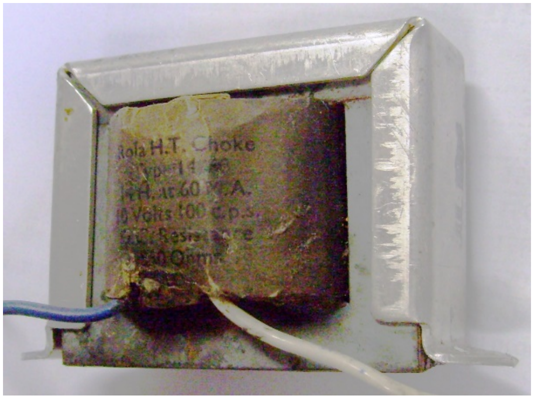
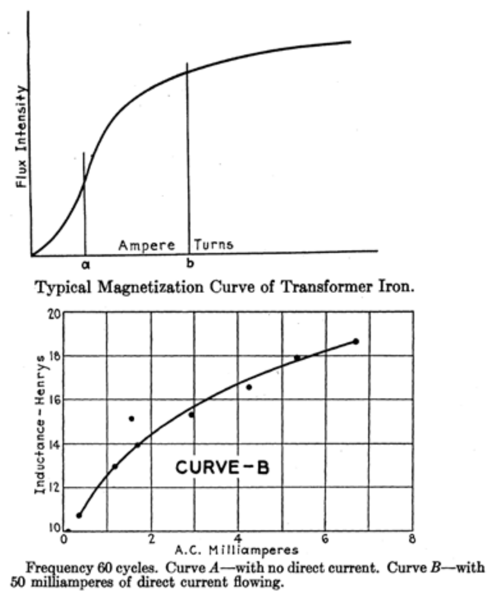
Old power supply chokes typically don't come with a rating plate stating their inductance and DC current rating. Manufacturers like Rola were an exception, with labelling such as 14H at 60mA measured at 10V 100Hz, with 560Ω DC resistance for the choke type 14/60.

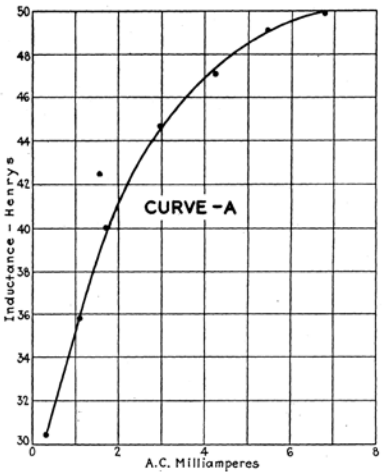
Within a valve amplifier, the high voltage (HT) DC supply with "choke input" filter applies a very large 100Hz AC voltage across the choke which is much greater than 10V, and contains substantial higher harmonic levels (one end of the choke cycles from 0V to the peak of the AC supply, and the other end of the choke is pinned to the HT DC voltage). Whereas a smoothing choke application, with the choke connected between two capacitors, experiences a much lower AC voltage (likely to be less than 10V at 100Hz, with relatively low harmonic levels).

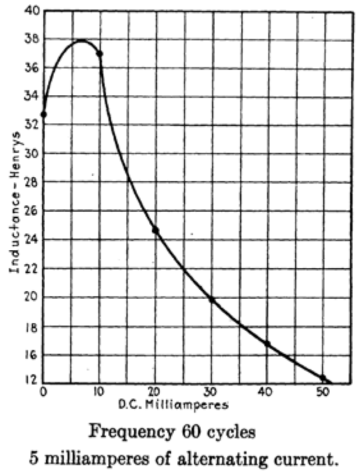


ROLA 14/60 choke

The inductance of an iron-cored choke can vary significantly with applied AC voltage (ie. ac current), and with the level of DC current passing through the choke. Results below, from [1], show those characteristics. So it is important to compare choke ratings only when similar operating conditions are being applied, and to be aware that the choke inductance value by itself is only half the story for power supply use.





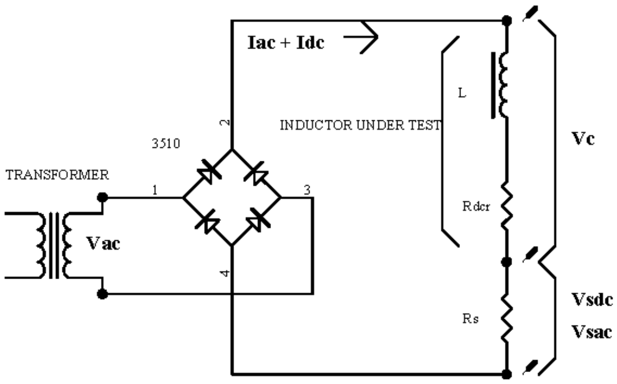


Choke inductance measurements [1] showing variation with AC & DC current.

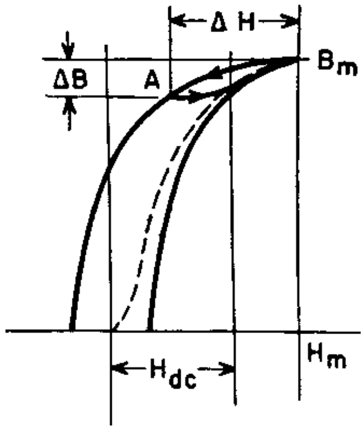
Simple measurement scheme

Choke inductance can be measured using a relatively simple method that passes DC plus AC current through the choke. The test circuit uses the choke to load the rectified output of a transformer power supply. A low value sense resistor Rs is typically used to make Idc and Iac current measurements. The choke is shown as an inductance L and a DC resistance Rdcr. The total DC resistance of the loading circuit is Rdcr + Rs.

By using different AC supply voltage levels, Vac (rms), the level of DC current in the choke can be varied. The AC waveform applied to the choke is a rectified sinewave with a DC voltage level of 0.9*Vac, and so a DC current of about Idc = 0.9*Vac/(Rdcr + Rs) flows through the choke.

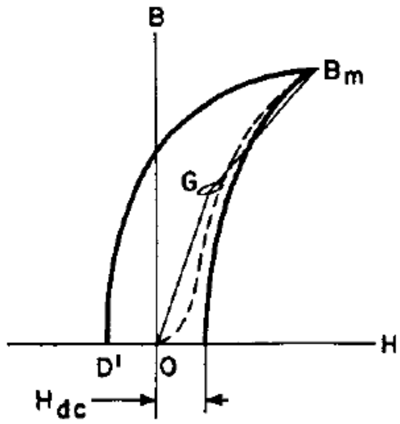


The AC voltage across the choke has a level of Vc=1.27*Vac/(n^2-1), where n=2,4,6.. (ie. the even harmonics of the mains frequency) [2]. The harmonic levels drop off rapidly, so simply using just the n=2 (ie. 100Hz) harmonic frequency indicates that the applied AC voltage on the choke is approximately Vc = 0.42*Vac. The AC current can be approximated by Iac = Vac/(1500*L), where L is in Henry - this approximation assumes f=100Hz, the choke reactance (2.π.f.L) is much larger than Rdcr, and only 2^{nd} harmonic current is significant. If we assume Rdcr>>Rs, then the previous equations can be rejigged to show that DC current is larger than the AC current by the ratio of about Idc/Iac = 1350*L/Rdcr, which is 38 times for the Rola choke example.



With Rdcr>>Rs, this test measures the small signal (incremental) inductance of the choke, where a relatively large DC current is passing in comparison to the AC current, and is similar to a smoothing choke application. With respect to what the choke core experiences for this application, the graph on the right shows the choke core magnetised with the DC magnetising force Hdc, and a smaller AC magnetisation level ΔH is superimposed which causes a cyclical magnetisation loop to be followed between A and Bm.

For choke-input filter applications, the AC magnetisation level is much larger, and the graph on the right shows a flux swing ΔB from 0 to Bm, and a hysteresis loop followed from 0 up to Bm and back down to D' then to 0. For comparison, the choke still operates with a DC magnetising force Hdc, and if the AC flux was (only) reduced to a small level then the hysteresis loop would shrink to a minor loop as shown by G.



The choke current waveform is noticeably unsymmetric in this situation, and causes higher ripple than anticipated. When the core flux is more positive than Hdc, the effective inductance is the slope of the line from G to Bm, which is a lower inductance than for the negative flux swing as approximated by the slope of the line from 0 to G. As the DC level increases in the choke, and as AC flux pushes Bm further towards deep saturation, the average inductance falls.

As the measurement scheme uses average (RMS) measures of choke AC voltage and AC current, any detail of the change in incremental inductance is lost unless multiple measurements are made with small AC level as DC is step increased. Also care is required when applying high levels of AC voltage.

This measurement scheme does not inherently measure inductance at just a specific frequency and excitation voltage, due to measurement waveform distortion including mains frequency harmonics and non-harmonic distortion from the mains voltage/transformer/diode rectifier. The influence of shunt capacitance is also neglected, as it is likely to be >> 100x the inductive impedance. However, in practise the scheme gives very good inductance measurement precision when compared with impedance measurement techniques (see later). For the purpose of power supply choke design, the test frequency and waveform are typical of that application, where choke inductance can vary so much with operating conditions.

The above measurement is made at twice the mains frequency, and a separate measurement is needed to determine the general self-resonant frequency (SRF) of the choke. The self-capacitance in the choke winding causes the rising choke impedance with frequency to level off at the SRF and then impedance falls for ripple frequencies higher than SRF (see later plot). Vintage power chokes of 10-14H, and DC current ratings of 60-125mA are likely to have a self-resonant frequency of about 3-5kHz. Modern fluorescent ballast type chokes typically have significantly higher SRF of at least 10kHz.

When the mains supply is turned off, or the supply disconnected in some manner, and twice during each mains cycle, the DC current in the test circuit commutates through the diode bridge, which acts as a free-wheeling diode (similar in action to the protection/suppression diode typically placed across a DC relay coil).

Test Method

Use a true-rms meter to measure Vsac across sense resistor Rs (to derive Iac=Vsac/Rs), and to measure Vc across the choke. Choke impedance Z is then Z= Vc / Iac. For most types of choke, the choke inductance can be approximated by the impedance, such that choke inductance L = Z/(2.π.f), as |Z| = √((2.π.f.L)^2+Rdcr^2)

and $(2.\pi.f.L)^2$ >>$Rdcr^2$. A calculation spreadsheet is available [4] with equations given after the references, and accounts for the effect of Rdcr on the choke inductance calculation. Measure the DC Voltage Vsdc across sense resistor Rs. DC current through the choke is then Idc=Vsdc/Rs.

Using a small value for Rs (ie. 10Ω) will require a meter with at least 1-10mV resolution, such as a cheap Aneng AN8009. Some DVM's like a Fluke 115 handheld won't do (although it has a 600mV AC-DC range, this can over-range due to the DC level exceeding 600mV even though the AC level being measured is low, and so 6VAC range is only available). Raising Rs value to say 100Ω will help with poorer resolution meters, and shouldn't really affect accuracy or be significant compared to Rdcr for many chokes. Check your meter performance specification as part of preparing to take measurements. Choke input filter parts are designed for higher applied AC voltage – this requires a larger Rs (eg. 470Ω with higher power rating >20W) to apply say 50Vrms and pass over 100mAdc, otherwise the measured inductance will be lower than rated.

A tapped transformer can be used to change the Vac level, to apply different DC current levels, and allow inductance droop to be plotted. My first test setup used 12V, 20V, 32V and 52VAC secondaries, and two multi-tapped 0-24VAC transformers would be quite practical, but I now use the heater supply of a vintage valve tester with 0.6 to 117V in 19 steps. The supply needs sufficient current rating to suit the DC current being applied to the choke (eg. a 1A secondary rating would suit many chokes used in valve amps). Any diode bridge with 6A or more rating should be fine.

If needed, the value of the sense resistor Rs can be increased in order to lower the DC current level relative to the applied inductor AC voltage level, as Idc/Vac ~ 0.9 /(Rdcr + Rs), allowing inductance to be measured under power supply conditions applicable to a choke-input filter. If needed, the rectified waveform could be RC filtered before the choke is connected, so as to attenuate higher ripple frequencies.

Note that there is a lower limit to Vac that is needed to generate a level of Idc, due to inherent Rdcr.

An example choke measurement jig is presented in [7] and provides assessment of an example measurement.

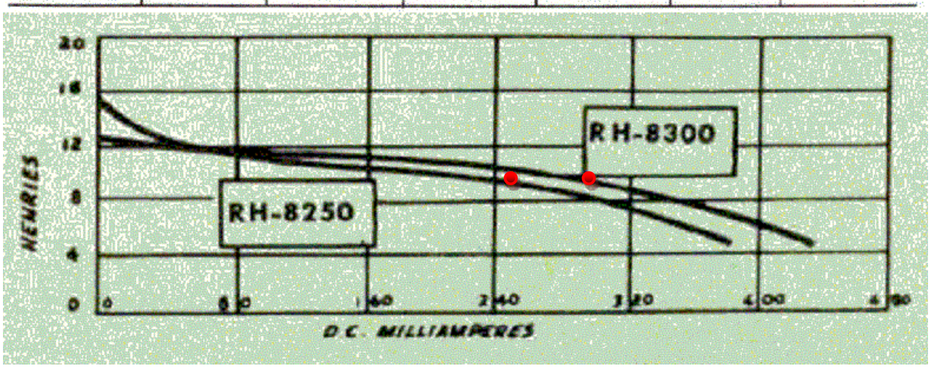
Smoothing Choke Performance

The example 14H Rola choke was measured using the described test method. The nominal transformer voltage Vac used for four measurement points is given in the following table. Rdcr was measured at 535Ω, and SRF at 6kHz (C≈50pF).

Vac	12 V	20 V	32 V	52 V
Idc	17 mA	30 mA	50 mA	82 mA
Iac	0.6 mA	0.9 mA	1.4 mA	2.7 mA
Vc	5.85 V	9.17 V	14.1 V	23.1 V
L	15.5 H	16.2 H	16.1 H	13.6 H

The test results agree well with the 14H at 60mA DC part rating, noting that Vc is greater than the spec level of 10Vrms for Idc=50mA, and hence measured L would be a bit lower at the Vc spec level. As Vc increases when larger Vac is applied, the measured inductance can increase even though Idc has increased. For comparison, an LCR meter (ESI 250DA) measured 12.4H at 1kHz at 10Vac with no DC.

Catalog No.	Inductance Henries	Max. D-C Current, Ma.	D-C Resistance in Ohms	Insulation Test Volts RMS	Case Size	Wt. Lbs.
RH-8250	8	250	90	2500	22	10½
RH-8300	8	300	60	3500	22	12½



The measured drop in inductance with DC current, along with the DC resistance of the choke, can provide a good estimate of the manufacturer's DC current rating for the part. The above product curves of inductance are from Chicago Transformer chokes at 10V 60 Hz excitation [3]. The power loss at rated max DC current is about 5.5W for each choke (note that these are large chokes). The much smaller example Rola choke has a max power loss of only 2W at rated 60mA DC. Hubelhank presented a consistent test result using a similar measurement technique, circa 1956 [5].

A manufacturer may consider many factors when stating a current limit to a choke – for example internal factors such as insulation temperature ratings are known, but maximum ambient temperature and access to free air cooling would be estimated external factors. Based on temperature, there is no certain way to identify a maximum rated current for an unknown choke. Comparison of physical size and construction with a choke of known current rating is a reasonable method, especially if the DCR is similar. And any particular application could modify a rating due to the anticipated maximum ambient temperature, and access to free-air cooling. The increase of copper resistance by 4% for each 10°C rise above ambient could be used to estimate a maximum current rating, however the thermal gradient from inner to outer copper layers tends to blur the estimate of what the hottest (innermost) wire temperature would reach. A Rola 14/60 exhibited a 10% increase in DCR after 45 minutes at 70mA (2.5W) in free ambient air.

Choke-input filter Choke Performance

In addition to the inductance at max rated choke current, this application also needs to know the choke inductance at a minimum load current that maintains continuous choke current above zero (Fig.14-16 in [12]) - which is termed the critical inductance (Lc in H), and is approximated by Lc = R / 900 , for 50Hz mains, where R is the DC load resistance (Ω).

Some catalog data of chokes specifically for choke-input filter applications show two sets of inductance @ dc current ratings, where the largest dc current value is the rated (max) current for the choke, and the other value is typically 10% to 25% of rated. Designers then use the inductance at 10-25% of rated current to align with Lc. However, those stated inductances are typically for 10Vac, and so need to be adjusted for the application's level of Vac – either by applying a fudge-factor or by measurement. Note also that catalog data typically includes a manufacturing tolerance of 10%; and there may be a difference due to the manufacturer using a sinewave at mains frequency for testing (compared to the half-sinewave applied in practice); and the data may not be for the current where Lc is required.

Compared to a smoothing choke application, a choke-input filter application applies a significantly higher Vac across the choke. The increase in inductance obtained from operating at a higher Vac is related to the B+ voltage level being generated, and the DC current. [9] indicates the % increase, over a value measured at 1Vac, is about +60% at 10% of rated DC current, down to +30% at 100% of rated DC current. Red Line catalog data indicates a nominal 40% inductance increase at 80Vac, compared to 10Vac, at rated current and an undefined lower current.

Some chokes have been designed specifically for this application, and are often called a 'swinging choke' – which implies the gap in the core has been optimised to achieve a high inductance at some low % of rated current, whilst still achieving a relatively high inductance at rated current. The designer can then align the critical inductance requirements with the load range, as well as knowing the inductance (and hence estimating ripple) at max rated current. Crowhurst provides a general understanding of operation here.

One 'trick' [13] that effectively doubles the inductance presented by the choke at low DC current is to add an RC network across (in parallel to) the choke, as described in the Ripple Trap section latter. This RC is tuned for twice the mains frequency with the inductance available at the critical inductance operating condition, and significantly raises the impedance at the rectified frequency applied to the choke input. This added RC network also acts to snubber transient voltage on the rectifier end of the choke, and can avoid the need for that node to be protected by a voltage suppression device like a MOV, or a bypass cap to 0V.

A cross-check can be made of Lc by lowering load current to the point where output voltage regulation is lost (Fig.3 in [9]), and calculating the achieved Lc for the application specific Vac. This test incorporates all application specific conditions, providing confidence in the actual allowed range of DC load current.

Uncommon iron-cored chokes for valve amp power supplies

The typical flouro ballast choke is compact, double insulated, uniformly gapped by two rows of C laminations butting to a square lamination central core, and appears fine to sit at 600VDC or more and be used for a choke-input filter. A 240VAC 18/20W choke is very common, measures about 1.5-2H at 10Vac, and would be suitable for up to 300mA DC (power dissipation up to 5W). A 240VAC 9/13W choke measures 3H at 100mAdc and 10Vac, and 2.7H at 200mAdc, with Rdc=140Ω and SRF=5kHz, and would be fine for up to about 200mAdc (power dissipation about 5W). In normal operation, a flouro choke for 240Vac mains supports a Vac ~150-200V, which is similar to choke-input filter operating conditions.

An ATCO EC18/20 240VAC 50Hz choke gave measurement levels of Rdcr=54Ω, SRF=10kHz (150pF shunt):

Vac	12 V	20 V	32 V	52 V
Idc	147 mA	260 mA	420 mA	517 mA
L	1.88 H	1.69 H	1.45 H	1.26 H

Some Wurlitzer organs included a large number of note inductors (iron-cored with variable gap setting), of which a few provide up to 4H inductance and are suitable for up to 30mA DC (eg. suitable for screen and preamp filtering).

A Wurlitzer 500407 inductor from a 4100B organ (set with minimum gap) gave measurement levels of Rdcr=266Ω:

Vac	12 V	20 V	32 V
Idc	30 mA	50 mA	90 mA
L	4.1 H	2.3 H	0.9 H

Vintage black & white TV's may have a vertical output transformer operating in a single-ended mode stage where the primary winding can act as a choke with substantial inductance at DC levels exceeding 50mA. An AWA 50-00 series TV chassis has a 43340 marked transformer with 3 wires, where the 3rd wire is a small secondary winding connected to the primary winding in auto-transformer style, and the primary winding measures 19H at 20mAdc with 6Vac, reducing to 11H at 60mAdc at 12Vac, and the 370Ω DCR winding should cope with 80mAdc.

Ripple trap assessment

The test circuit can be used to measure the changing AC current harmonics passing through a choke with a parallel capacitor (and series dampening resistance), sometimes referred to as a ripple trap (a technique used in power supplies to enhance the attenuation of the dominant 2f ripple component – see [6]). Displaying the ripple current (voltage across sense resistor) on a spectrum analyser shows the increasing attenuation of the 2f harmonic as the parallel capacitance value is increased towards LC resonance, but also shows a corresponding increase in the magnitude of higher ripple frequencies being passed through. The filter capacitor following the choke bypasses the ripple currents, with the net result of a lower rms ripple voltage across that capacitor.

Given the likelihood of choke inductance being higher than its rated value when DC current is below the rated level, and given the increase in higher order harmonics with increasing capacitance, it is recommended that a lower capacitor value is used than what would be expected to tune the rated inductance at 2f – perhaps at least 20% lower. That is especially the case if the choke is used under choke-input conditions with a large Vac above what is used in this test circuit. The dampening resistance R_C in series with the capacitor is typically twice the choke R_L, although the Q can be calculated as $\sqrt{(LC)} / (R_C+R_L)$.

Output Transformer Primary Inductance

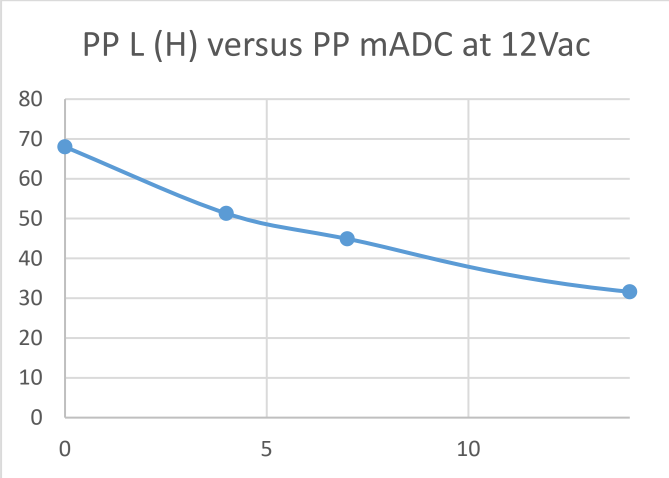
OT primary inductance influences the low frequency roll-off of a typical valve amplifier, and forms an RL high pass filter with the output stage valve's internal resistance Ra. The choke test circuit can be used to measure primary winding inductance at a given DC current level for an SE output transformer, and to indicate the change in inductance at zero, idle and twice idle current. In a PP amp, apart from the OT design itself, a DC imbalance from valve mismatch and/or bias mismatch can significantly lower primary inductance L.

Plate-Plate winding inductance of a PP output transformer can be measured with an unbalanced DC current level. When testing the P-P inductance of an output transformer, the test circuit applies DC current in both half-primary windings, but as the DC current is not being cancelled by the CT feed location, then the DC current level equates to an imbalance level twice as large. It is likely that the test circuit Rs will need to be made fairly large in order to suppress Idc down to a level typical of an unbalanced output stage.

The plot on the right includes a 68H P-P inductance value from a simple transformer fed test circuit (ie. no DC bias), as well as 3 test values taken in the choke test circuit when using high values of Rs (up to 6k8Ω).

The Red Line AF5/20 transformer has 5kΩ PP, and 15W hi-fi ratings. If idle bias current was 50mA nominal, then the 4mA test value would be equivalent to an 8mA imbalance between valves (eg. 46mA + 54mA). In that situation, the primary inductance would be down about 25%, compared to a balanced output stage.

Similarly, a common-mode choke can be measured for differential inductance with an unbalanced DC current level.



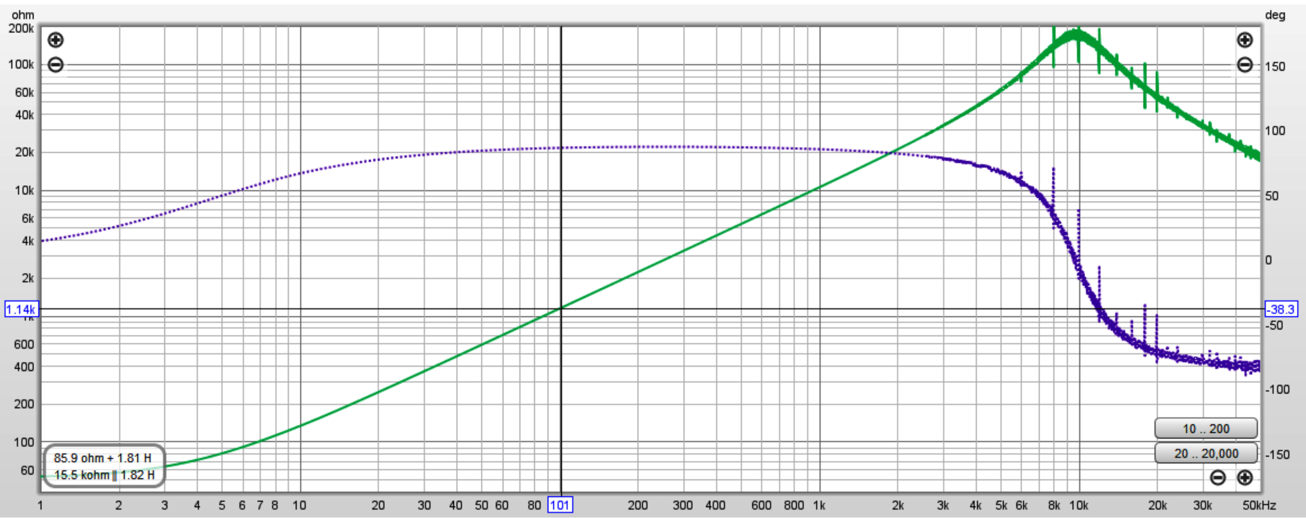
Impedance measurement

Modern soundcard interfaces, and software like Room EQ Wizard (REW), allow passive parts like chokes to be measured for impedance across a wide frequency range (eg. 2Hz to 96kHz). The software allows an automated easy scan to be made to identify SRF and the AC signal inductance (with no DC current), which can be cross-checked against the measured inductance with DC current as described earlier in this article.

The excitation voltage applied to a choke depends on the soundcard output – for example the EMU 0404 USB interface I use has a headphone output with up to 2Vrms into low impedance parts when using a 100Ω sense resistor. When the interface test setup is accurately calibrated using 1% tolerance resistors or better, the inductance results are similarly accurate.

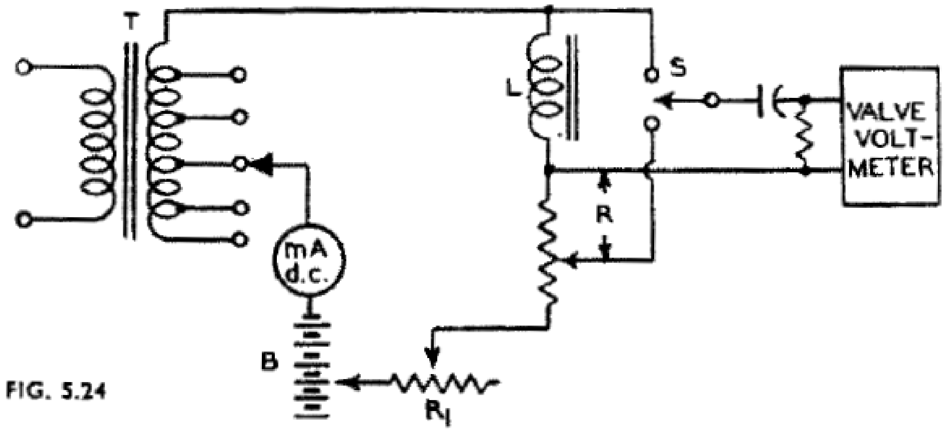
The impedance plot below is of the ATCO EC18/20 240VAC 50Hz choke identified in the earlier section on uncommon iron-cored chokes. The frequency span is from 1Hz to 50kHz and the green impedance magnitude (ohm) trace clearly shows the SRF at 10kHz, and the impedance reducing towards the DC resistance of 54Ω as frequency falls through 1Hz. The purple impedance phase (deg) trace shows the expected nearly +90 deg phase shift in the frequency band from about 30Hz to 2kHz, with phase falling to a capacitive -90 deg on the higher side of the SRF. Below about 30Hz, the phase starts to fall towards 0 deg as the part acts more like a pure resistance and can't support being inductive. The inductance at 100Hz is shown as 1.81H, which is comparable to the 1.88H measurement result shown earlier for 12Vac excitation with 150mAdc bias. Above 100Hz, the inductance slowly falls as core permeability falls with frequency, with inductance of 1.67H at 1kHz.

Although REW can calculate an equivalent lumped model of an inductor part, the model is too simple to represent typical laminated steel core chokes, and often the measurement frequency span has to be constrained otherwise the model defaults to a capacitor part. Hence it is better to record the choke inductance at a specific test frequency like 100Hz, and at the test excitation voltage level, to allow valid comparison with other measurement instruments and methods.



Other measurement methods

Radiotron Designer's Handbook 4th Edition (p.250) describes one classic measurement method shown in the diagram below. Two separate supplies are connected in series, requiring the AC transformer secondary to carry the test DC current, and the battery and DC ammeter to carry the test AC current. Switch S is toggled and 'R' is adjusted to show the same AC voltage across the choke as across 'R', and then the value of 'R' is measured and equated to the choke impedance (2πfL). Note that the measurement is made at the mains frequency, rather than twice the mains frequency as applied to a power supply filter choke. This method is not easy to set up due to the requirement for a battery, and care is required to avoid any significant capacitive coupling paths.



Vintage laboratory style measurements were made with a bridge technique, with the Hay's bridge as shown below (from Terman, 1935) being the most appropriate (as a normal bridge using a reference inductance arm would be unwieldy with an air-cored reference of sufficient inductance). The DC path is only through the lower arms of the bridge (as capacitors block DC through the upper arms and through the oscillator). A filter reactor and headphones allow the bridge balance point to be identified. The method is not simple due to complexity of parts and a need to keep stray capacitance negligible to balance the bridge.

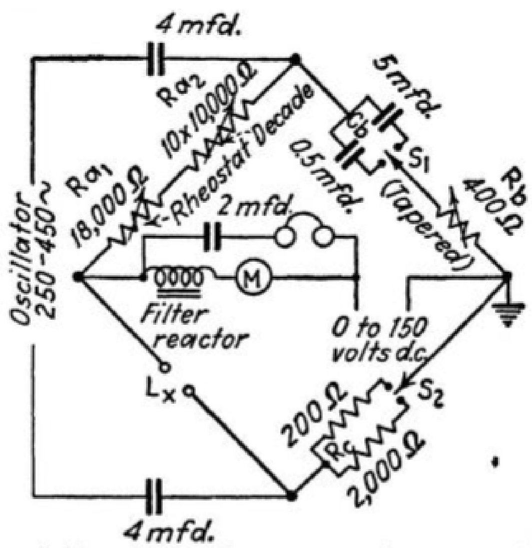
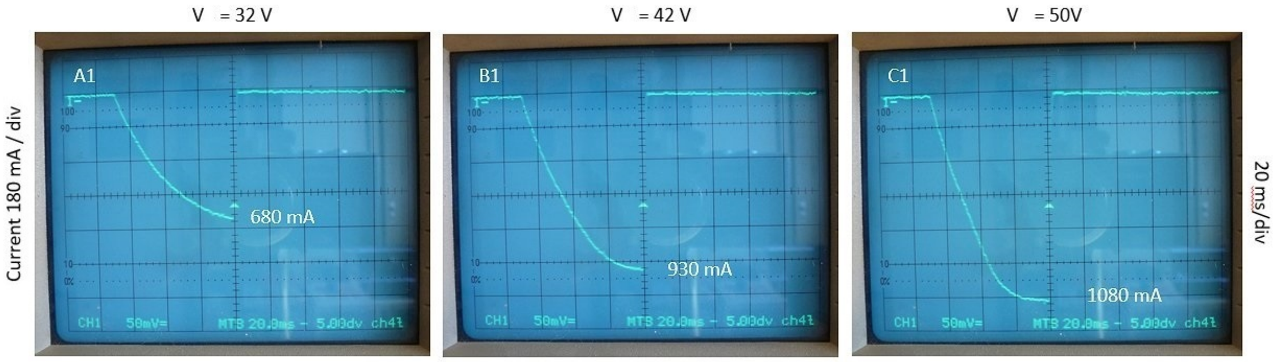


Fig. 39.—Hay bridge arranged to measure incremental inductance.

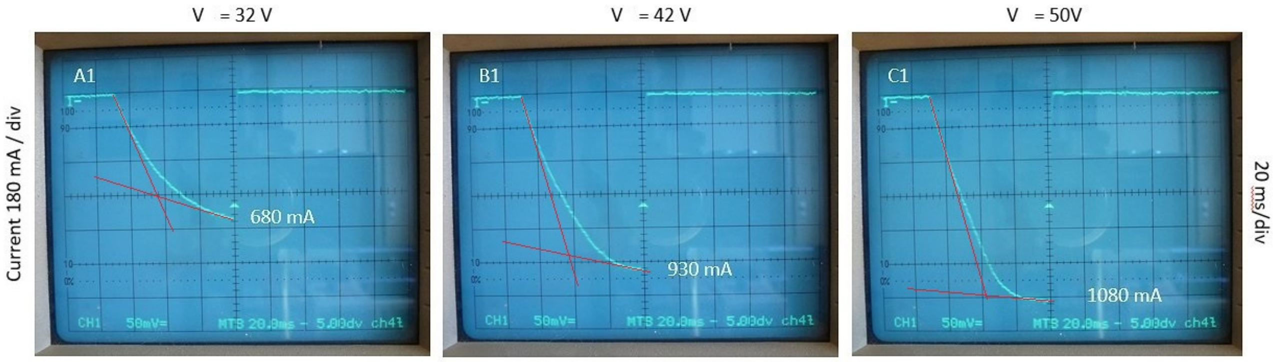
Another commonly used Bridge technique was the Owens Bridge, which is also not simple to implement.

Another indirect measurement method [13] is practical to use when adjusting the gap of a choke in order to achieve an optimum inductance for a specific power supply. A test power supply comprising rectifier and capacitor filter is connected to an LCR filter and load comprising the choke under test and using C and R values that mimic the specific application. A scope or spectrum analyser is then used to discern the 100Hz ripple level across the load R, and the choke gap adjusted to obtain a minimum 100Hz ripple level. The measured attenuation of 100Hz ripple can then be used to calculate the effective inductance of the choke. The test supply doesn't need to operate at high DC voltage (as per an application) but is preferably not too low in voltage. Additional CR filters can be added across the load R to attenuate frequencies below 50Hz, and assist with scope display, or preferably allow a soundcard-based spectrum analyser to be used to easily assess the 100Hz ripple magnitude.

Another inductance measurement method is based on the equation V = L di/dt, where an inductance L switched across a voltage V will exhibit a changing current of level di/dt. Ronald Dekker shows this measurement [8] for a flouro ballast choke, similar to the ATCO EC18/20 discussed earlier.



In the three acquired scope screen shots above, the same choke is switched across 32Vdc for plot A1, across 42Vdc for plot B1 and across 50Vdc for plot C1. Each plot shows the choke current (Y axis) versus time (X axis), with choke current at 0 up to the switch-on time at t=30ms (1.5 div from left side), and then the choke current increasing (negatively for this measurement setup) up to a switch-off time at t=100ms (5 div). In that 70ms switch-on duration the choke current increases in magnitude, with the final magnitude increasing with applied voltage.



At the start of switch-on, a red gradient line can be drawn to indicate the value of di/dt occurring due to the inductance L ~ 32V x 30ms /(3.5 x 180mA) = 1.52 H for plot A1, and similarly 42V x 30ms /(5.2 x 180mA) = 1.35 H for plot B1, and 50V x 30ms/(5.5 x 180mA) = 1.52 H for plot C1. Accuracy of inductance measurement is limited by the application of a gradient line estimate to the available plot data.

As the current through the choke increases, its incremental inductance falls from the initial level of ~1.5H. The incremental inductance can be estimated at any time from a straight-line tangent to the plot, however the choke resistance (Rdcr = 44Ω) reduces the effective voltage being applied as the current increases beyond zero, which makes the measurement of inductance more complicated and liable to error, especially as the dc voltage drop due to resistance approaches the applied external dc voltage. To illustrate this a red tangent line is drawn at the time just prior to turn-off, and for plot A1 the inductance is estimated at (32V-44Ω*0.68A) x 80ms/(1.2 x 180mA) = 0.78 H where 32V is reduced to just 2.1V due to internal DCR voltage drop. From the curve of choke current versus time, the incremental inductance can be inferred to fall as current level increases, consistent with previously presented data. Inspection of the gradient of the tangent lines for plots B1 and C1 indicates the incremental inductance does fall as the peak current further increases, which is consistent with the choke B-H operating point being pushed further into the core's saturation region.

This short duration measurement method has the benefit of gaining insight into how incremental inductance changes for conditions of deeper core saturation. In contrast, attempting a steady-state measurement would rapidly overheat and stress the winding and insulation.

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[11] The Economical Design of Smoothing Filters - QST April 1932.

[12] Theory and Applications of Electron Tubes. Reich 1944.

[13] Chokes Page 1. Patrick Turner (RIP) website.

[14] Chokes Page 2. Patrick Turner (RIP) website.

Additional on-line test measurement resources that I have come across:

https://www.angelfire.com/electronic/funwithtubes/Filter_Choke_Analyzer.html

https://www.qsl.net/i0jx/supply.html

Spreadsheet calculations [4] | User input value (ie. measured) | Calculated output value

Mains frequency (f)	50	Hz	
Rs (sense resistance)	148	Ohm	
Sense resistor dissipation	0.0	W	= Vsdc * Vsdc / Rs
Rdcr (series resistance of choke)	338	Ohm	
Vsdc (Rs dc voltage)	1.39	Vdc	
Vc (choke ac voltage)	5.62	Vrms	
Vsac (Rs ac voltage)	0.0334	Vrms	
Choke AC current (Iac)	0.2	mArms	= 1000 * Vsac / Rs
Choke impedance (Z)	24903	Ω	= 1000 * Vc / Iac
Choke reactance (X)	24901	Ω	= √(Z * Z – Rdcr * Rdcr)
Choke inductance (L)	39.63	H	= X / (2 * π * 2 * f)
Choke DC current (Idc)	9.4	mA	= 1000 * Vsdc / Rs
Choke Rdcr dissipation	0.0	W	= Rdcr * Idc * Idc / 1000000