Calculating RC Snubbers for Yoke Damping

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Abstract *¾* A common problem encountered in designing CRT displays is that of ringing in the deflection circuits. A magnetically deflected CRT beam may exhibit ringing after a retrace and appear as alternating bright and dark bars in the left side of the image (raster scan). A common solution is to add an RC snubber across the yoke coils to reduce the Q. This paper presents a simple method for calculating optimum RC component values.

Keywords *¾ Yoke, ringing, damping, snubber, modulation.*

1 Introduction

Most CRT displays use magnetic deflection whereby the sawtooth-shaped sweep current is generated by an assymetrical RLC tank circuit. This circuit is both efficient and inexpensive. However, after a retrace the current waveform must settle quickly to a new slope. This abrupt change in current can cause ringing in an underdamped deflection circuit. Any ringing in the deflection waveform will appear as distortions in the displayed image. This "velocity modulation", as it is sometimes called, results in the bunching or spreading of pixels in the left side of the image, causing both linearity an intensity (light/dark bars) distortions.

The cause of this ringing is all of the parasitic capacitances and inductances found in the typical magnetic defleciton circuit. The yoke itself is a complex circuit at high frequencies, much more than a series RL. Extra "components" can be found in wires, etch, and the parasitics of transistors, diodes, capacitors, etc. Damping of a horizontal circuit requires judicious analysis and optimization of the circuit, components, and layout.

This paper will concentrate on the damping of a yoke, although the method can be used on many other circuits using inductors or transformers. A well-known cure for damping a yoke is to place a series RC snubber across the coil. Traditionally this method involved iterative guesses of component values until a satisfactory solution is found. Optimum values can be calculated directly if a few characteristics of the yoke are known.

2 Yoke

A yoke coil is much more than just an inductor. There is series resistance (including skin effect) and inter-winding capacitance. In addition there are core loss effects from the ferrite and inter-coil coupling (horizontal to vertical). The parasitic capacitances are distributed rather than lumped making the situation even worse.

For this analysis of yoke damping we will approximate the yoke using a simple RLC equivalent circuit.

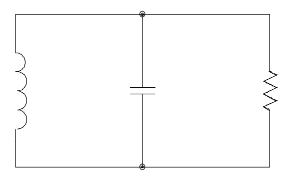

Figure 1. Yoke equivalent circuit.

The L is the coil inductance (series resistance is small enough to be ignored), C is the total inter-winding capacitance, and R is the resistance of the snubber to be added. Inductance is easy to measure and is usually specified. The capacitance is often not known but can be accurately measured by finding the self-resonant frequency (SRF) which is given by

$$f_r = \frac{1}{2p\sqrt{LC}}.$$

One method of measuring the self-resonant frequency uses the circuit shown in Figure 2.

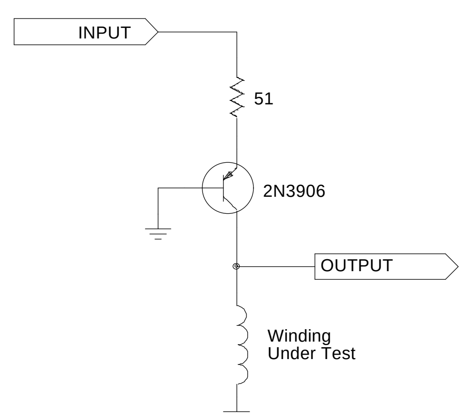

Figure 2. Test circuit for measuring SRF.

The input pulse is from a 50 Ohm generator set where high is 2V for about 1µs and low is 1V for about 20µs. The duty cycle must be small to insure enough time to capture the ringing frequency on an oscilloscope. The output voltage from this circuit appears as in Figure 3.

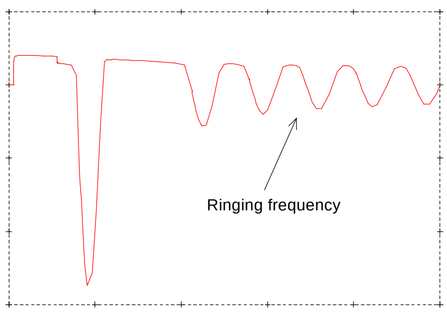

Figure 3. Oscilloscope waveform of SRF.

3 Snubber

The equivalent circuit developed in the previous section has a second order response of the form

$$T(s) = \frac{w_n^2}{s^2 + s(2zw_n) + w_n^2}$$

where the ringing frequency $\omega_n = 2\pi f_r$. Equating the characteristic equation of our circuit to T(s) and solving for R results in

$$R = \frac{1}{2z} \cdot \sqrt{\frac{L}{C}} = \frac{pf_r L}{z}.$$

Hence, the amount of damping is inversely proportional to the snubber resistance. The greater the resistance the lesser the damping. Since we want critical damping where there is no overshoot, we set ζ to about 0.7. Finally, the solution for optimum snubber resistance reduces to

$$\boxed{R \approx 4 f_r L}.$$

The reason for the capacitor in the snubber is to reduce power dissipation in the resistor. The cutoff frequency of the snubber must be low enough so that the resistor can perform its damping yet be as high as possible to reduce power consumption. The minimum frequency required is the SRF of the yoke. A cutoff frequency that is 2π times lower than the SRF conveniently results in a capacitance of

$$\boxed{C \approx \frac{1}{Rf_r}}.$$

Calculating the power dissipation in the resistor turned out to be rather complicated. It is a function of horizontal flyback time, peak voltage, duty cycle, and R and C. Power dissipation is usually on the order of a few Watts.

4 Example

A 150µH yoke is measured to have an SRF of 1MHz. The equivalent capacitance calculates to about 170pF. The snubber resistance is calculated as

$$R = 4(1MHz)(150uH) \approx 620\Omega.$$

The snubber capacitor is then calculated as

$$C = \frac{1}{(620\Omega)(1MHz)} \approx 1500\,pF.$$

The combination has a time constant of about 1µs. The time constant should be much less than the retrace time or a significant amount of power will be dissipated in the snubber.

5 Considerations

Construction of yokes can vary. Often there are two windings per coil. Depending on the availability of terminals, not every winding can be damped. If both windings can be accessed, damp them individually first, then damp the combination (optional). Damping of a vertical coil can reduce crosstalk between horizontal and vertical by reducing the high frequency resonant energy.

A damped yoke does not necessarily result in a perfect ring-free image. Other components in the horizontal tank circuit will also contribute instabilities. Width coils can be damped the same as a yoke, but retrace capacitors may require an old trick — adding an RL created by several turns of magnet wire wrapped around a small value flame-proof power resistor.

Careful selection of components is necessary for a snubber to work properly. The resistor should be a non-inductive power type capable of both high pulsed power and voltage. The capacitor must also be capable of high pulsed currents and voltages. Mica and polypropylene types are the best, although some ceramics may also do well.

6 Conclusion

This paper presented formulas for calculating the optimum values of an R-C snubber to be used on a deflection yoke. An example was given showing the simplicity of implementation. The author has succesfully used this method for damping yokes, width coils, transformers, and inductors.

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