IN_CIRCUIT CAPACITOR TEST

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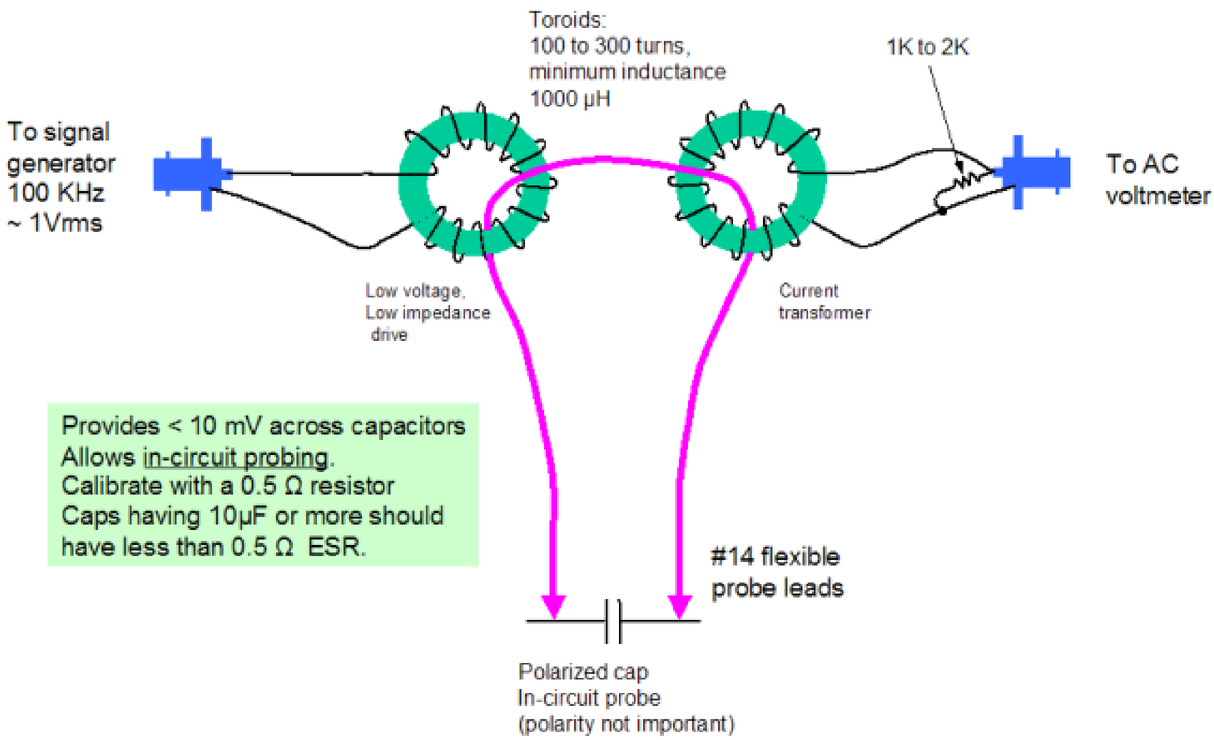


$Vin := 1$	Primary voltage
$f := 0.1$	Freq in MHz
$N := 240$	Step down / up ratio (same for both xfrms), as used here
$L := 5000$	Primary Inductance uH
$Rs := 50$	Source resistance at drive xfrm
$RL := 1000$	Current xfrm load
$Rc := 0.05$	Probe leads resistance
$Lc := 0.20$	Probe leads inductance uH
$Rx := 0$	Rx measured
$Cx := 1000$	Capacitor being tested uF

Reactance functions

$$XL(L,f) := j\cdot 2\cdot\pi\cdot f\cdot L$$

$$XL(L,f) = 3.142i \times 10^{3}$$

$$XC(C,f) := \frac{1}{j\cdot 2\cdot\pi\cdot f\cdot C}$$

Drive transformer

$$Vout := \frac{Vin}{N}$$

$$Vout = 4.167 \times 10^{-3}$$

At drive xfrm secondary

$$Zout := \frac{\frac{Rs}{N^2}\cdot XL\left(\frac{L}{N^2}, f\right)}{\frac{Rs}{N^2} + XL\left(\frac{L}{N^2}, f\right)}$$

$$Zout = 8.678 \times 10^{-4} + 1.381i \times 10^{-5}$$

Note Rs and L appear as parallel components at the secondary

Current transformer input Lp and Rp:

$$Lp := \frac{L}{N^2}$$ $Lp = 0.087$ Shunt L uH at current xfrm input

$$Rp := \frac{RL}{N^2}$$ $Rp = 0.017$ Shunt R at current xfrm input

Sum of Impedances in the loop:

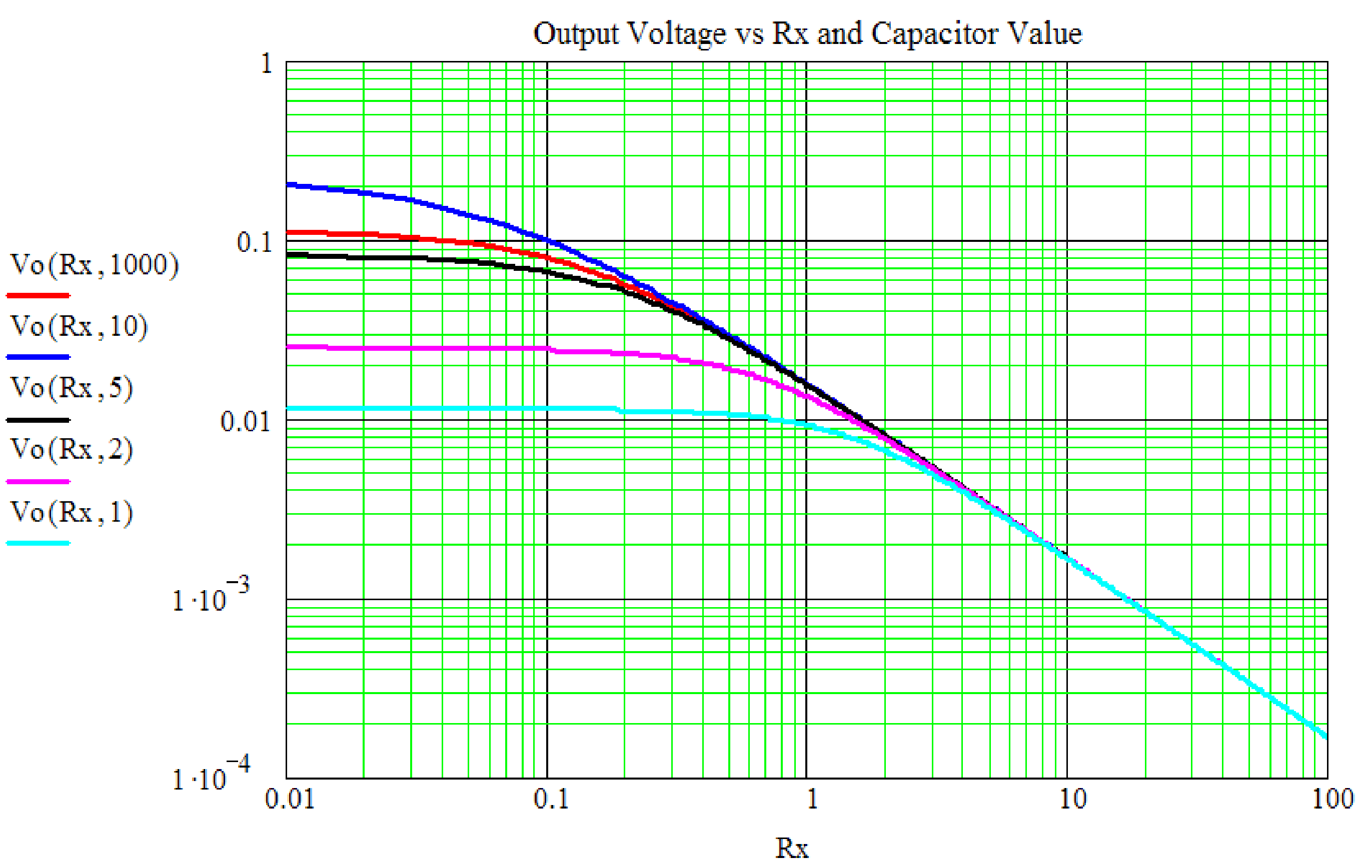
$$Zload(Rx, Cx) := \frac{Rp \cdot XL(Lp, f)}{Rp + XL(Lp, f)} + XL(Lc, f) + Rc + Rx + XC(f, Cx) + Zout$$

$Zload(Rc, Cx) = 0.117 + 0.129i$

Voltage across RL:

$$Vo(Rx, Cx) := \left| Vin \cdot \frac{\frac{Rp \cdot XL(Lp, f)}{Rp + XL(Lp, f)}}{Zload(Rx, Cx)} \right|$$ $Vo(Rx, Cx) = 0.114$ Current xfrm output voltage

$Rx := 0.01, 0.02 .. 100$



Observations

- This model assumes that the transformers have a coupling factor of 1

- The winding resistance of the toroids has not been included here, since its value will only have a small effect on the results.
  If desired add winding resistance to Rs and RL. However winding resistance should be less than 10 ohms. In my case it was less than 1 ohm.

- Note that RL is made "high" (in the Kohms) to get a voltage step-up. Larger voltages are easier to measure. The voltmeter could be tuned if necessary to reject noise.

- The capacitance of the cable connecting to the voltmeter has not been included in this model. With a winding inductance of 5 mH, it will resonate with 500 pF. With RL at 1K, the Q is less than 1, which is fine. Note that the 500 pF includes the winding self capacitance.

- Commercial toroids that I found had larger inductances even at 100 turns. That could limit their frequency response at 100 KHz.

- The core losses have not been modelled. In my case the Q at 100 KHz was ~ 80, indicating low losses.

- The relative permeability of my toroids was ~ 100

- If the core material provides a stable inductance, then it could possibly be part of an L-C oscillator that provides the 100 KHz source. (the driver transformer)

- The reactance of the windings (ωL) should at least a few times larger than the source and load resistance Rs and RL. An op-amp connected as a current to voltage converter could be used to provide an essentially 0 ohm load at RL.

- Refer to the graph on the previous page.
  In the above design, capacitors around 10 uF resonate with the lead inductance Lc.
  For Rx values below 0.2 ohms it gives the highest voltage.
  This resonance is broad and capacitor values above 5 uF give equal voltages at Rx=0.5 ohms while 2 uF caps will give 2/3 of the reading while 1 uF cap will give 1/3 of the normal reading.

- I intend to build the above circuit using speaker wire for the probe leads. These are very flexible and they make a parallel pair line with a low and rather constant inductance. (Lc)
  Note that the loop impedance Zload has more inductive reactance than resistance at Rx=0.
  So it's a good idea to minimize Lc by keeping the probe leads parallel... up to the probes.

- I have not tried to optimize anything - excepted minimizing the lead inductance.
  I keep searching for commercial toroids that everyone could use. So far, TRIAD current sense transformers look interesting. Mine came from my "junk box".