Optimization

Circuit Optimization Strategies

This page covers practical strategies for optimizing your VIC circuit design using the calculator. Learn how to achieve specific goals like maximizing Q, hitting a target frequency, or optimizing voltage magnification.

Optimization Goals

Different applications may prioritize different characteristics:

Goal	Optimize For	Trade-offs
Maximum Voltage	High Q, matched resonance	Narrower bandwidth, critical tuning
Stable Operation	Moderate Q, wide bandwidth	Lower peak voltage
Frequency Flexibility	Lower Q, broader response	Reduced magnification
Energy Efficiency	Minimize losses (DCR, R_{sol})	May require larger components

Strategy 1: Maximizing Q Factor

Q determines voltage magnification and selectivity. To maximize Q:

Reduce Choke DCR:

- Use larger wire gauge (lower AWG number)
- Use copper instead of aluminum

- Minimize wire length (fewer turns with higher-μ core)
- Consider Litz wire for high frequencies

Reduce Solution Resistance:

- Increase water conductivity slightly (add small amount of electrolyte)
- Increase electrode area
- Decrease electrode gap (but watch capacitance change)
- Ensure good electrode contact

Increase L or Decrease C:

- Higher L/C ratio raises $Z_0 = \sqrt{(L/C)}$
- $Q = Z_0/R$, so higher Z_0 means higher Q
- Must maintain same $f_0 = 1/(2\pi\sqrt{LC})$

Q Factor Relationships:

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Q = 2?f?L/R = Z?/R = ?(L/C)/R
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To double Q: halve R, or quadruple L (while quartering C to maintain f_0)

Strategy 2: Hitting Target Frequency

When you need a specific resonant frequency:

Approach A: Fixed L, Adjust C

1. Design or select choke for desired L
2. Calculate required C: $C = 1/(4\pi^2 f_0^2 L)$
3. If $C_{wfc} \neq$ required C:
    - Add parallel capacitor if C_{wfc} is too low
    - Modify electrode geometry if adjustment is large

Approach B: Fixed C, Adjust L

1. Measure or calculate WFC capacitance
2. Calculate required L: $L = 1/(4\pi^2 f_0^2 C)$
3. Design choke for that inductance

Approach C: Adjust Both

1. Start with practical component ranges
2. Use calculator to explore L/C combinations
3. Choose combination that also optimizes Q

Fine-Tuning Frequency

Adjustment	Effect on f_0	Typical Range
Add parallel capacitor	Decreases f_0	1-50 nF typical
Adjust core gap (if gapped)	Changes L → changes f_0	±20% L adjustment
Add/remove turns	Changes L significantly	$L \propto N^2$

Adjustment	Effect on f_0	Typical Range
Change water level	Changes C → changes f_0	Proportional to area

Strategy 3: Matching Primary to Secondary

For maximum energy transfer, align primary and secondary resonances:

Exact Match ($f?_{pri} = f?_{sec}$):

- Maximum voltage transfer at resonance
- Narrow combined response
- Requires precise tuning

Slight Offset (5-10% difference):

- Broader frequency response
- More tolerant of drift
- Slightly reduced peak transfer

Calculator Approach:

1. Design secondary (L2 + WFC) first—this is usually more constrained
2. Calculate secondary f_0

3. Select C1 to tune primary to match: $C1 = 1/(4\pi^2 f_0^2 L1)$
4. Verify with simulation

Strategy 4: Optimizing for Available Components

When working with existing components:

Step 1: Characterize What You Have

- Measure L of available chokes
- Measure C of your WFC
- Note DCR values

Step 2: Calculate Natural Resonance

`f? = 1/(2??LC)`

This is where your circuit wants to resonate.

Step 3: Evaluate Performance

- Is f_0 in your driver's range?
- Is Q acceptable at this frequency?
- Are there SRF issues?

Step 4: Adjust as Needed

- Add tuning capacitor if f_0 is too high
- Consider different choke if f_0 is way off
- Accept the natural f_0 if performance is good

Sensitivity Analysis

Understanding how sensitive your design is to variations:

Parameter Change	Effect on f_0	Effect on Q
L +10%	f_0 -5%	Q +5%
C +10%	f_0 -5%	Q -5%
R +10%	No change	Q -10%
Temperature +10°C	f_0 +2% (due to ε_r drop)	Q +5% (R_{sol} drops)

Common Optimization Mistakes

? Chasing Extreme Q

Very high Q makes the circuit sensitive to drift and hard to tune. Q of 50-100 is often more practical than Q > 200.

? Ignoring SRF

A design that works on paper fails if operating frequency is too close to SRF. Always check this!

? Forgetting Water Resistance

Solution resistance often dominates losses. Pure distilled water has higher resistance than you might expect.

? Not Accounting for Parasitics

Real circuits have stray inductance and capacitance. Leave margin for these effects.

? Over-constraining the Design

If you fix too many parameters, you may have no degrees of freedom for optimization.

Optimization Checklist

1. ☐ Define your primary optimization goal
2. ☐ Identify fixed constraints (available components, frequency range)
3. ☐ Calculate baseline performance
4. ☐ Identify largest loss contributor (DCR vs R_{sol})
5. ☐ Make targeted improvements to dominant loss
6. ☐ Verify SRF is >3× operating frequency
7. ☐ Check that primary/secondary are reasonably matched
8. ☐ Run simulation to verify improvements
9. ☐ Consider sensitivity to variations
10. ☐ Document final design parameters

Remember: Optimization is iterative. The calculator makes it easy to try variations quickly. Don't expect to find the optimal design on the first try—explore the design space!

Next: Interpreting Calculation Results →

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