# Simulation Tab

# Simulation Tab Explained

The Simulation tab provides visual analysis of your VIC circuit design. It generates frequency response curves, time-domain waveforms, and key performance metrics that help you understand and optimize circuit behavior.

# Simulation Overview

The simulation performs several types of analysis:

### 1. Frequency Domain Analysis

Sweeps through a frequency range to show how the circuit responds at different frequencies.

### 2. Impedance Analysis

Shows how circuit impedance varies with frequency, identifying resonant points.

### 3. Time Domain Analysis

Simulates actual voltage and current waveforms during pulse operation.

### 4. Ring-down Analysis

Shows how oscillations decay after excitation stops.

# Frequency Response Display

The frequency response plot shows amplitude vs. frequency:

```
Amplitude
    ↑
    |
    |            /\
    |           /  \            ← Secondary resonance
    |          /    \
```

```
|          /       \
|   /\    /         \
|  /  \  /           \
| /    \/             \
|/      X              \
└─────────────────────────→ Frequency (kHz)
    ↑           ↑
 Primary     Secondary
 resonance   resonance
```

# Key Features in Plot

| Feature | What It Means | Ideal Characteristic |
|---|---|---|
| Peak Height | Voltage magnification at resonance | Higher = more voltage gain |
| Peak Sharpness | Q factor (sharp = high Q) | Depends on application |
| Peak Location | Resonant frequency $f_0$ | Should match design target |
| -3dB Bandwidth | Frequency range at 70.7% of peak | Narrower = higher Q |
| Multiple Peaks | Primary and secondary resonances | Aligned for max transfer |

# Calculated Metrics

The simulation calculates and displays these key values:

## Resonance Parameters

| | |
|---|---|
| **Primary $f_0$:** | Resonant frequency of L1-C1 tank |
| **Secondary $f_0$:** | Resonant frequency of L2-$C_{wfc}$ tank |
| **Match Status:** | How well primary and secondary are tuned |

## Q Factor Metrics

| | |
|---|---|
| **Primary Q:** | Q factor of primary circuit |
| **Secondary Q:** | Q factor of secondary circuit |
| **System Q:** | Effective Q of coupled system |

## Performance Metrics

| | |
|---|---|
| **Voltage Magnification:** | $V_{out}/V_{in}$ at resonance |
| **Bandwidth:** | -3dB frequency range |
| **Ring-down Time:** | Time constant τ = 2L/R |
| **Ring-down Cycles:** | Oscillation cycles during decay |

# Impedance Plot

Shows circuit impedance magnitude and phase vs. frequency:

```
|Z| (Ω)                          Phase
   ↑                                ↑
   |      /\                        |         /———
   |     /  \     ← Peak at        |        /
   |    /    \      resonance      |       /
   |   /      \                     |————————╳  ← 0° at f₀
   |  /        \                    |      /
   | /          \                   |     /
   |/            \                  |———/————
   └──────────────────→ f          └──────────────→ f
```

# Interpreting Impedance

- **Peak impedance:** Maximum at parallel resonance
- **Minimum impedance:** At series resonance points

- **Phase = 0°:** Indicates resonant frequency
- **Positive phase:** Inductive behavior (current lags)
- **Negative phase:** Capacitive behavior (current leads)

# Time Domain Waveforms

The time-domain view shows actual voltage and current over time:

## Waveforms Displayed:

- **Input Voltage:** The driving pulse waveform
- **Primary Current:** Current through L1
- **WFC Voltage:** Voltage across the water cell
- **WFC Current:** Current through the cell

## What to Look For:

- Voltage build-up during resonance
- Ring-down oscillations after pulse ends
- Phase relationship between V and I
- Settling time and stability

# Ring-Down Display

Shows oscillation decay after excitation stops:

```
Voltage
   ↑
   |/\
   |  \/\
   |     \/\
   |        \/\
   |           \/\
```

```
|          \/\
|            \/—— → Envelope decay
|              \
└─────────────────────→ Time

←—— τ ——→
(63% decay)
```

## Ring-Down Metrics

| Metric | Formula | Significance |
| --- | --- | --- |
| Time Constant (τ) | $\tau = 2L/R$ | Time to decay to 37% |
| Ring-down Cycles | $n \approx 0.733 \times Q$ | Oscillations before decay |
| Settling Time | $\sim 5\tau$ for 99% decay | Time to reach steady state |

# Warning Indicators

The simulation flags potential issues:

| Warning | Meaning | Action |
| --- | --- | --- |
| ⚠ Near SRF | Operating frequency close to choke SRF | Reduce frequency or redesign choke |
| ⚠ Low Q | Q factor below recommended threshold | Reduce losses (DCR, water R) |
| ⚠ Frequency Mismatch | Primary and secondary not aligned | Adjust C1 or component values |
| ⚠ High Voltage | Magnified voltage exceeds safe limits | Verify insulation ratings |

# Using Simulation Results

## Design Iteration Process:

1. Run initial simulation with your component values

2. Check if resonant frequency matches your target
3. Evaluate Q factor—is it sufficient for your goals?
4. Look for warnings and address them
5. Adjust parameters and re-simulate
6. Compare before/after to verify improvements

**Pro Tip:** Save your circuit profile before making changes. This allows you to compare different configurations side-by-side and roll back if needed.

*Next: Circuit Optimization Strategies →*

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Revision #1
Created 2026-01-01 20:45:26 UTC by Chris Bake
Updated 2026-01-01 20:45:37 UTC by Chris Bake