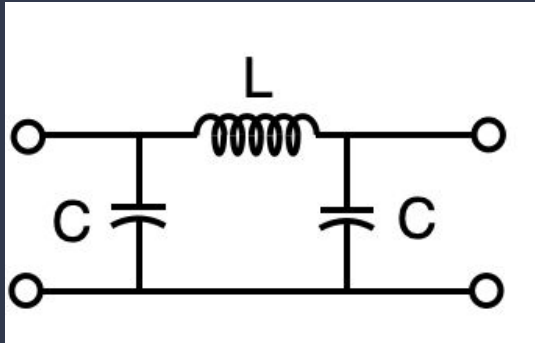


Pi Phase Shifter

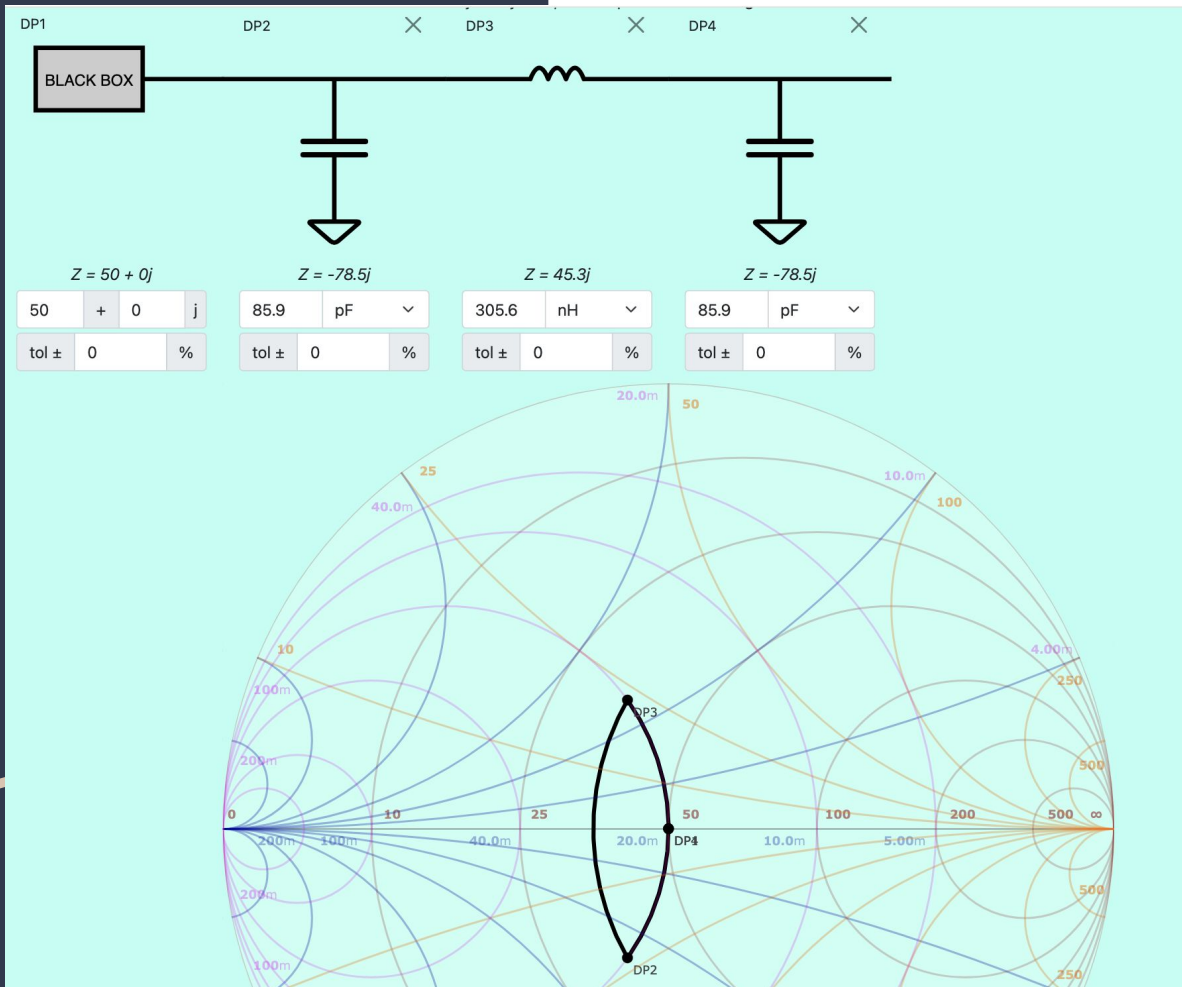
By: Kyle Woo

A dark blue diagonal gradient bar that starts from the bottom left corner and extends towards the top right corner, covering the lower half of the slide.

What is pi phase shifter.



- The phase shifter provides precise phase control at a specific frequency by leveraging reactive components to manipulate the signal's phase and impedance.
- A π -phase shifter introduces a “specific phase shift” to a signal
 - Composed of: two shunt capacitors (C) and one series inductor (L)
- Capacitors (C): Add **phase lead** (negative reactance).
- Inductor (L): Adds **phase lag** (positive reactance).

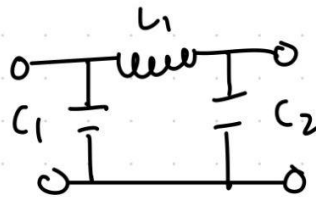


$$f = 23.6 \text{ MHz}$$

$$\omega = 2\pi f = 1.482 \times 10^8$$

Phase of 130° shift $\rightarrow 65^\circ$ for half wavelength π phase shifter

Radians: $\frac{65\pi}{180}$



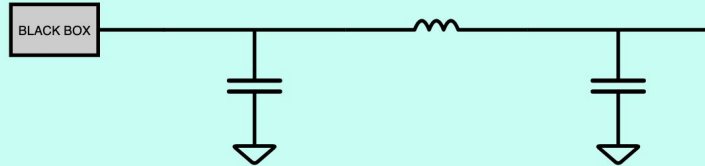
$$L\omega = Z_0 \sin(\beta l)$$

$$L = \frac{Z_0 \sin(\beta l)}{\omega} = \frac{50 (0.906)}{1.482 \times 10^8} = 305.6 \text{ nH}$$

$$C\omega = \frac{\sin(\beta l)}{Z_0 (1 + \cos(\beta l))}$$

$$C = \frac{\sin(\beta l)}{\omega Z_0 (1 + \cos(\beta l))} = \frac{(0.906)}{50 (1.482 \times 10^8) (1 + 0.423)} = 85.9 \text{ pF}$$

DP1 DP2 DP3 DP4



$Z = 0 - 178j$

0	+	-178	j
tol ±	0		%

$Z = -78.5j$

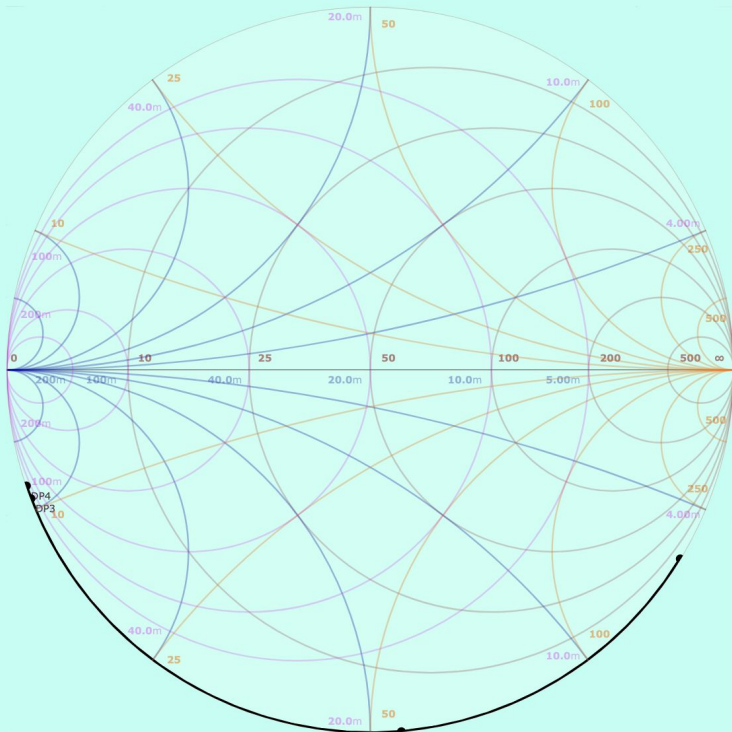
85.9	pF	▼
tol ±	0	%

$Z = 45.3j$

305.6	nH	▼
tol ±	0	%

$Z = -78.5j$

85.9	pF	▼
tol ±	0	%



The actual values were:
37.7pF for the initial capacitor

85.9pF for the two parallel capacitors ($39\text{pF} + 82\text{pF}$)
301nH for the inductor (subject to slight variance due to stretch and compression of coils)



Sweep control

Start 10MHz Center 20MHz
Stop 30MHz Span 20MHz
Segments 3 66.23kHz/step

Sweep settings ...

100%

Sweep

Stop

Markers

Marker 1 23.64235MHz ■ ●
Marker 2 10MHz ■ ●
Marker 3 10MHz ■ ●
☐ Enable Delta Marker ☐ Reference
Hide data Locked ●

TDR

Estimated cable length: 0.821m

Time Domain Reflectometry ...

Marker 1

Frequency: 23.6424 MHz
Impedance: $-j175\ \Omega$
Series L: $-1.1769\ \mu\text{H}$
Series C: $38.507\ \text{pF}$
Parallel R: $-\Omega$
Parallel X: $38.506\ \text{pF}$

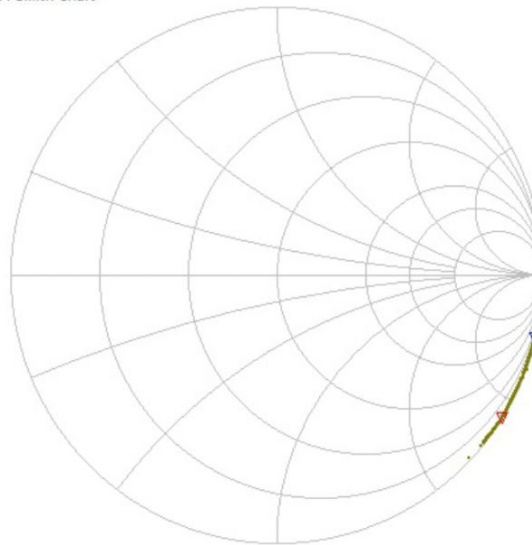
VSWR: inf
Return loss: 0.016 dB
Quality factor: 281.8
S11 Phase: -31.92°
S21 Gain: $-87.387\ \text{dB}$
S21 Phase: 57.43°

Marker 2

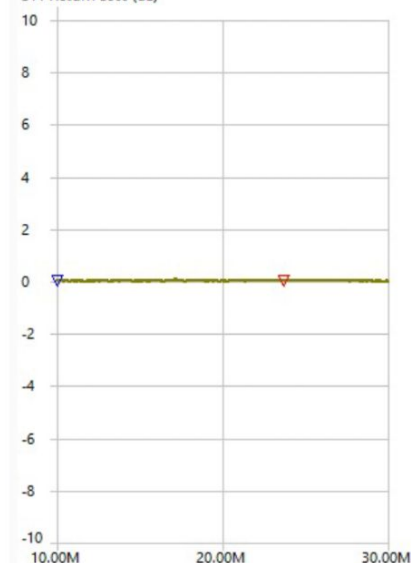
Frequency: 10.0000 MHz
Impedance: $-j430\ \Omega$
Series L: $-6.85\ \mu\text{H}$
Series C: $36.979\ \text{pF}$
Parallel R: $-\Omega$
Parallel X: $36.978\ \text{pF}$

VSWR: inf
Return loss: 0.008 dB
Quality factor: 250.1
S11 Phase: -13.25°
S21 Gain: $-92.248\ \text{dB}$
S21 Phase: -145.01°

S11 Smith Chart



S11 Return Loss (dB)

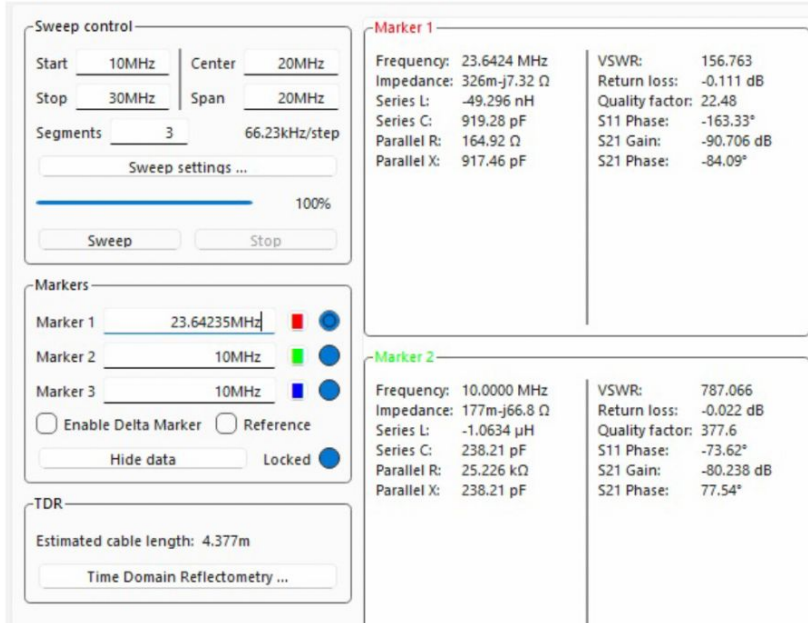


Marker 1

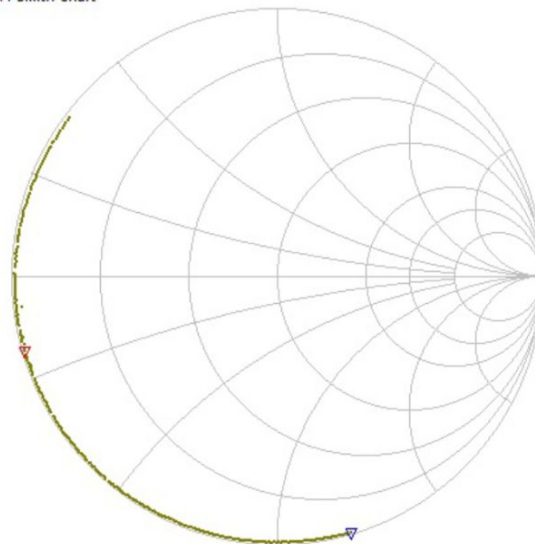
Frequency: 23.6424 MHz
Impedance: $-j175\ \Omega$
Series L: $-1.1769\ \mu\text{H}$
Series C: $38.507\ \text{pF}$
Parallel R: $-\Omega$
Parallel X: $38.506\ \text{pF}$

VSWR: inf
Return loss: 0.016 dB
Quality factor: 281.8
S11 Phase: -31.92°
S21 Gain: $-87.387\ \text{dB}$
S21 Phase: 57.43°

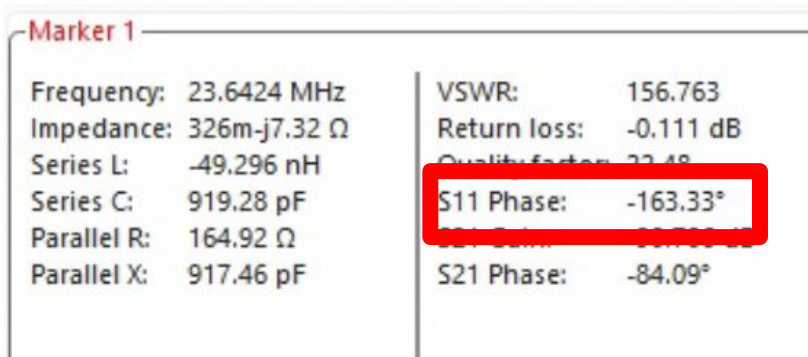
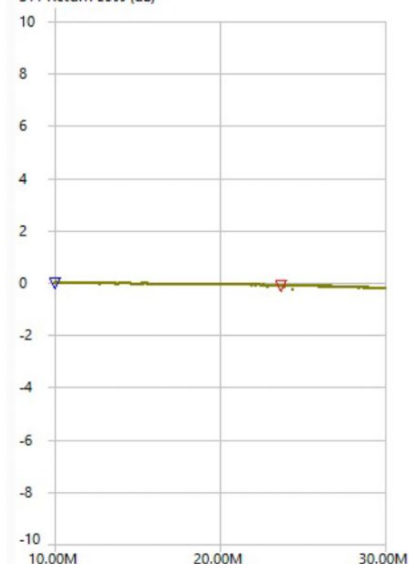
Initial phase was around
-32 degrees for the singular
capacitor



S11 Smith Chart

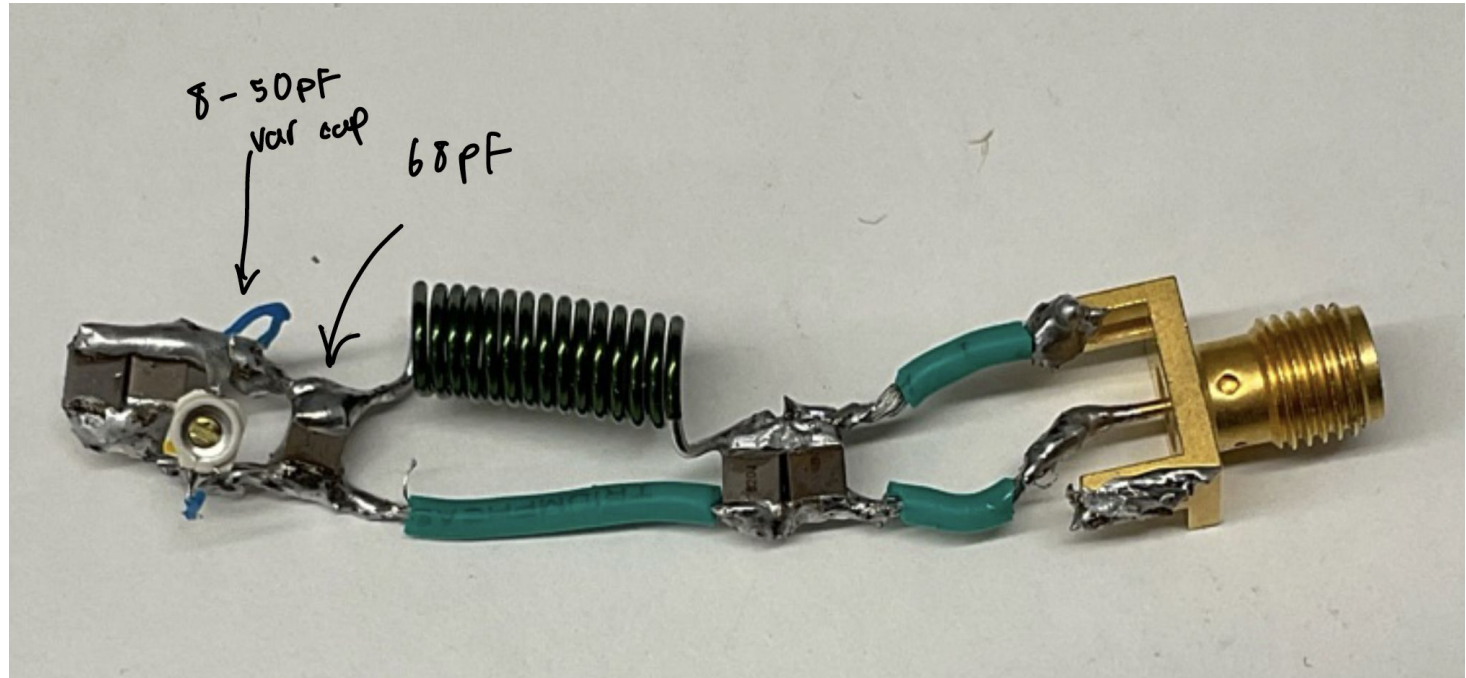


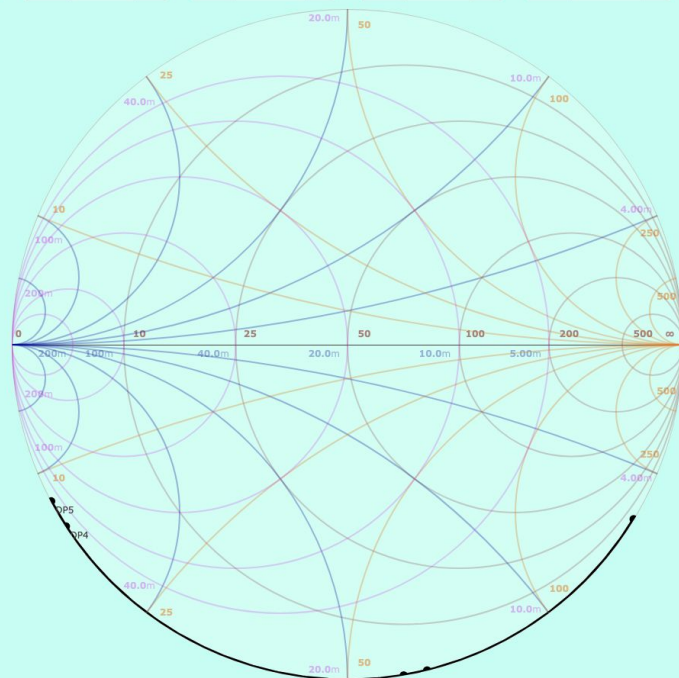
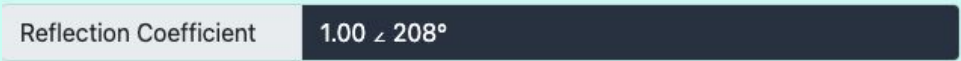
S11 Return Loss (dB)

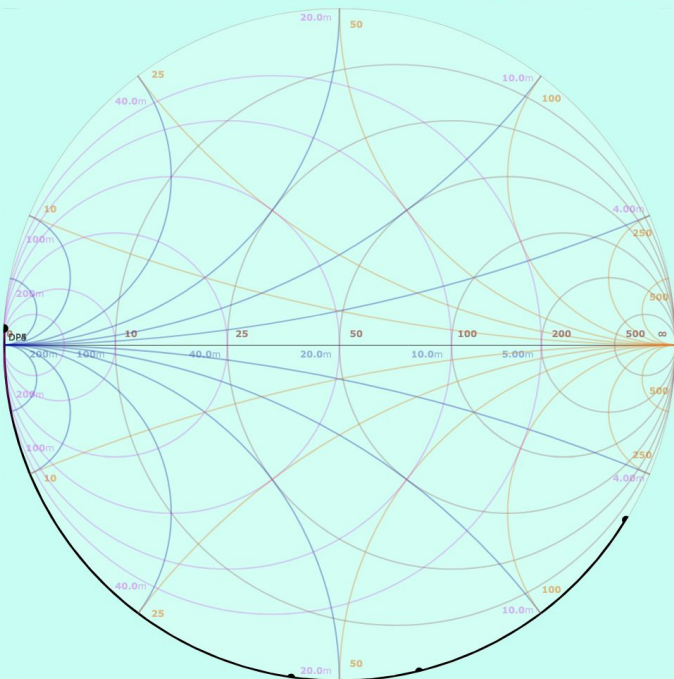
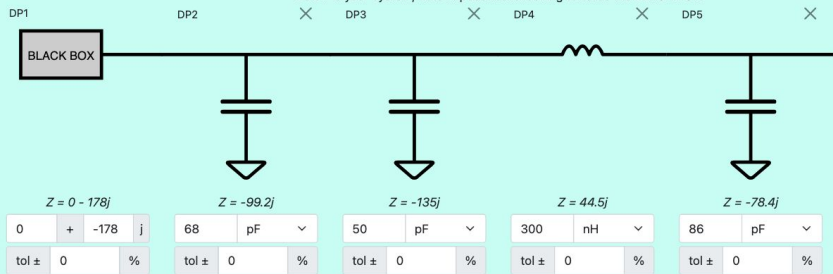


Had a phase shift of approximately 130 degrees.

Now we move onto to the version with a variable cap



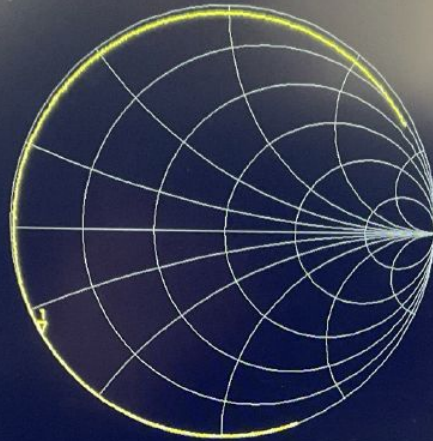




Reflection Coefficient

1.00 \angle 177°

Tr 1 S11 Smith 1.000U/ 1.00U



► 1: 23.592 MHz 131.13 mΩ
507.47 pF -13.29 Ω

1

>Ch1: Start 10.0000 MHz —

Stop 40.0000 MHz

Tr 2 S11 LogM 10.00dB/ 0.00dB



► 1: 23.592 MHz -0.04 dB

2

>Ch1: Start 10.0000 MHz —

Stop 40.0000 MHz

The measured phase is roughly -160 degrees, which matches our intended target. When the variable capacitor is adjusted, the phase changes by about ± 20 degrees in either direction.