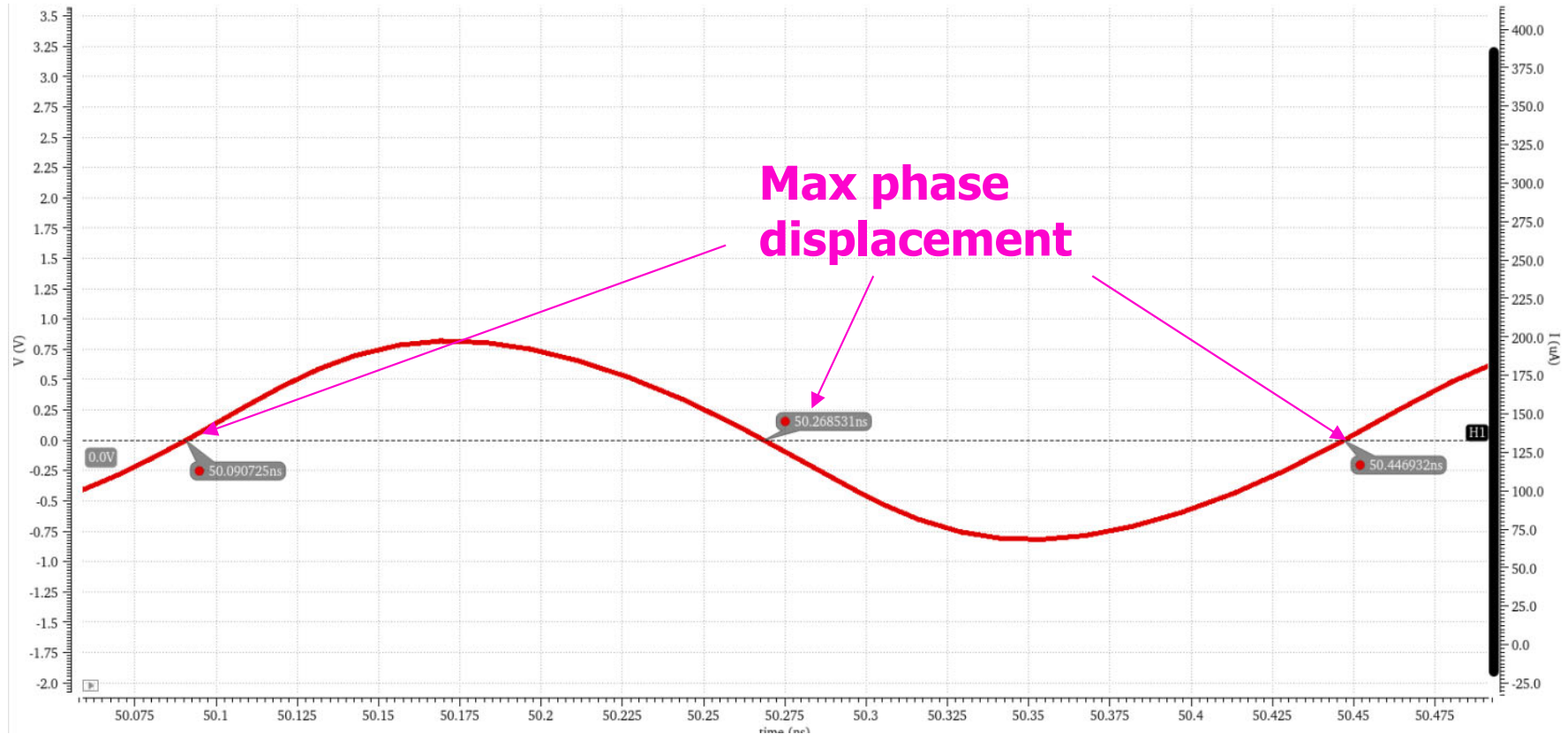
- The INJ delay should be swept over the oscillator period and the resulting phase shift from VCO 1 to VCO 2 should be plotted
- Delay the injection until the oscillators have started up properly
- After injection wait for the resulting phase shift to settle before taking the value of the resulting phase shift
- The phase can be acquired by measuring the resulting delay between VCO 1 and VCO 2 and converting it to phase
- Normalize the resulting phase shifts to get the ISF

Resulting Phase Displacement



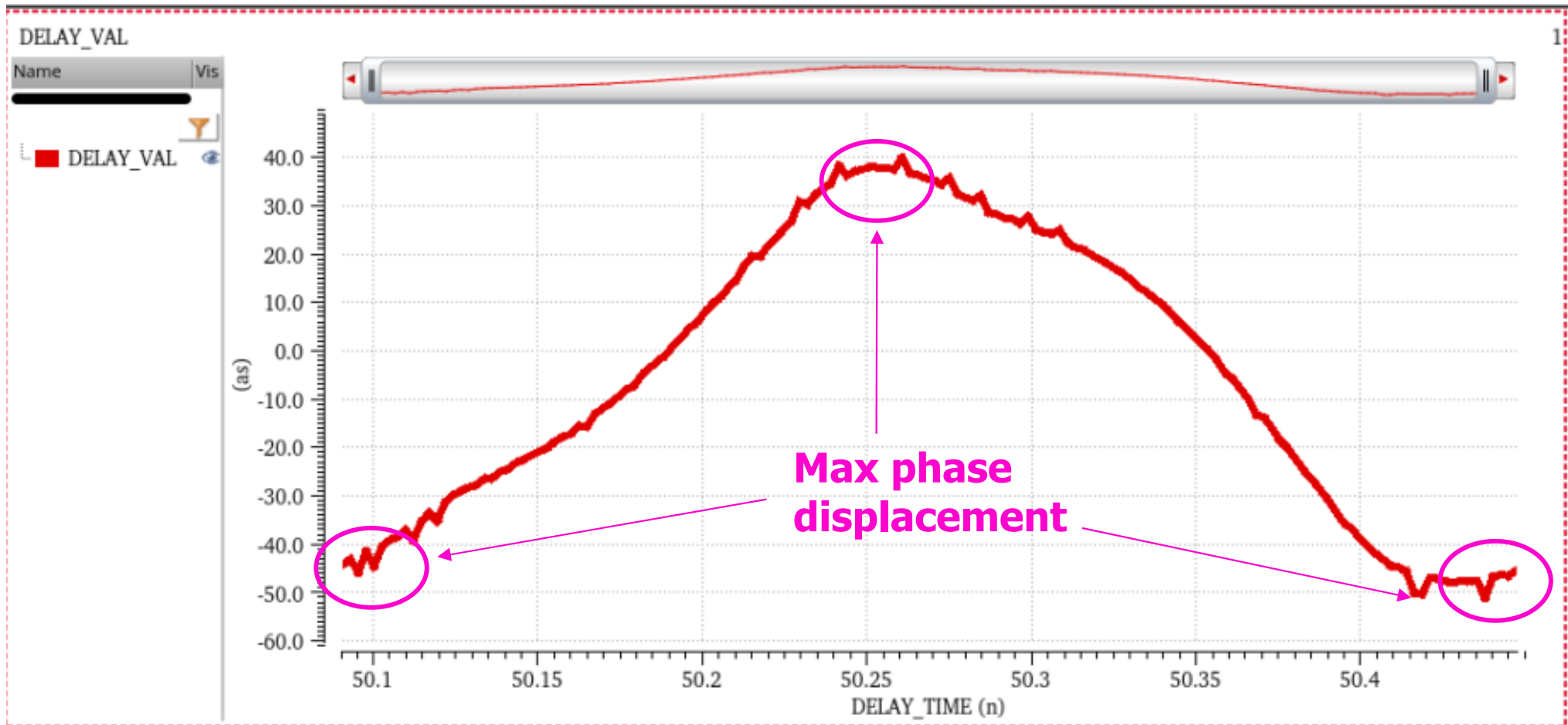
- The phase displacement should look something like this, this is the un-normalized raw delay value between VCO 1 and VCO 2

ISF Sanity Check



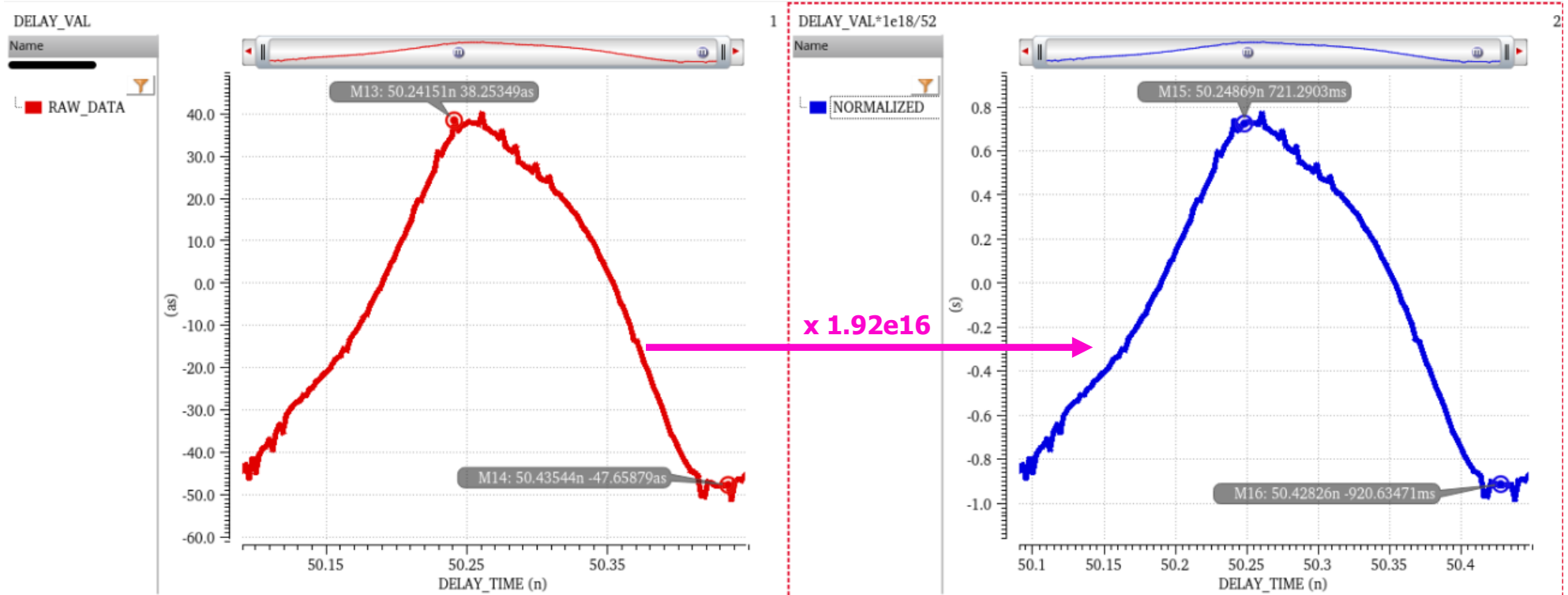
- Overall the maximum phase displacement should occur with injection at the zero crossings of the differential VCO output, and the minimum phase displacement should occur at the peaks of the differential outputs

ISF Sanity Check Continued



- From the previous slides, the zero crossing times line up with the peak phase displacement on the ISF

ISF Normalize and Compare



- Take all of your generated ISF curves(save as psf) and multiply by a normalization constant that makes the absolute peak 1
 - In the example above the absolute peak is negative and this is normalized to -1
- For comparison use the same multiplication factor for the ring and LC-VCO given that the magnitude and width of the injected currents are the same(the total injected charge)

Ring Oscillator Note

- For the ring oscillator you might need to change the overall pulse width to be smaller to fit into the rise and fall times of the ring oscillator which is where the ISF peaks
- If you change your pulse width to be narrower, scale the pulse magnitude by the same amount to keep the injected charge the same while maintaining the ring oscillator in the linear range
- Overall, to compare the ring oscillator and VCO the total injected charge to both should be the same