Experimental Validation

Experimental Validation Methods

Theoretical calculations and simulations must be validated with actual measurements. This page covers practical techniques for measuring VIC circuit parameters and comparing results to predictions.

Essential Test Equipment

Equipment	Purpose	Key Specifications
Oscilloscope	Waveform viewing, frequency measurement	2+ channels, 100+ MHz bandwidth
Function Generator	Provide test signals	1 Hz - 1 MHz, variable duty cycle
LCR Meter	Measure L, C, R	Multiple test frequencies (1 kHz, 10 kHz)
Multimeter	DC resistance, voltage	True RMS, low-ohm capability
Current Probe	Non-contact current measurement	AC/DC, appropriate bandwidth
High-Voltage Probe	Measure high voltages safely	1000:1 or 100:1, rated voltage

Component Verification

Measuring Inductance

Method 1: LCR Meter (Preferred)

1. Set LCR meter to inductance mode
2. Select test frequency (1 kHz typical)
3. Connect inductor, read value
4. Repeat at 10 kHz to check for frequency dependence

Method 2: Resonance with Known C

1. Connect inductor with known capacitor C
2. Drive with function generator, sweep frequency
3. Find resonant frequency f_0 (voltage peak)
4. Calculate: $L = 1/(4\pi^2 f_0^2 C)$

Measuring DCR

Four-Wire (Kelvin) Measurement:

For accurate low-resistance measurement, use 4-wire method to eliminate lead resistance:

- Use dedicated low-ohm meter
- Or use LCR meter in R mode
- Allow reading to stabilize (self-heating)

Expected accuracy: ±1-5% compared to calculated value

Measuring WFC Capacitance

1. Fill WFC with water at operating temperature
2. Measure with LCR meter at 1 kHz and 10 kHz
3. Values should be similar (if EDL effects are small)
4. Note the ESR reading as well

Expected accuracy: ±10-20% compared to calculated value

Resonant Frequency Measurement

Frequency Sweep Method

Setup:

```
Function ──→ [VIC    ] ──→ Oscilloscope
Generator    [Circuit]      Ch1: Input
                           Ch2: Output (across WFC)
```

Procedure:

1. Set function generator to low amplitude sine wave
2. Start at low frequency (1/10 of expected f_0)
3. Slowly increase frequency while watching Ch2 amplitude
4. Note frequency of maximum amplitude—this is f_0
5. Also note -3dB frequencies (where amplitude = 0.707 × peak)

Calculate Q from Measurement:

Q = f? / (f_{high} - f_{low}) = f? / BW

Phase Measurement Method

1. Display both input current and output voltage
2. Use X-Y mode or measure phase with oscilloscope
3. At resonance, phase difference = 0°
4. More accurate than amplitude peak for high-Q circuits

Q Factor Measurement

Method 1: Bandwidth

Measure -3dB bandwidth and calculate:

```
Q = f? / BW
```

Method 2: Ring-Down

1. Excite circuit with single pulse at f_0
2. Observe decaying oscillation on oscilloscope
3. Count cycles to decay to 1/e (37%)
4. Q ≈ π × (number of cycles to 1/e decay)

Alternatively, measure time constant τ:

```
? = 2L/R = Q/(?f?)
```

Method 3: Voltage Magnification

1. Measure input voltage V_{in}
2. Measure output voltage V_{out} at resonance
3. $Q \approx V_{out}/V_{in}$

Caution: This assumes lossless input coupling. Actual Q may be higher due to source impedance effects.

Comparing Calculated vs. Measured

Parameter	Acceptable Difference	If Larger Difference
Inductance	±20%	Check core μ_r, turn count
DCR	±10%	Check wire gauge, connections
WFC Capacitance	±20%	Check geometry, water level
Resonant Frequency	±15%	Check L and C values
Q Factor	±30%	Look for missing losses

Troubleshooting Discrepancies

Measured f? Lower than Calculated:

- Stray capacitance adding to total C
- Actual L higher than calculated
- Check for loose connections (add L)

Measured f? Higher than Calculated:

- Actual L lower (core saturation, wrong μ_r)
- WFC capacitance overestimated
- Air bubbles reducing effective C

Measured Q Lower than Calculated:

- Additional losses not accounted for
- Core losses at operating frequency
- Poor connections adding resistance
- Radiation losses at high frequency

No Clear Resonance Observed:

- Operating above SRF (choke is capacitive)
- Very low Q (Q < 2) makes resonance hard to see
- Measurement setup loading the circuit

Documentation Template

Record for Each Test:

```
Date: ___________
Circuit ID: ___________

COMPONENT VALUES (Calculated / Measured):
```

```
L1: _______ mH / _______ mH
L2: _______ mH / _______ mH
DCR1: _______ Ω / _______ Ω
DCR2: _______ Ω / _______ Ω
C_wfc: _______ nF / _______ nF
C1: _______ nF / _______ nF

RESONANCE (Calculated / Measured):
f₀_primary: _______ kHz / _______ kHz
f₀_secondary: _______ kHz / _______ kHz

PERFORMANCE (Calculated / Measured):
Q: _______ / _______
Bandwidth: _______ Hz / _______ Hz
V_magnification: _______ / _______

NOTES:
_________________________________
```

Safety Considerations

?? High Voltage Warning:

- VIC circuits can develop high voltages at resonance
- Always use proper high-voltage probes
- Keep one hand in pocket when probing live circuits
- Discharge capacitors before handling

?? Gas Production:

- WFC produces hydrogen and oxygen—ensure ventilation
- No open flames or sparks near operating cell
- Use appropriate gas collection if needed

Best Practice: Always compare measured values to calculator predictions. This builds confidence in both your construction skills and the calculator's accuracy. Document discrepancies—they often reveal important lessons about real-world effects.

Chapter 8 Complete. See Appendices for reference tables and formulas. →

Revision #1
Created 2026-01-01 20:47:12 UTC by Chris Bake
Updated 2026-01-01 20:47:24 UTC by Chris Bake