AADE L/C Meter IIB
A Review by Clifton Laboratories

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Why is the ability to accurately measure inductance and capacitance important to radio experimenters?

- Lord Kelvin said it well:

  "When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind: it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the state of science."

- Or, as Lord Kelvin was quoted by Prof. Mike Scherba in Transmission Lines class (ca. 1966, Wayne State University, Detroit, Michigan), in more memorable language:

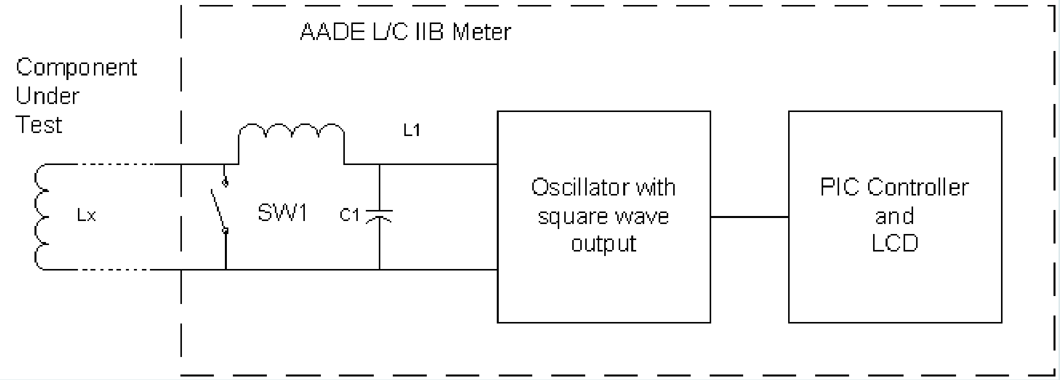
  "If you can't measure it, it's not worth a damn."

What is theAADE L/C Meter IIB?

- An inexpensive instrument that measures inductance and capacitance, available as a kit or assembled and tested from AADE. Details at http://www.aade.com/lcmeter.htm
  - Complete kit including machined case with front panel decal $99.95
  - Assembled and tested unit $129.95.
  - $6 S/H U.S.A. and Canada ($12.00 S/H foreign)
- Performance Specifications
  - Range
    - .001 mHy (1 nHy) to 100 mHy (most units measure to 150 mHy)
    - .010 pF to 1 mFd (most units measure to 1.5 uFd)
  - Accuracy
    - 1% of reading Typical

Simplified Theory of Operation

- At start-up, SW1 (a relay under control of the PIC) is closed. C1 is a known value, and the oscillator's frequency is measured by the PIC. Since C1 and frequency are known, the firmware calculates L1. This is frequency f1.
- When an inductive component, Lx, is tested, it is, in effect, in series with L1. This reduces the frequency. The frequency measured with the unknown Lx in series with L1 is frequency f2.
- The measurement frequency depends upon the value of Lx and is always below 750 KHz.



- From the known values of L1, C1, f1 and f2, the value of Lx can be computed.
- A similar technique is used to measure unknown capacitance Cx. It is placed in parallel with C1, and the resonant circuit is comprised of L1, C1 and Cx.
- From knowledge of f1, f2 (with Cx connected), L1 and C1, Cx's value can be computed.
- The measurement frequency depends upon the value of Cx but is always below 750 KHz

Operation

- Upon power-on, the instrument undergoes a brief self-calibration.
- For better accuracy, perform a secondary calibration using a shorting bar for inductance or open circuit for capacitance, and then pressing the "zero" button. The short or open calibration is performed with test leads in place, as the purpose is to compensate for their inductance and capacitance.
- Select inductance or capacitance as the component being measured and read the results on the LCD.

Strengths and Weaknesses of this Design

Strengths

- Inexpensive.
- Capable of reasonable accuracy at the (unknown) test frequency.
- Small, portable device, battery powered with digital readout.
- Very good post-sale support, even long after warranty expired.

Weakness

- No control over frequency of test.
- No control over amplitude of test signal.
- Only inductance or capacitance is measured, not Q or D or resistance.
- Cannot be used to determine distributed capacitance of inductor or self-resonant frequency of inductor.
- Unshielded plastic case causes internal circuitry to be affected by nearby metal objects. Several pF shift between a wooden bench-top and a metal bench-top can be seen.

History of the Unit Tested

- Owned by Bob, K7HBG and loaned to Clifton Laboratories for review.
- Originally examined in September, 2009 and found to be significantly worse than specifications indicated.
- The instrument was approximately 14 years old and had not been calibrated during its life.
- The meter was returned to Bob, who, in turn, submitted it to AADE for recalibration or repair.
- The instrument was found to be outside tolerance by AADE a refurbished instrument returned to him.
- The measurements in this review are of the refurbished instrument.

Standards Used for Comparison

Inductance

- Boonton 513 and 518 precision inductors
- Boonton 103-series working inductors
- Home made inductors
- All inductors measured at RF frequencies with an HP4192A LF Impedance Analyzer (5 Hz – 13 MHz) and some with an HP4342A Q-meter

Capacitance

- Various 1% to 5% tolerance capacitors.
- All capacitors verified with:
  - HP4192A
  - GR1658 Digi-bridge (1 KHz)

Error in Comparison Standards Determination

- The HP4192A and GR1658 instruments used for verifying the inductance and capacitance samples are rated with accuracy in the range of 0.25% or better, depending upon frequency, component value and test voltage applied.
- Cross comparison between the HP4192A and GR1658 indicate agreement in the 0.1% range.
- The HP4342A Q-meter has an accuracy of ±3%.

Fixtures

- Accurate measurements require knowledge or at least compensation for fixture errors. This is done in the HP4192A by an open/short calibration and in the AADE meter by a short (for inductance) or open (for capacitance).
- The AADE meter uses an unusual binding post spacing of approximately 1.156 inches. The industry standards are:
  - ¾ inch (most common standard; also available in the AADE L/C IIB meter at no additional charge upon request when ordering).
  - 1 inch (Boonton and HP Q-meters and associated inductance standards).

Adapter from 1.00” to AADE L/C IIB Spacing

- Banana plugs on center-to-center spacing to match AADE meter.
- Holes drilled to accept 1 inch center-to-center banana plugs from inductor under test.
- Adapter designed for minimum added inductance and shunting capacitance.
- Measured shunt capacitance of adapter is 1.25 pF.
- Inductance added is estimated at 10nH, but is compensated for by the instrument zero process.
- A shorting bar with 1.00 inch spacing was also fabricated and used in the measurement process.

Shorting bar

Adapter in place on 103A-21 working inductor.

With shorting bar in place

With 103A-21, 100uH working inductor.

Inductors Used for Comparison

Boonton 513 & 518 Q Standard type (left) and Boonton 103A-xx "Working Standard" (right)

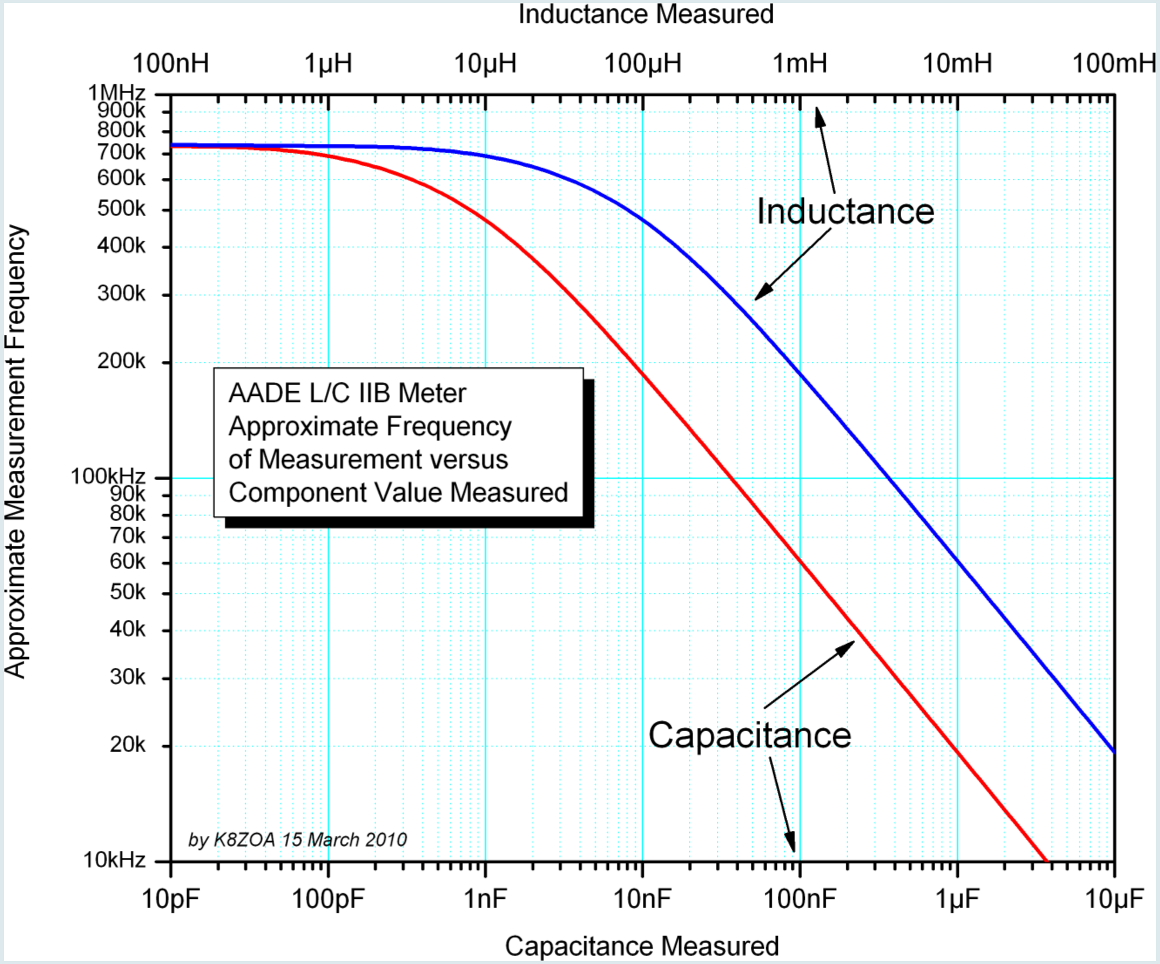
Both use banana plugs on 1.00 inch centers

Home made inductor, mounted on Teflon strip with 1.00 inch center banana plugs

Boonton 513 and 518 Q Standards come in oak boxes, with fitted mounts.

Frequency of Measurement

- Based upon an elementary circuit analysis, it is a simple matter to calculate the frequency at which a measurement is made, based upon the value of the capacitor or inductor being measured.
- The figure at the right provides an easy way to determine the test frequency.
- There is some unit-to-unit variation depending upon the precise value of C1 and L1, but differences of a few KHz in test frequency are not material to the device under test's gross behavior in most circumstances.
- For example, a 10mH inductor will be measured around 60 KHz, and a 1000pF (1nF) capacitor will be measured at about 480 KHz.
- The meter's firmware uses a precise frequency measurement and calibration process to determine the inductance and capacitance. This graph allows the user to know the approximate frequency for things such as assessing how the inductance might change when used in a circuit at a higher or lower frequency than that applied by the AADE meter.



Effective Inductance or True Inductance?

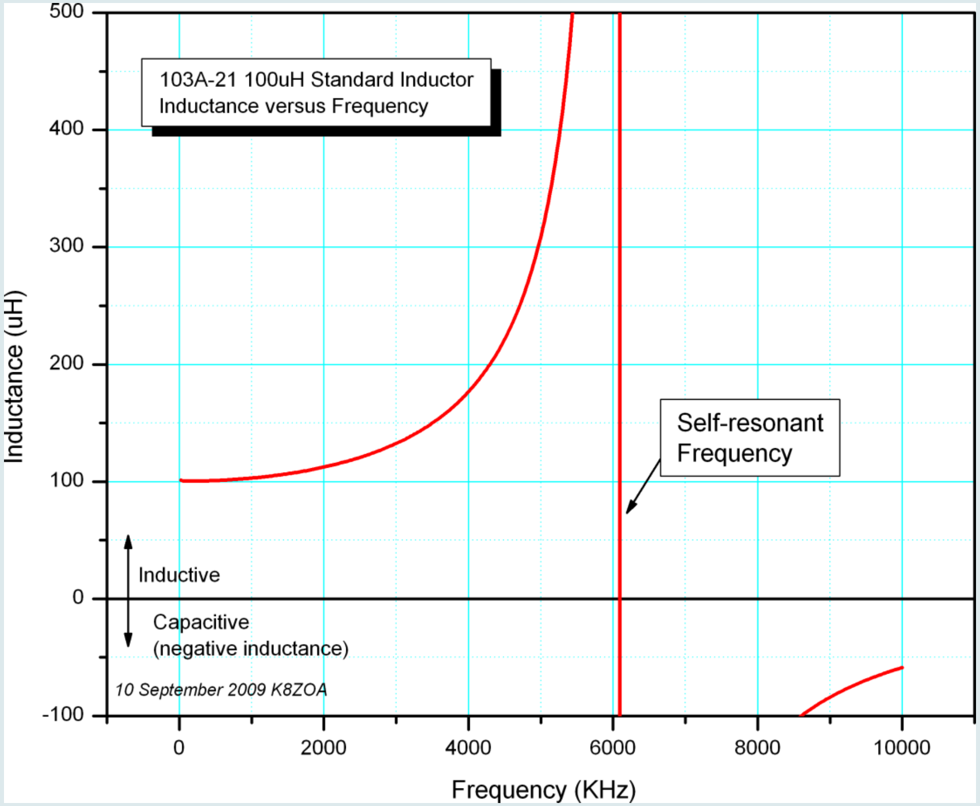
- The Boonton 103A, 513-A and 518-A series inductors have a nameplate value based upon the "true" or "DC inductance." This is the inductance that would be measured at a very low frequency, at which the effect of distributed capacitance and other effects are negligible.
- Inductance meters, including the L/C IIB, Q-meters and Impedance meters measure the "effective inductance" or Le. Le is larger than L and represents the modifying effect of distributed capacitance upon the inductor.
- The relationship between true inductance L and effective inductance Le is given by:

$$L = \frac{Le}{1 + \omega^2 LeCd}$$

$$Le = \frac{L}{1 - \omega^2 LCd}$$

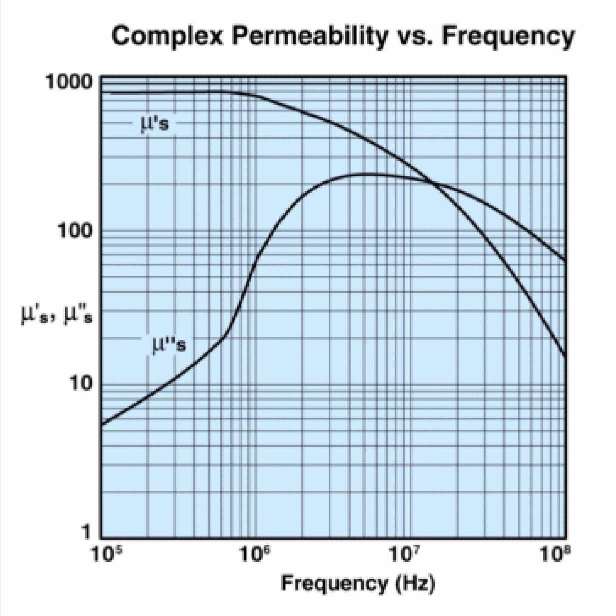
Effective Inductance or True Inductance? (continued)

- The plot shows Le versus frequency for a 103A-21, 100µH working inductor.
- As the frequency increases, the apparent or effective inductance increases. At the self-resonant frequency, the inductance becomes very high and then reverses sign, as the inductor plus distributed capacitance becomes capacitive.
- Hence, when comparing measured inductance with the nameplate values, the measured Le value must be corrected for distributed capacitance.
- Standard inductors often will include the distributed capacitance on the nameplate for this reason. If not, other techniques are available to determine the distributed capacitance.



Other Frequency Effects

- In addition to distributed capacitance, other frequency related effects must be considered in inductance measurements.
  - Current distribution in an inductor's windings changes with frequency due to skin effect and proximity effect. As frequency increases, the current flows more on the outside of the conductor (skin effect). Moreover, the current flow is not uniform as magnetic fields from adjacent windings alter the current distribution (proximity effect.) Consequently the effective dimensions of a solenoid inductor change with frequency and hence the inductance changes with frequency. This is true of an air core coil as well as one with a magnetic core.
  - Magnetic materials have a frequency dependent permeability, with ferrite material being particularly notorious for wide changes in permeability with frequency. The figure at the right shows the complex permeability of a commonly used ferrite material, Fair-Rite type 43. Inductance is proportional to u' (u" determines loss or Q) and at frequencies above 1 MHz, permeability rapidly declines. For example, at 10 MHz, a toroid inductor wound on type 43 material will have an inductance about 25% of that at 100 KHz.
  - In many cases, the changes in permeability with frequency can be safely ignored, but this is not always so.



Comparison with Standard Inductors

Model	Value	Units	L/C IIB Raw	Raw Error	Corrected for Cd	Corrected Error	Measurement Frequency (KHz)
103A-11	10	uH	9.968	-0.32%	9.957	-0.43%	691.1
103A-12	25	uH	24.95	-0.20%	24.89	-0.44%	632.9
103A-2	2.5	uH	2.489	-0.44%	2.488	-0.47%	726.9
103A-21	100	uH	100.9	0.90%	100.37	0.37%	470.9
103A-22	250	uH	254.0	1.60%	252.2	0.89%	342.3
103A-25	500	uH	508.9	1.78%	504.25	0.85%	256.1
103A-32	2.5	mH	2.543	1.72%	2.514	0.55%	120.4
103A-41	10	mH	10.16	1.60%	10.026	0.26%	60.8
103A-42	25	mH	25.5	2.00%	25.161	0.64%	38.5
103A-5	5	uH	4.947	-1.06%	4.944	-1.12%	714.3
103A-50	500	nH	483	-3.40%	483.0	-3.41%	737.4
103A-51	250	nH	242	-3.20%	242.0	-3.20%	738.8
513A	251	uH	253.8	1.12%	251.6	0.22%	341.7
518-A1	250	nH	248	-0.80%	248.0	-0.80%	738.8
518-A2	2.5	uH	2.507	0.28%	2.506	0.24%	726.9
518-A3	25	uH	25.63	2.52%	25.56	2.23%	632.9
518-A4	2.5	mH	2.656	6.24%	2.616	4.65%	120.4
518-A5	25	mH	26.05	4.20%	25.617	2.47%	38.5
Average Error				0.81%		0.19%	

Error Analysis

- After adjustment for distributed capacitance, the average error for the ensemble of 18 Boonton standard inductors is 0.19%. Quite impressive, right?
- Not so fast—further analysis is warranted. While many measured values are quite close to the nameplate values, two areas of divergence stand out.
  - 103A-50 and 103A-51 small value (500nH and 250nH, respectively)
  - 518-A3, A4 and A5. These range in value from 25uH to 25mH.
- These likely have different error mechanisms, so lets look at them separately.

Low Value Inductors

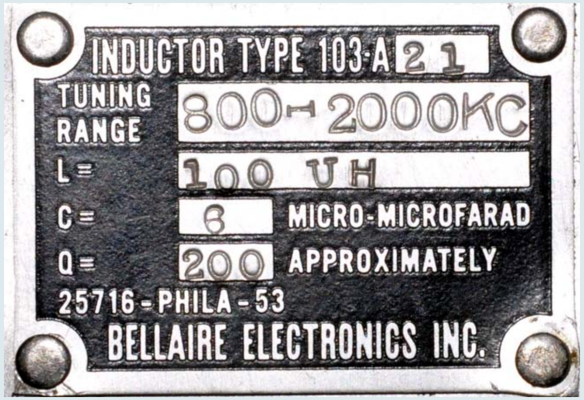
- Inductors in the nanohenry range are likely to give the L/C IIB meter problems for two reasons.
  - The frequency shift caused by adding a couple hundred nH to the 68uH series reference inductor is small, so that small errors in frequency measurement or in determining the reference inductor value translate into greater calculated component value error. (14 Hz difference in frequency corresponds to 1% error in the L/C IIB meter for a 250 nH component.
  - Nanohenry inductors are normally used at frequencies far above the 700 KHz measurement frequency used in the AADE meter. Hence the proximity and skin effect factors may be at work. In other words, an inductor designed to have 250 nH inductance at 40 MHz may have 230 nH inductance at 700 KHz.
  - To assess the contribution of the second factor, the 103-51, 250 nH inductor was measured at 40 MHz with an HP4342A Q-meter. The raw reading, after correcting the 4342A residual inductance is 283nH. The 103-51 nameplate distributed capacitance is 5.5pF. After adjusting the raw Q-meter reading for distributed capacitance, the true inductance is 250.1 nH, matching the nameplate value. This degree of agreement has a large component of happenstance, as the Q-meter's rated accuracy is ±3%.
  - As a cross-check, the 103A-51 inductor was measured on an HP4192A LF Impedance Meter at 738.8 KHz, nearly the same frequency used by the L/C IIB meter for this component value. The result is 235.7nH
  - Both the L/C IIB and HP4192A measure the 103A-51's inductance at 738.8 KHz well below the nameplate value, which is demonstrated to be approximately correct at 40 MHz, within the range of frequencies for which the 103A-51 inductor is rated for use.
  - Consequently, it is reasonable to attribute at least part of the error in the 103A-51 case to a real change in inductance with frequency, likely resulting from skin and proximity effects being considerably reduced from those in effect at the frequencies for which the 103A-51 inductor is rated.
  - If a highly accurate measurement of a nanohenry inductor is needed, it should be made at the operating frequency, not at a frequency nearly two orders of magnitude below its intended operating frequency.

Nameplate	L/C IIB Corrected for Cd	L/C IIB Corrected Error	HP4192A Corrected for Cd	HP4192A Corrected Error
250nH	242.0	-3.20%	235.7	-5.72%

518-Ax Series Inductors

- Boonton 518-A series inductors are not provided with nameplate values of inductance and capacitance. (The 513A is, as are the 103A-series.) The values in the earlier table are the catalog “nominal” figures.
- 518A inductors were intended to calibrate the 160 and 260 Q-meters as well as the later HP4342A Q-meter. Consequently the parameters are defined in terms of how many pF (or, rather μμF considering the date of manufacture) the Q meter capacitance dial will read.
- The resonating capacitance will be slightly different between a Boonton 260A and an HP4342A Q-meter because the two instruments have different residual inductance and stray capacitance effects.
- The 518A inductors are higher quality than the 103A “working inductors” and are packaged in a hermetically sealed copper can, filled with helium. (Or at least it was filled with helium when manufactured 50+ years ago.)
- It is possible to deduce a nameplate value from the frequency and resonating capacitance values, but without a good knowledge of the strays of a Boonton 260A, error will be introduced.

518-A5 nameplate



103A-21 Nameplate (this inductor was made by Bellaire electronics on a government contract, not Boonton.)

Practical Study-Building a Z10020 Band-Reject Filter

- The Z10020 band-reject filter suppresses AM medium wave frequencies in the range 500-1700 KHz, whilst passing lower and higher frequencies.
- It is used to prevent receiver overload from nearby strong medium wave stations.
- The Z10020 has seven tuned circuits, each of which requires accurate inductance and capacitance measurement. The tuned circuits are resonant at a frequency fo depending on the Z10020's options (special versions move the upper and lower cutoff points, for example, to permit receiving 518 KHz NAVTEX signals, compared with the stock filter's 490 KHz lower cutoff.) However, fo for all options fall in the range 900-975 KHz.
- Construction practice for the Z10020 filter is to wind and adjust the seven inductors (wound on Mix-7 powdered iron toroid cores) to be within ±1.0% of the required value, when measured at fo, using an HP4192A LF Impedance meter. A Q check is also made. In almost all cases, the actual error is considerably less than 1%.
- After the seven inductors are coated with Q-dope, they are re-measured at fo with the HP4192A and the required resonating capacitance computed. Parallel combinations of 5% polystyrene film capacitors are selected and measured at fo to be within ±1% of the required value, and in almost all cases, the actual error is considerably less than 1%.
- One Z10020 filter was built with component values also measured with the L/C IIB meter.

Inductance Results

- Results suggest it would be difficult to hit the target ±1% with an L/C IIB meter.
- This conclusion assumes the HP4192A is meeting its rated accuracy, which is supported by the inductance comparisons with Boonton standard inductors and that constructed filters match the design performance rather closely.
- It also assumes that ±1% is an appropriate tolerance for filter components.

ID	Design uH	HP4192A Measured	Error from Target	L/C IIB Measured	Difference from target	HP4192A to L/C IIB
L1	3.036	3.023	-0.43%	3.003	-1.09%	-0.66%
L2	11.325	11.332	0.06%	11.24	-0.75%	-0.81%
L3	2.126	2.131	0.24%	2.106	-0.94%	-1.17%
L4	11.957	11.928	-0.24%	11.84	-0.98%	-0.74%
L5	2.126	2.118	-0.38%	2.082	-2.07%	-1.70%
L6	11.325	11.358	0.29%	11.28	-0.40%	-0.69%
L7	3.036	3.048	0.40%	3.028	-0.26%	-0.66%

Effect of Test Fixture Inductance

- To measure a 2uH inductor within 1% requires an accuracy of 20nH or less.
- Part of the error in measuring small value inductors can be ascribed to careless use of test leads.
- In this example (perhaps on the extreme side, but not totally impossible) a 2uH inductor measured with the test leads in the center photo but with zero set as in the upper photo would be 2.5% in error just from lead inductance effects alone without considering instrument error.
- This is one reason the standard inductors were attached by a specially made test fixture.

Clip leads together and use the zero function to compensate for lead inductance

Moving the leads to reduce the area within the loop reduces the inductance by 43 nH (resulting in -43 nH reading on the L/C IIB

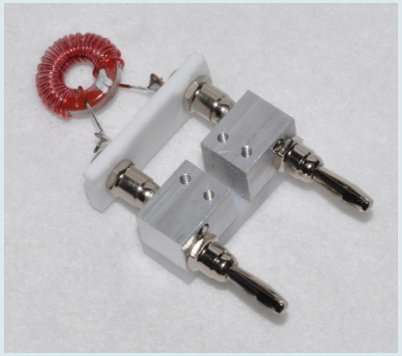
At an intermediate point, with the leads resting on an eraser, the inductance has shifted by 24 nH from the "zero" value.

Effect of Test Fixture Inductance (cont'd)

- If clip leads are desired for convenience, a rigid arrangement as illustrated below can be used. The alligator clips mount on the end of banana plugs.
- Better accuracy will be found, however, if the component under test is connected directly to the meter's binding posts.
- HP4192A meter and 16047A fixture "swallow" the component leads to reduce lead inductance.
- The fixture and instrument are also of Kelvin or "4-wire" design which greatly reduces other error modes.
- It also calibrates out fixture inductance and capacitance when measuring L, C and R.

Low Q Inductance Accuracy

- To assess the effect of Q (inductor loss) upon instrument error, three inductors were custom made.
- Each consists of 25 turns of #22 AWG magnet wire on a T68-2 powdered iron core. The nominal inductance of the coils is 4uH. The windings were fixed in place with General Cement "Q-Dope."
- To provide samples of high, medium and low Q coils, resistors were added in parallel with two of the inductors. The target Q's were 50 (medium) and 10 (low).
- The inductors and resistors are mounted on Teflon strips, with banana plugs, on 1 inch centers to be used with other test equipment, or with the L/C IIB meter through the adapter plug.
- This arrangement permits zeroing the L/C IIB meter with a shorting bar and avoids movement in the fixture, thereby improving accuracy.
- The inductors were measured before and after adding the Q-adjusting resistors on an HP4342A Q-meter at 7.9 MHz.



Low Q Inductance Accuracy (cont'd)

HP4342A Q-Meter

- No change in inductance observed.
- Instrument accuracy is ±3%.
- Test frequency 7.9 MHz
- Inductor II has no Q-adjusting resistor and is the control inductor.

ID	L before	Q before	L after	Q after
I	4.10	190	4.10	42
II	4.18	204	4.18	204
III	4.38	194	4.38	7.8

AADE L/C IIB

- Very slight change noted, on the order of 0.1%, well within the margin of error due to slight movement of the inductor during the process of installing and removing the resistor.
- It would not be possible to note a 0.1% change on the HP4342A Q-meter.
- Since the frequency at which the measurements are conducted are so different, and the distributed capacitance is undetermined, a comparison between the HP4342A and L/C IIB values is not meaningful.

ID	L before	L after
I	3.994	4.000
II	4.073	4.073
III	4.240	4.246

Inductors with Core-Based Frequency Sensitivity

- To assess possible problems related to frequency dependent inductance, four ferrite core inductors of roughly 100uH inductance were made and attached to 1.00 inch spaced fixtures.
- The inductors are:
  - 38 turns, FT50-61 core
  - 15 turns, FT50-43 core
  - 6 turns, FT50-75 core
  - 6 turns, Steward 35T0501 core

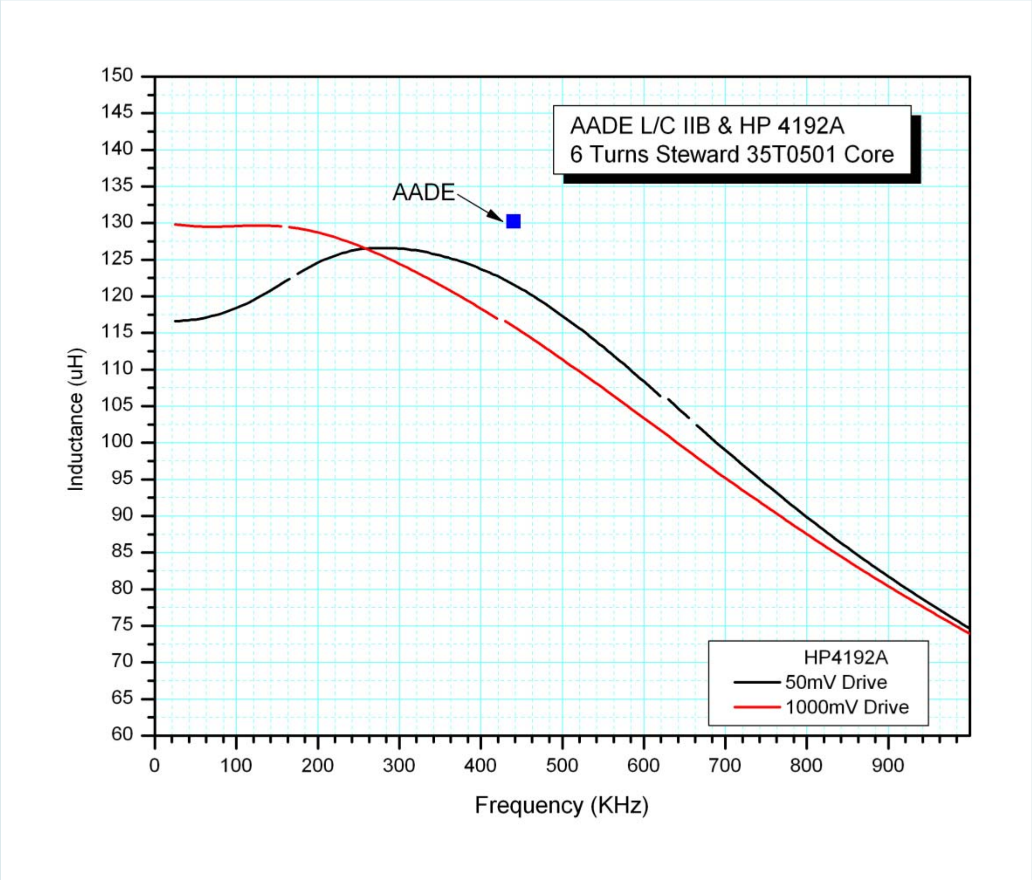
Inductors with Core-Based Frequency Sensitivity (cont'd)

- All inductance in uH. L/C IIB frequency of measurement is approximately 450 KHz. HP4192A is 100 KHz, with 1000mV drive.
- Type 61's permeability is relatively stable with respect to frequency up well into the MHz range and it shows relatively small difference in inductance between the two instruments.
- The point is not to focus upon "accuracy" here as it is to illustrate that measurements made at frequency fx with some core materials cannot be extrapolated to frequency fy accurately. Rather, the inductance must be determined near the operating frequency.

Windings & Core	HP4192A @ 100 KHz	L/C IIB	Difference
38T, FT50-61	89.94	93.26	3.69%
15T, FT50-43	134.84	102	-24.35%
6T, FT50-75	127.62	129.9	1.79%
6T, 35T0501	129.59	129.7	0.08%

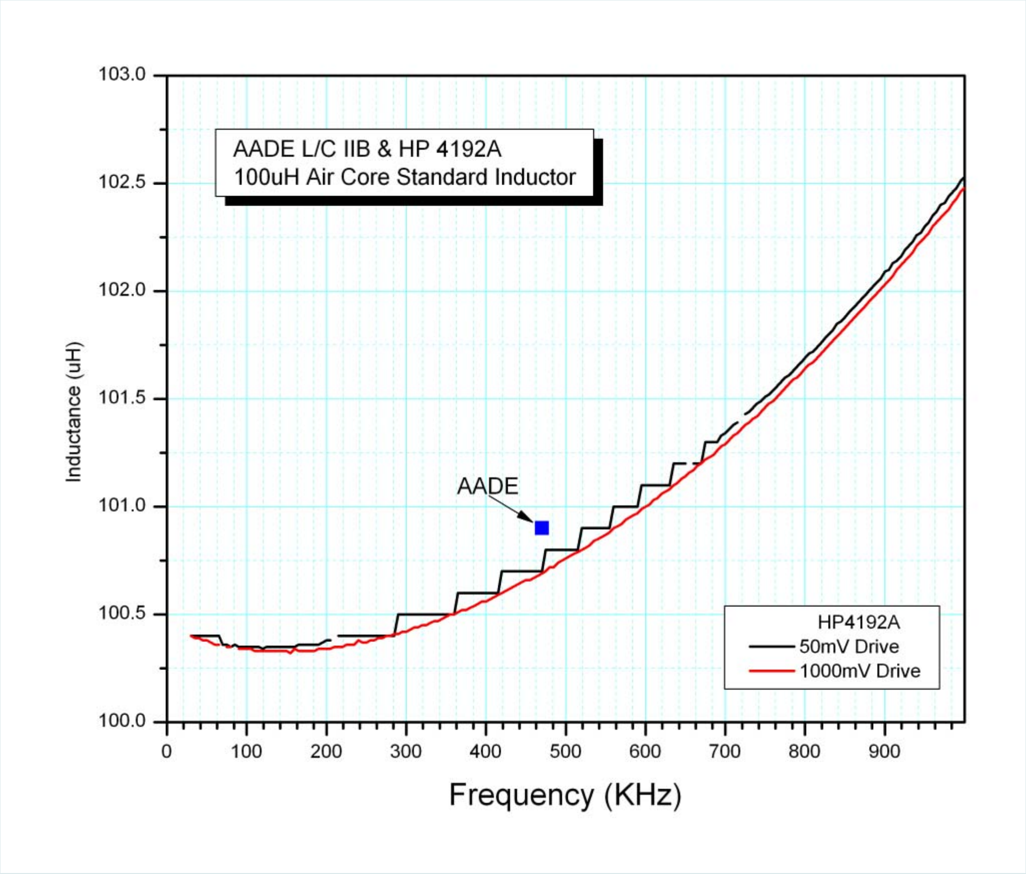
Inductors with Core-Based Frequency Sensitivity (cont'd)

- Plotting inductance versus frequency (and drive level) for the Steward 35T0501 inductor illustrates the problem.
- What is the inductance? Is it 130uH? Or is it 75uH?
- The answer is that it is both, and many other values as well, depending upon the frequency at which the measurements are made and the excitation level applied to the inductor by the test equipment.
- In general, neither of these parameters are known to L/C IIB users, nor may they be independently controlled.
- This data shows the near perfect agreement between the L/C IIB and the HP4192A meter for this inductor is happenstance, as the frequency of measurement is considerably different and the true value at the frequency at which the L/C IIB meter measures the inductor is considerably less than the displayed value.



Inductors with Core-Based Frequency Sensitivity (cont'd)

- To illustrate the difference between a frequency-dependent inductance and one that is stable, consider the air core 103A-21, 100uH inductance standard.
- Over the same frequency range, it has an essentially stable value, with the increase in apparent inductance being due to distributed capacitance effects.
- The slight difference in inductance with drive is due to the HP4192A dropping one digit of resolution with low drive levels.
- Note that the agreement between the L/C IIB and the HP4192A is much better in this case, as frequency effects are largely washed out.
- The difference between the two instruments can be further reduced if an adjustment for distributed capacitance is made, as discussed earlier in this review.



Capacitance Accuracy

- Most common capacitor dielectrics are not frequency sensitive.
- Frequency effects are much more related to physical considerations such as lead length or plate structure.
- The most commonly used dielectric with a frequency dependent dielectric constant is polyester, which may decline as much as 2.5% between 1 KHz and 100 KHz. Trade names for polyester include Mylar, and it is also referred to as PET, PETE, or PET.
- Extensive comparisons between my HP4192A and GR 1658 DigiBridge indicate agreement within 0.1% in capacitance measurements, with an average discrepancy of 0.01% for 15 samples of 1% capacitors between 100 pF and 0.22uF. This agreement suggests the two instruments are likely reporting accurate values.

Selected Capacitor Measurements

Nominal	Units	Tolerance	HP4192A Meas.	L/C IIB Meas.	H4192A to Nominal	L/C IIB to Nominal	HP4192A to L/C IIB
100	pF	1%	100.41	98.34	0.41%	-1.66%	2.06%
0.22	uF	1%	0.2209	0.2222	0.41%	1.00%	-0.59%
0.1	uF	1%	0.10052	0.1012	0.52%	1.20%	-0.68%
970	pF	3%	978.6	979.5	0.89%	0.98%	-0.09%
10000	pF	1%	10073	10090	0.73%	0.90%	-0.17%
95	pF	5%	96.47	96.36	1.55%	1.43%	0.11%
20000	pF	1%	20110	20024	0.55%	0.12%	0.43%
				Average:	0.72%	0.57%	0.15%

The most divergence is seen with the smallest value capacitors. This is not unanticipated given the L/C IIB architecture.

Except for the 100 pF capacitor, agreement between the HP4192A and the L/C IIB is excellent.

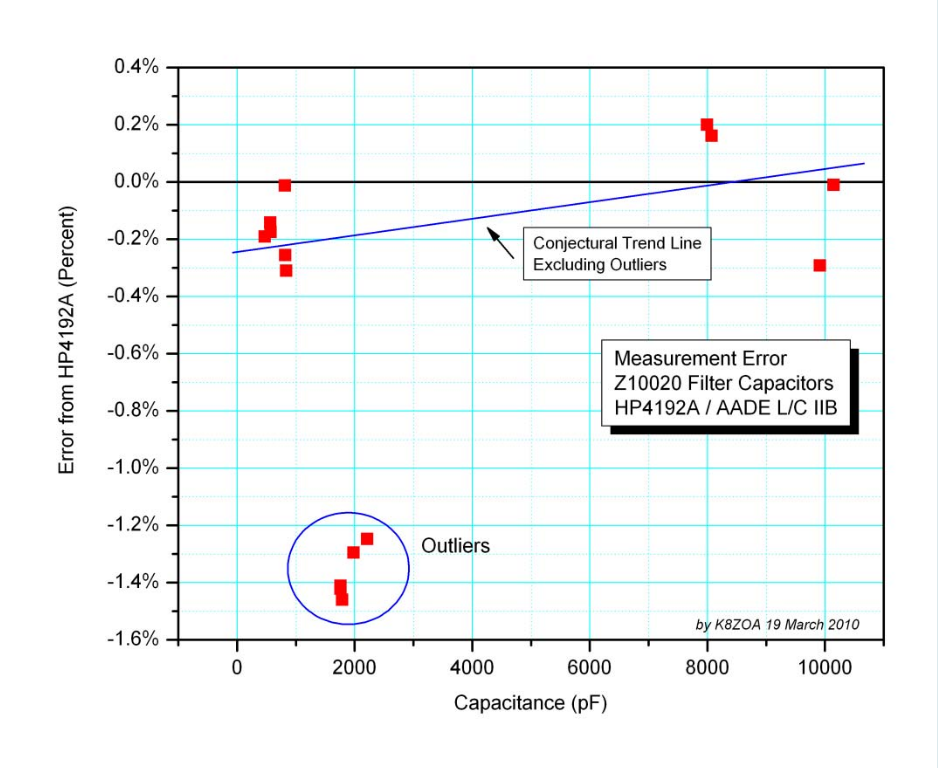
Capacitance Results (all in pF)

Associated Inductor	Resonating Capacitance	Measured HP4192A	Error	Measured L/C IIB	Error	Error HP-AADE
		8060		8073		0.16%
		822.2		820.1		-0.26%
L1	8873	8882.2	0.10%	8893.1	0.23%	0.12%
		1786.4		1761		-1.42%
		570.0		569		-0.18%
L2	2361	2356.4	-0.19%	2330	-1.31%	-1.12%
		816.9		816.8		-0.01%
		1814.5		1788		-1.46%
		9943		9914		-0.29%
L3	12618	12574.4	-0.35%	12518.8	-0.79%	-0.44%
L4	2246	2244	-0.09%	2216	-1.34%	-1.25%
		10151		10150		-0.01%
		2007		1981		-1.30%
		472.7		471.8		-0.19%
L5	12618	12630.7	0.10%	12602.8	-0.12%	-0.22%
		1785.2		1760		-1.41%
		565.0		564.2		-0.14%
L6	2356	2350.2	-0.25%	2324.2	-1.35%	-1.11%
		7981		7997		0.20%
		838		835.4		-0.31%
L7	8811	8819	0.09%	8832.4	0.24%	0.15%

- The capacitors used in a Z10020 band reject filter were also measured with the L/C II. The table shows the individual capacitor measurements along with the total capacitance in each of the Z10020's tuned circuits.
- The total tuned circuit capacitance is on the line identifying the associated inductance.
- Capacitance is measured more accurately by the L/C IIB meter than inductance, although several instances of larger difference than desirable exist.
- The Z10020's resonating capacitance is obtained by parallel combination of multiple capacitors in most cases. In some instances, L/C IIB meter reads high on some paralleled values and low on others, thereby providing offsetting errors. This cancellation is happenstance and cannot be relied upon.

Capacitance Error Observations

- Plotting the divergence between HP4192A and L/C IIB capacitor readings suggests an error trend as indicated at the right.
- Something, and I don't know what, caused a significant change around 2000pF.
- Leaving aside the 2000pF oddities, the L/C IIB meter measured capacitors with a more than acceptable accuracy.



Conclusions

- AADE L/C IIB meter represents a bargain, providing good accuracy of both inductance and capacitance for most hobby and semi-professional purposes. It is not a laboratory grade instrument, nor is it marketed or described as such.
- An understanding of its limits will aid the user:
  - Be careful in accepting inductance values of coils with frequency-dependent (and amplitude dependent) permeability, such as most ferrites.
  - For best accuracy when measuring low inductance devices, do not use flexible test leads.
- What could be improved?
  - Default banana post spacing should be 0.75 inches (or 1.00 inches), not the oddball spacing supplied unless the purchaser specifically requests 0.75 inches. This will allow standard accessories to fit the instrument.
  - Mechanically flimsy feel to the instrument and the function switches have a similar flimsy feeling.
  - The instrument has little to no internal shielding. One effect of this can be see if the capacitance is zero'ed while on a non-conductive surface and then moved to a metal benchtop. The zero reading will shift several pF.
  - Instruction manual is limited at best and does not adequately cover the instrument's operating envelope, theory of operation, etc., omitting even simple things such as a chart relating component value to the measurement frequency. Nor is the effect of distributed capacitance on inductance (true L versus effective L) discussed. Particularly for an instrument aimed at the beginner in electronics, the manual should provide greater detail on these real world effects.