

Primary Side

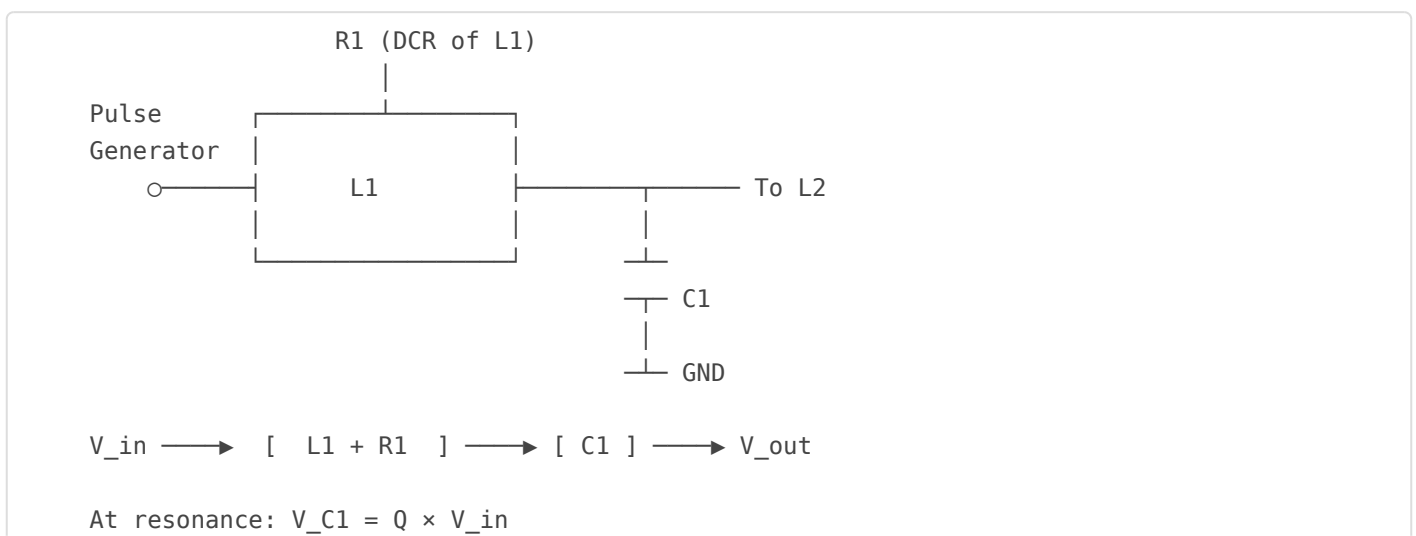
Primary Side (L1-C1) Analysis

The primary side of the VIC consists of the first inductor (L1) and tuning capacitor (C1). This stage receives the driving signal and provides the first stage of voltage magnification. Understanding its behavior is crucial for successful VIC design.

Primary Tank Circuit

L1 and C1 form a series resonant tank circuit. At the resonant frequency, this circuit:

- Has minimum impedance (ideally just the DC resistance)
- Draws maximum current from the source
- Develops magnified voltage across L1 and C1



Resonant Frequency Calculation

Primary Resonant Frequency:

$$f_r = \frac{1}{\sqrt{L1 \times C1}}$$

Rearranging to Find Components:

$$L1 = 1 / (4\pi^2 f^2 C1)$$

$$C1 = 1 / (4\pi^2 f^2 L1)$$

Example Calculations

Target f_0	Given L1	Required C1
10 kHz	1 mH	253 nF
10 kHz	10 mH	25.3 nF
25 kHz	1 mH	40.5 nF
50 kHz	500 μ H	20.3 nF

Q Factor of Primary Side

The Q factor determines voltage magnification:

Q Factor:

$$Q_{L1C} = (2\pi \times f \times L1) / R1 = X_{L1} / R1$$

Voltage Magnification:

$$V_{C1} = Q_{L1C} \times V_{in}$$

Example:

- $f_0 = 10 \text{ kHz}$, $L1 = 10 \text{ mH}$, $R1 = 10 \Omega$
- $X_{L1} = 2\pi \times 10,000 \times 0.01 = 628 \Omega$
- $Q = 628 / 10 = 62.8$
- With 12V input: $V_{C1} = 62.8 \times 12 = 754V$

Characteristic Impedance

The characteristic impedance of the primary tank affects matching:

$$Z_0 = \sqrt{L_1 / C_1}$$

Relationship to Q:

$$Q = Z_0 / R_1$$

Higher Z_0 (more L, less C) means higher Q for same resistance.

Design Trade-offs

Design Choice	Advantages	Disadvantages
High L1, Low C1	Higher Z_0 , potentially higher Q	More wire, higher DCR, harder to wind
Low L1, High C1	Less wire, lower DCR, easier construction	Lower Z_0 , may need larger capacitor
High frequency	Smaller components, lower SRF concern	Skin effect losses, harder switching
Low frequency	Lower losses, easier switching	Larger components, SRF may be issue

Current and Power Considerations

At resonance, the circuit draws maximum current:

Resonant Current:

$$I_{res} = V_{in} / R_1$$

Power from Source:

$$P_{in} = V_{in}^2 / R_1 = I_{res}^2 \times R_1$$

Reactive Power (circulating):

$$P_{reactive} = V_{C1} \times I_{res} = Q \times P_{in}$$

Note: The reactive power circulates between L1 and C1 but is not consumed.

Bandwidth and Tuning Sensitivity

The 3dB bandwidth of the primary tank:

$$BW = f_0 / Q_{L1C}$$

Example:

$$f_0 = 10 \text{ kHz}, Q = 50 \rightarrow BW = 200 \text{ Hz}$$

The driving frequency must be within ± 100 Hz of f_0 for good response.

Practical Implication:

High-Q circuits are sensitive to component tolerances and temperature drift. You may need PLL (Phase-Locked Loop) control to maintain resonance.

Component Selection Guidelines

L1 (Primary Choke)

- **Inductance:** 100 μ H to 100 mH typical
- **DCR:** As low as practical (determines Q)
- **SRF:** Should be well above operating frequency (10 \times minimum)
- **Core:** Ferrite, iron powder, or air-core depending on frequency
- **Wire:** Copper preferred; resistance wire reduces Q

C1 (Tuning Capacitor)

- **Value:** Selected to resonate with L1 at desired frequency
- **Voltage rating:** Must exceed $Q \times V_{in}$
- **Type:** Film (polypropylene, polyester) or ceramic
- **ESR:** Low ESR for minimal losses
- **Temperature stability:** NPO/C0G ceramic or film preferred

Practical Assembly Tips

1. **Measure L1 accurately:** Use an LCR meter at multiple frequencies
2. **Start with calculated C1:** Then fine-tune for best response
3. **Use variable capacitor or parallel caps:** For easy tuning
4. **Check for SRF:** Ensure L1's SRF is well above f_0
5. **Monitor temperature:** Component values drift with heat

VIC Matrix Calculator: The calculator determines optimal L1 and C1 values based on your target frequency and available components. It also shows the expected Q factor and voltage magnification.

Next: Secondary Side (L2-WFC) Analysis →

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