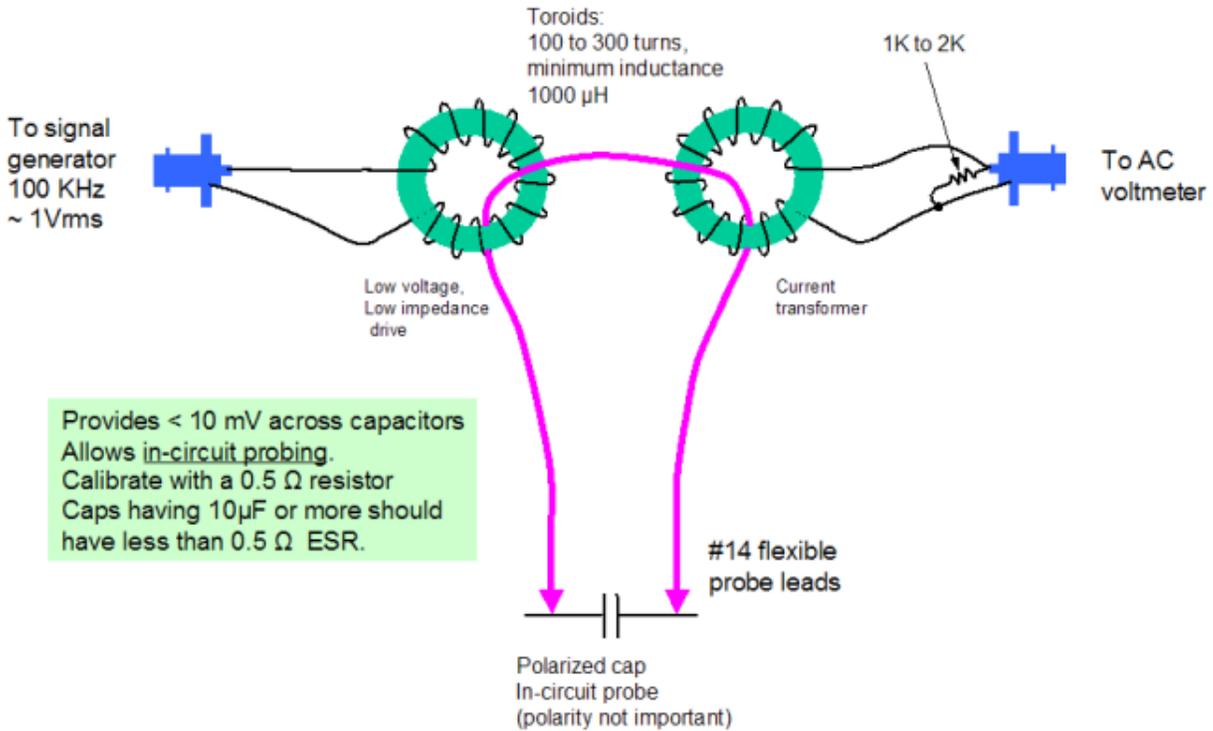


IN_CIRCUIT CAPACITOR TEST

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$V_{in} := 1$	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 μ H
$R_s := 50$	Source resistance at drive xfrm
$R_L := 1000$	Current xfrm load
$R_c := 0.05$	Probe leads resistance
$L_c := 0.20$	Probe leads inductance μ H
$R_x := 0$	R_x measured
$C_x := 1000$	Capacitor being tested μ F

Reactance functions

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

$$X_L(L, f) = 3.142i \times 10^3$$

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

Drive transformer

$$V_{out} := \frac{V_{in}}{N}$$

$$V_{out} = 4.167 \times 10^{-3} \quad \text{At drive xfrm secondary}$$

$$Z_{out} := \frac{\frac{R_s}{N^2} \cdot X_L\left(\frac{L}{N^2}, f\right)}{\frac{R_s}{N^2} + X_L\left(\frac{L}{N^2}, f\right)}$$

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

Note R_s and L appear as parallel components at the secondary

Current transformer input L_p and R_p :

$$L_p := \frac{L}{N^2}$$

$$L_p = 0.087$$

Shunt L uH at current xfrm input

$$R_p := \frac{R_L}{N^2}$$

$$R_p = 0.017$$

Shunt R at current xfrm input

Sum of Impedances in the loop:

$$Z_{load}(R_x, C_x) := \frac{R_p \cdot X_L(L_p, f)}{R_p + X_L(L_p, f)} + X_L(L_c, f) + R_c + R_x + X_C(f, C_x) + Z_{out}$$

$$Z_{load}(R_c, C_x) = 0.117 + 0.129i$$

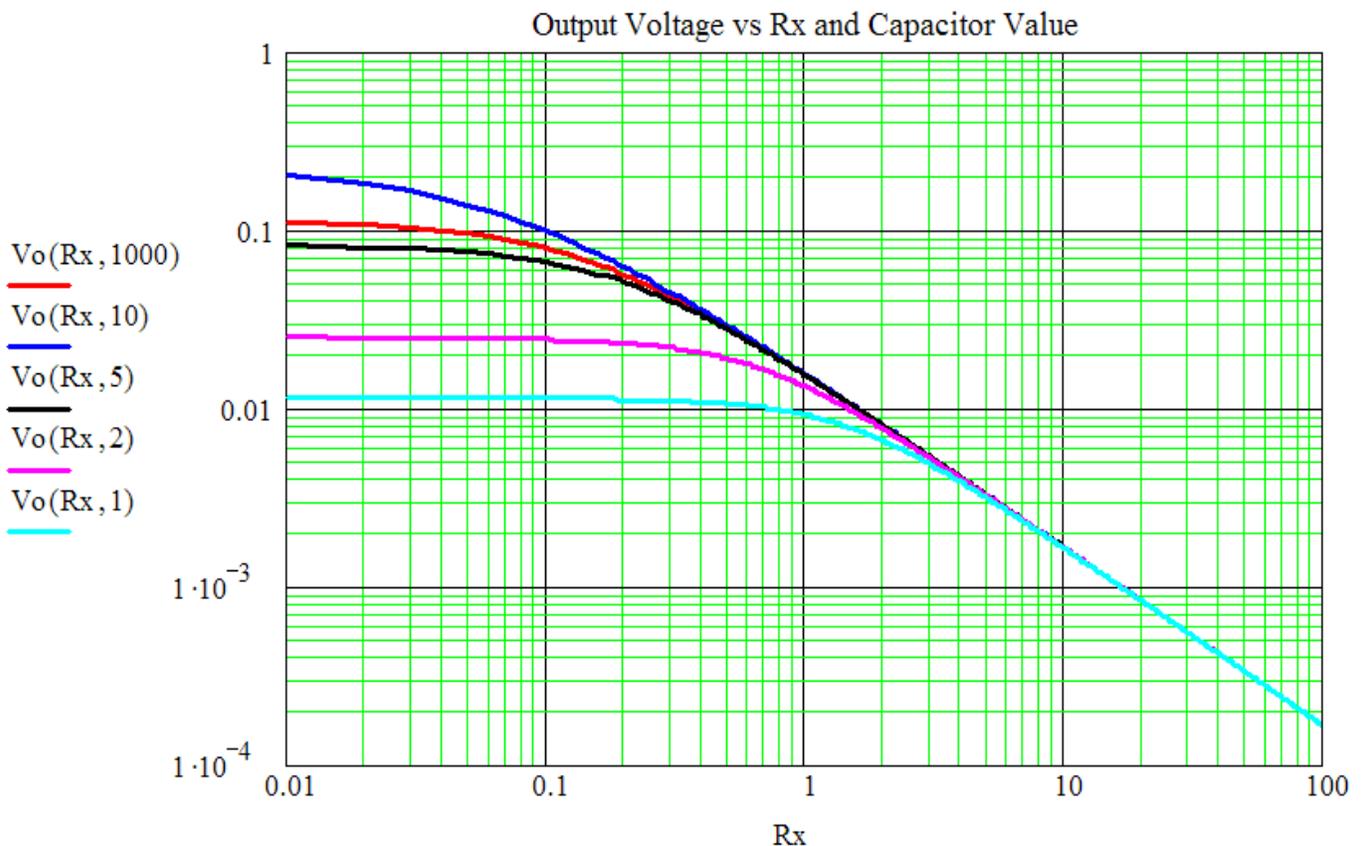
Voltage across R_L :

$$V_o(R_x, C_x) := \left| V_{in} \cdot \frac{\frac{R_p \cdot X_L(L_p, f)}{R_p + X_L(L_p, f)}}{Z_{load}(R_x, C_x)} \right|$$

$$V_o(R_x, C_x) = 0.114$$

Current xfrm
output voltage

$$R_x := 0.01, 0.02 \dots 100$$



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 R_s and R_L . However winding resistance should be less than 10 ohms. In my case it was less than 1 ohm.
- Note that R_L 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 R_L 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 R_s and R_L . An op-amp connected as a current to voltage converter could be used to provide an essentially 0 ohm load at R_L .
- Refer to the graph on the previous page.
In the above design, capacitors around 10 uF resonate with the lead inductance L_c . For R_x values below 0.2 ohms it gives the highest voltage.
This resonance is broad and capacitor values above 5 uF give equal voltages at $R_x=0.5$ 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. (L_c)
Note that the loop impedance Z_{load} has more inductive reactance than resistance at $R_x=0$.
So it's a good idea to minimize L_c 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".