# Resonant Matching

# Matching WFC to Circuit

For optimal VIC performance, the WFC must be properly matched to the circuit—its capacitance must resonate with the secondary choke at the desired operating frequency. This page covers the matching process and strategies for achieving good resonance.

## The Matching Problem

In a VIC circuit, we have three interdependent parameters:

$$f? = 1 / (2??(L? \times C_{wfc}))$$

### Design Challenge:

> - **$f_0$** is set by the pulse generator (typically 1-50 kHz)
> - **$C_{wfc}$** is constrained by electrode geometry and water properties
> - **$L_2$** must be designed to complete the resonant match

## Matching Strategies

### Strategy 1: Design L? for Given WFC

When WFC geometry is fixed (existing cell):

1. Measure $C_{wfc}$ with LCR meter
2. Choose target frequency $f_0$
3. Calculate required $L_2$:

$$L? = 1 / (4?^2 f?^2 C_{wfc})$$

## Example:

- $C_{wfc}$ = 10 nF (measured)
- $f_0$ = 10 kHz (desired)
- $L_2 = 1 / (4\pi^2 \times 10^{42} \times 10^{-8}) = 25.3$ mH

# Strategy 2: Design WFC for Given L?

When using a pre-wound or available choke:

1. Measure $L_2$ with LCR meter
2. Choose target frequency $f_0$
3. Calculate required $C_{wfc}$:

$$C_{wfc} = 1 / (4?^2 f?^2 L?)$$

4. Design electrodes to achieve that capacitance

# Strategy 3: Tune with Additional Capacitor

When exact match isn't achievable:

### If $C_{wfc}$ is too low:

Add capacitor in parallel with WFC

$C_{total} = C_{wfc} + C_{tune}$

### If $C_{wfc}$ is too high:

Add capacitor in series with WFC (less common)

$1/C_{total} = 1/C_{wfc} + 1/C_{series}$

# Impedance Matching Considerations

Beyond frequency matching, impedance levels affect energy transfer:

### Secondary Characteristic Impedance:

Z? = ?(L?/$C_{wfc}$)

### Example Comparison:

| $L_2$ | $C_{wfc}$ | $f_0$ | $Z_0$ |
|---|---|---|---|
| 10 mH | 25 nF | 10 kHz | 632 Ω |
| 50 mH | 5 nF | 10 kHz | 3162 Ω |
| 100 mH | 2.5 nF | 10 kHz | 6325 Ω |

**Higher $Z_0$ = Higher voltage for same energy**

# Primary-Secondary Matching

For dual-resonant VIC with both L1-C1 and L2-WFC tanks:

| Configuration | Condition | Effect |
|---|---|---|
| Same frequency | $f_{0,pri} = f_{0,sec}$ | Maximum voltage magnification |
| Slight offset | $f_{0,sec} \approx 0.95\text{-}1.05 \times f_{0,pri}$ | Broader response, easier tuning |
| Harmonic | $f_{0,sec} = 2\times$ or $3\times$ $f_{0,pri}$ | Secondary resonates on harmonic |

# Finding Resonance

## Method 1: Frequency Sweep

1. Connect oscilloscope across WFC
2. Sweep generator frequency slowly
3. Watch for voltage peak
4. Note frequency of maximum amplitude

## Method 2: Phase Measurement

1. Monitor current and voltage simultaneously
2. At resonance, current and voltage are in phase (phase = 0°)
3. Below resonance: capacitive (current leads)
4. Above resonance: inductive (current lags)

## Method 3: Minimum Current

For a series resonant circuit driven from a voltage source:

- Current is minimum at anti-resonance (parallel resonance)
- May need to reconfigure measurement

# Troubleshooting Mismatch

| Symptom | Likely Cause | Solution |
|---|---|---|
| No clear resonance peak | Very low Q (high losses) | Reduce water conductivity, lower DCR |
| Resonance far from expected | Wrong L or C values | Measure components, recalculate |

| Symptom | Likely Cause | Solution |
|---|---|---|
| Resonance drifts during operation | Temperature change, bubbles | Allow warmup, improve gas venting |
| Multiple resonance peaks | Coupled modes, parasitics | Check for stray coupling |

# Fine Tuning Tips

## For L? Adjustment:

- Add/remove turns (large adjustment)
- Adjust core gap if gapped (medium)
- Use adjustable ferrite slug (fine)

## For $C_{wfc}$ Adjustment:

- Add parallel capacitor (increases C)
- Change water level (changes effective area)
- Adjust electrode spacing (if possible)

## For Frequency Adjustment:

- PLL feedback to track resonance
- Variable frequency oscillator
- Multiple operating modes

# Complete Matching Checklist

1. ☐ Measure or calculate $C_{wfc}$
2. ☐ Measure or calculate $L_2$
3. ☐ Calculate expected $f_0 = 1/(2\pi\sqrt{(L_2C)})$
4. ☐ Verify $f_0$ is within driver frequency range
5. ☐ Calculate $Z_0 = \sqrt{(L_2/C)}$
6. ☐ Estimate $R_{total}$ (DCR + solution R)
7. ☐ Calculate $Q = Z_0/R$
8. ☐ Build circuit and measure actual resonance
9. ☐ Fine-tune as needed
10. ☐ Verify Q meets design goals

**VIC Matrix Calculator:** The Simulation tab performs complete matching analysis. Enter your choke and WFC parameters, and it calculates resonant frequency, Q factor, voltage magnification, and shows warnings if components are mismatched.

*Chapter 6 Complete. Next: The VIC Matrix Calculator →*

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