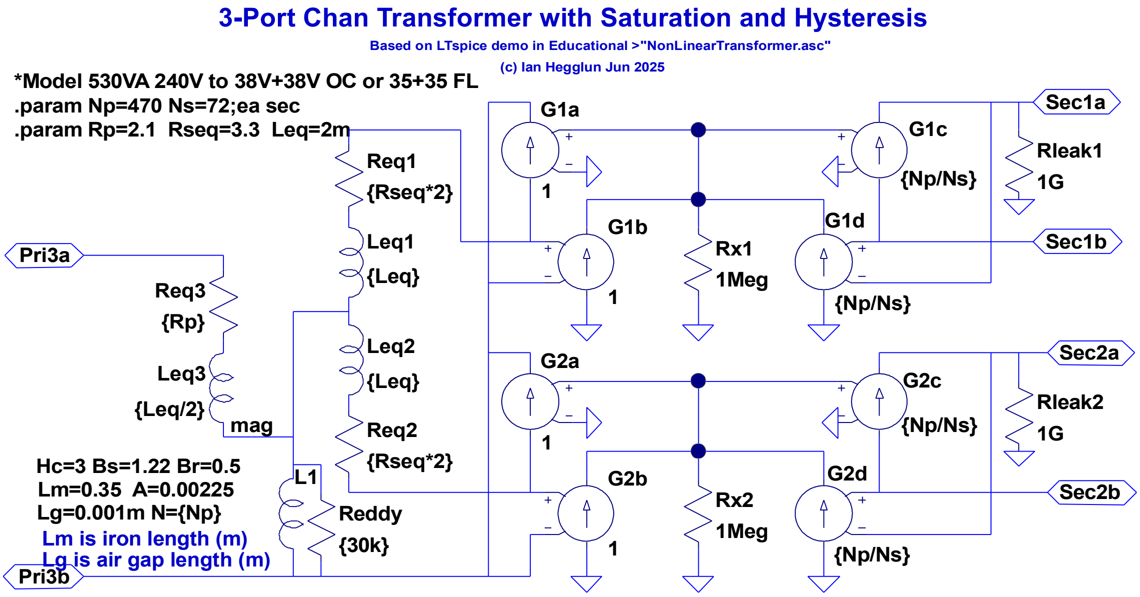
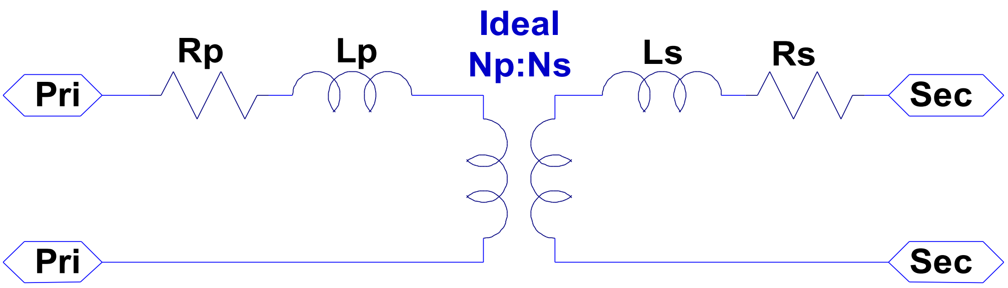
Fitting Params: Dual Secondary 530VA Chan Transformer with Saturation and Hysteresis

This relates to Post 277 and Post 278. The model I used for my 530VA transformer is updated here. Values for Req1 and Req2 are corrected. The simulated power dissipation in the transformer was under estimated by a factor of about 2. Also the leakage inductance Leq and Bs are updated and as shown below. This document explains how the dual secondary transformer model is derived and how the measured values are applied to the Chan transformer model.

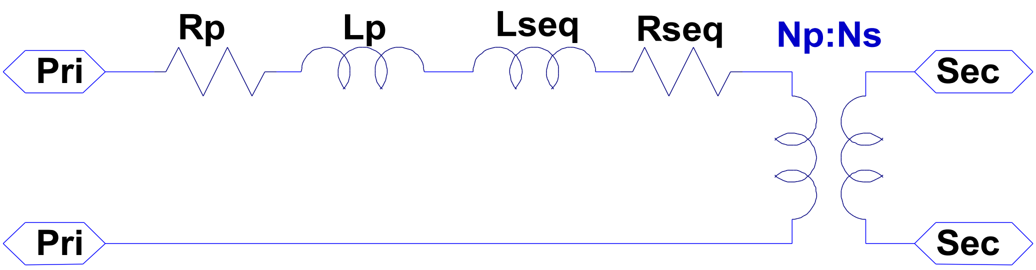


Deriving the dual secondary transformer model

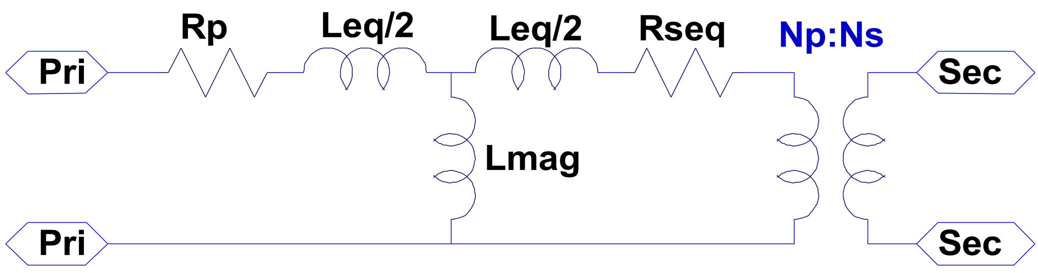
Step 1: The equivalent circuit with Rp & Lp on the primary and Rs & Ls on the secondary with an ideal transformer.



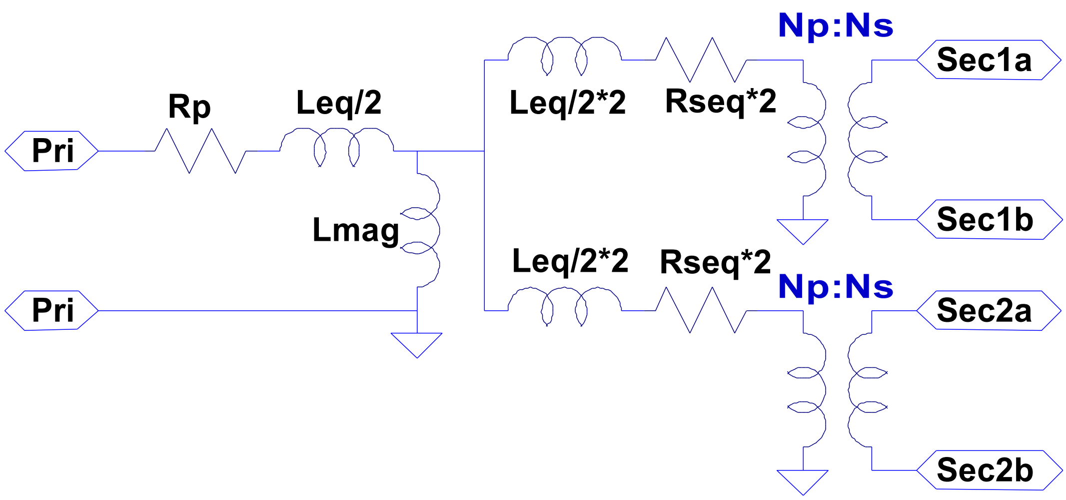
Step 2: The secondary and Ls are referred to the primary side as Rseq and Lseq. Rseq=Rs×Np/Ns, Lseq=Ls×Np/Ns.



Step 3: Split Lseq into two equal parts and add the magnetising inductor. Text books usually combine Rp+Rseq and split these in two equal parts also, but I keep them separated since Rp is directly measured with a DMM as 2.1Ω (warmed up). Rseq is found with the secondary shorted and applying 26.5Vrms AC to the primary and measure the primary current as 5.1A giving 5.2Ω. Then Rseq is 5.2Ω – 2.1Ω or 3.1Ω (neglecting the inductive component which is relatively small). Or 3.3Ω when warmed up.



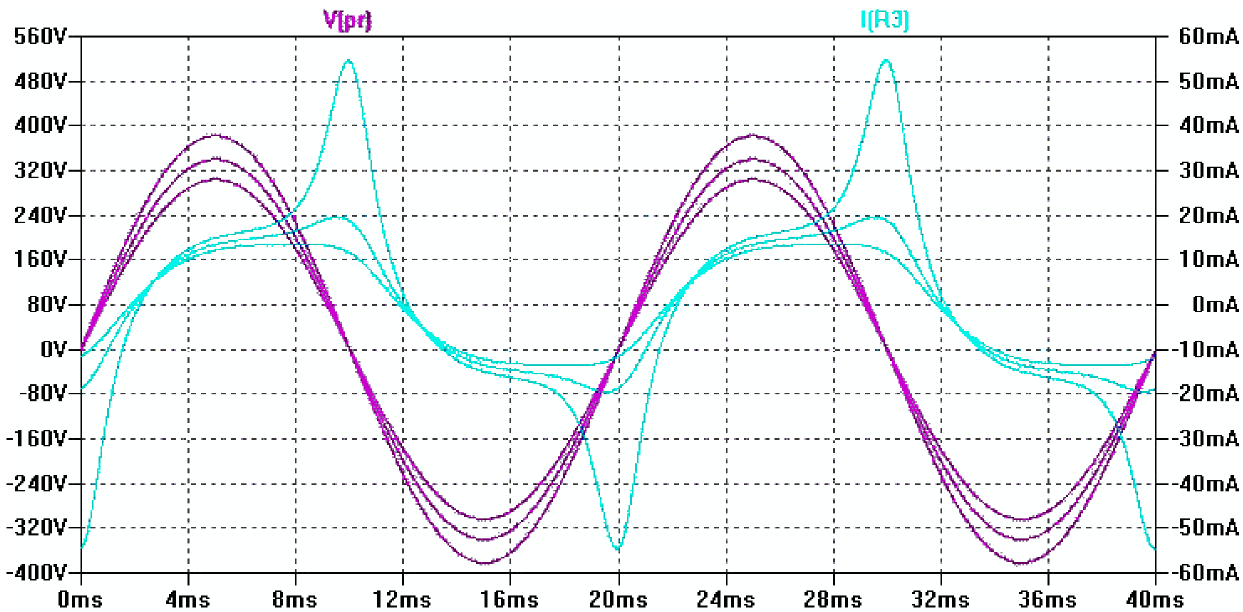
Step 4: Split the secondary into two equal parts. Np/Ns is now half the previous. The values for Rseq and Lseq are not affected since they are on the primary side. So only secondary voltages and currents are changed. Each branch has Rseq×2 since they are in parallel giving the net value of Rseq as previous. Likewise Lseq/2×2 for each branch which is shown as Lseq in the final model subcircuit above.



Final transformer subcircuit

Leq is assigned 1mH. It can be calculated by measuring the phase shift in the primary current with the secondary shorted test above. I measured 7 degrees. Tan 7° =0.12 so XL=5Ω×0.12=0.6Ω so L=0.6/2pi=2mH. Toroidal transformers usually have very low values of leakage reactance compared to the resistive component. Using a lower value does not affect the model by much.

Lmag in the Chan model is calculated internally by the values of Np, Bs, Br, Lm (iron length, not inductance), A and Lg (equivalent air gap). These were fitted by measuring the magnetising current at three primary voltages (215, 243, 272Vrms or 382, 340, 304Vpk) and plotting the primary current against time relative to the primary voltage with a 2 channel oscilloscope. I used a 22Ω 2W wire wound current sense resistor on the primary. The higher voltage than normal shows peaking of current near the voltage zero crossing due to core saturation. The model was adjusted for the same 3 primary voltages to get the same primary currents and saturation peaks. NB the Chan model needs a primary voltage ramp to get the magnetising current to settle in 10 cycles or so. See file “ChanTran-Imag-jig.asc”.



272Vrms fit for 55mA peak magnetising current. File: “ChanTran-Imag-jig.asc”

Tips:
Trim Bs, start from 1.5, for the saturation peak while also trim Br starting from 0.5 for the highest primary voltage.
Trim Lg and Hc for the curvature of the current waveform with the lowest primary voltage.

Reddy is estimated from no load power loss using the lowest primary volts. The primary current was 11mA and almost in phase with the primary voltage, so Reddy=214/10mA=21kΩ. This was tweaked to 30kΩ in simulation to get the same no load power loss of about 2W at 215Vrms.

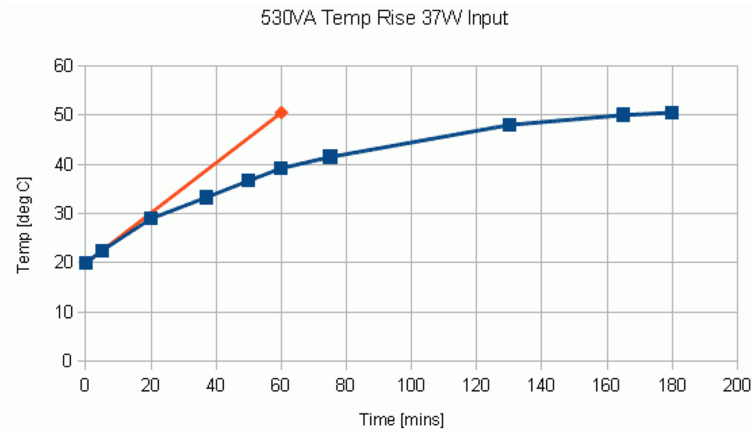
Do not use a DMM to measure the primary current directly as the turn on surge can blow the fuse and probably the meter sense resistor as well! As mentioned, I used a 22Ω 2W wire wound current sense resistor on the primary side. At 10mA it reads as 220mV AC, so even a 3 digit DMM is accurate enough for this test. An RMS meter is better since the current waveform can be peaky from saturation.

To get the primary turns Np wind say 10 turns and measure voltage to get the volts per turn. Then Np = Volts per turn*Vpri. Likewise Ns = Volts per turn×Vsec.

Temperature rise test

I used the shorted secondary test with 13.7Vrms applied to the primary giving 273mA near unity power factor, so transformer heating is 37.4 Watts. A thermocouple probe on the secondary started at 14°C and ended at 52°C after 3 hours. This is a rise of 38°C or Rca of 1.0°C/W. A plot with time at 63% rise gives the time constant of 1 hour.

Time	Temp	Tc
0	20	20
5	22.5	
20	29	
37	33.3	
50	36.7	
60	**39**	50.5
75	41.5	
130	48	
165	50	
180	50.5	



Checking the model: Run file: "ChanTran-RS-530VA-jig.asc"

The model power loss was checked with a resistive load (9.15Ω) with 240Vrms input for full load 530VA input. The power loss is 31 Watts. This would give a temperature rise of 31°C (recall above Rca=1°C/W). The manufacturer rates its full output at ambient 45°C which means the secondary temperature reaches 75°C at full load.