

# Bandwidth Ringdown

## Bandwidth & Ring-Down Decay

Understanding bandwidth and ring-down decay is essential for designing VIC circuits that maintain resonance under varying conditions and for predicting how the circuit behaves when the driving signal stops.

### Bandwidth Fundamentals

Bandwidth describes the frequency range over which a resonant circuit responds effectively. It's measured as the difference between the upper and lower frequencies where the response drops to 70.7% (-3dB) of the peak value.

#### Bandwidth Formula:

$$BW = f_0 / Q$$

Or equivalently:

$$BW = R / (2\pi L)$$

Where:

- BW = bandwidth in Hz
- $f_0$  = resonant frequency
- Q = quality factor
- R = total series resistance
- L = inductance

### Bandwidth and Q Relationship

Q Factor

Bandwidth (at  $f_0 = 10$  kHz)

Frequency Tolerance

Q = 10	1000 Hz	±5% (very forgiving)
Q = 50	200 Hz	±1% (requires tuning)
Q = 100	100 Hz	±0.5% (precise tuning needed)
Q = 200	50 Hz	±0.25% (critical tuning)

# Practical Implications of Bandwidth

## Narrow Bandwidth (High Q)

- **Advantages:** Maximum voltage magnification, better selectivity
- **Disadvantages:** Sensitive to frequency drift, requires precise tuning, may need PLL control

## Wide Bandwidth (Low Q)

- **Advantages:** Easier to tune, more stable, tolerant of component variations
- **Disadvantages:** Lower voltage magnification, less efficient energy storage

# Ring-Down Decay

When the driving signal stops, a resonant circuit doesn't immediately stop oscillating—it "rings down" as stored energy dissipates through resistance. This behavior provides insight into the circuit's Q factor.

## Decay Time Constant (?)

Decay Time Constant:

$$\tau = 2L / R$$

This is the time for the oscillation amplitude to decay to  $1/e$  ( $\approx 37\%$ ) of its initial value.

Relationship to Q:

$$\tau = Q / (\pi \times f)$$

## Decay Envelope

The amplitude of oscillations during ring-down follows an exponential decay:

$$A(t) = A_0 \times e^{-t/\tau} = A_0 \times e^{-\alpha t}$$

Where  $\alpha = R/(2L)$  is the damping factor.

## Damped Oscillation Frequency

During ring-down, the actual oscillation frequency is slightly lower than the natural frequency due to damping:

**Damped Frequency:**

$$f_d = \omega \left( \sqrt{1 - \frac{\alpha^2}{\omega^2}} \right)$$

For high-Q circuits ( $Q > 10$ ),  $f_d \approx f_0$  (the difference is negligible).

## Ring-Down Cycles

A practical measure of how long oscillations persist:

**Cycles to 1% Amplitude:**

$$N_{1\%} \approx Q \times 0.733$$

This is the number of oscillation cycles before amplitude drops to 1% of initial.

**Examples:**

- $Q = 10$ :  $\approx 7.3$  cycles to 1%
- $Q = 50$ :  $\approx 36.7$  cycles to 1%
- $Q = 100$ :  $\approx 73.3$  cycles to 1%

## Ring-Down in VIC Circuits

Understanding ring-down is important for VIC operation because:

# Pulsed Operation

- VIC circuits are typically driven by pulsed waveforms
- Between pulses, the circuit rings down
- The ring-down period affects how energy is delivered to the WFC

## Step-Charging Considerations

- Each pulse adds energy to the resonant system
- If pulses arrive before ring-down completes, energy accumulates
- This can lead to voltage build-up (step-charging effect)

## Measuring Ring-Down

To experimentally determine Q from ring-down:

1. Apply a burst of oscillations at the resonant frequency
2. Stop the driving signal and observe the decay on an oscilloscope
3. Count the number of cycles for amplitude to drop to 37% (1/e)
4.  $Q \approx \pi \times$  (number of cycles to 1/e)

**Oscilloscope Tip:** Use the "Single" trigger mode to capture the ring-down event. Measure from the point where driving stops to where amplitude reaches ~37% of initial peak.

## Summary Table

Parameter	Formula	Depends On
Bandwidth	$BW = f/Q = R/(2L)$	Resistance, inductance
Decay Time Constant	$\tau = 2L/R$	Inductance, resistance
Damping Factor	$\zeta = R/(2L)$	Resistance, inductance
Cycles to 1%	$N \approx 0.733 \times Q$	Q factor only

**Design Insight:** The VIC Matrix Calculator shows bandwidth and ring-down parameters for your circuit design. Use these to understand how sensitive your circuit will be to frequency variations and how it will behave during pulsed operation.

*Next: Voltage Magnification at Resonance →*

---

Revision #1

Created 2026-01-01 20:35:51 UTC by Chris Bake

Updated 2026-01-01 20:36:07 UTC by Chris Bake