HP 4342A Q Meter Tests

S/N: 1212J01342

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Intent of this Document

- Describe how I measured the important parameters of the HP4342A Q Meter and provide results.

- This is the classical instrument for measuring the Q factor, that I am fortunate to own.

- Will show how to build a low output impedance transformer, similar to the HP Q meter, giving a very low impedance.

- Will show how to correct the decrease un Q reading caused by the source resistance. (Excel sheet) For both HP4342A and Boonton 260A

- This complements my QEX article on Q factor measurements:
  See: http://ve2azx.net/technical/Q-FactorMeas_on_LC_Circuits.pdf
  and figure 1 below.

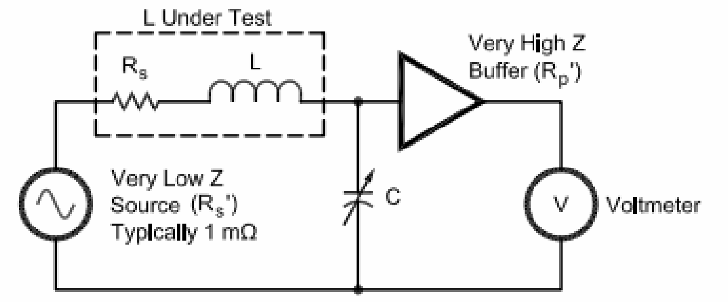
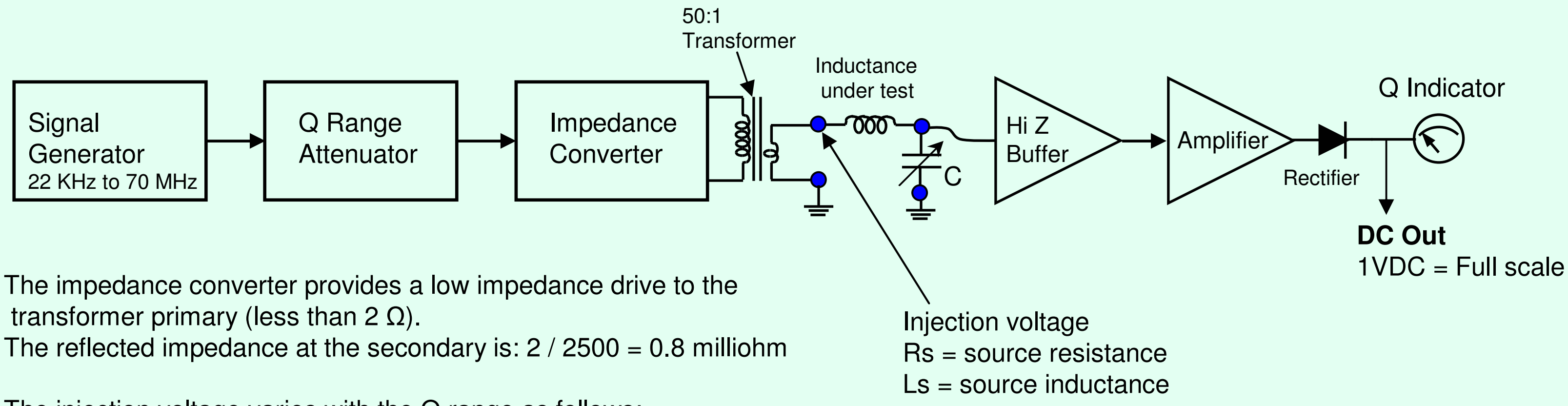


Figure 1 — Block diagram of the classical *Q* meter as used in the HP 4342A.

Block Diagram of the HP4342A Q Meter



The impedance converter provides a low impedance drive to the transformer primary (less than 2 Ω).
The reflected impedance at the secondary is: 2 / 2500 = 0.8 milliohm

The injection voltage varies with the Q range as follows:

Q range	Injection V	dBm (50Ω)
30	30 mV (as calibrated)	-17.45
100	9 mV	-27.90
300	3 mV	-37.45
1000	0.9 mV	-47.90

The Q Range attenuator must adjust levels according to the Q range selected.
To go from a Q range of 30 to 100 requires a level change of 100/30 = 3.333
Attenuation in dB = 20 * log(3.333) = 10.46 dB

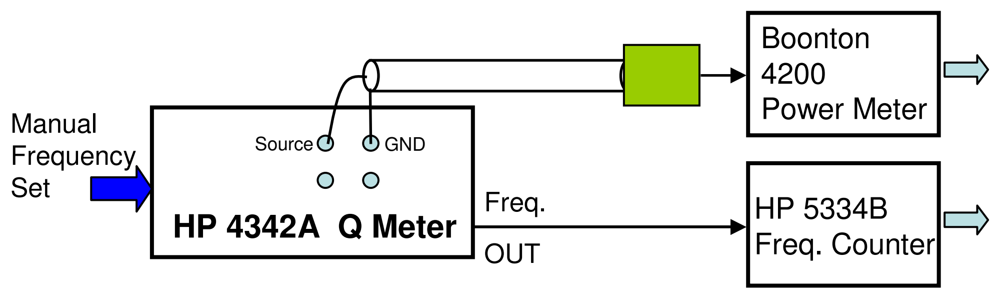
To go from a Q range of 100 to 300 requires a level change of 300/100 = 3.000
Attenuation in dB = 20 * log(3.000) = 9.54 dB

Note that to go from a Q range of 30 to 300 requires a level change of 300/30 = 10
Attenuation in dB = 20 * log(10) = 20 dB = 10.46 + 9.54

The calibration is done at 30 mV with the Q range set at 30.
This gives 30 mix 30 = 900 mV full scale at the voltmeter input, on all Q ranges.
The voltmeter is adjusted to read 900 mV at 50 KHz.

Measuring the Injection Source Flatness

At the transformer secondary

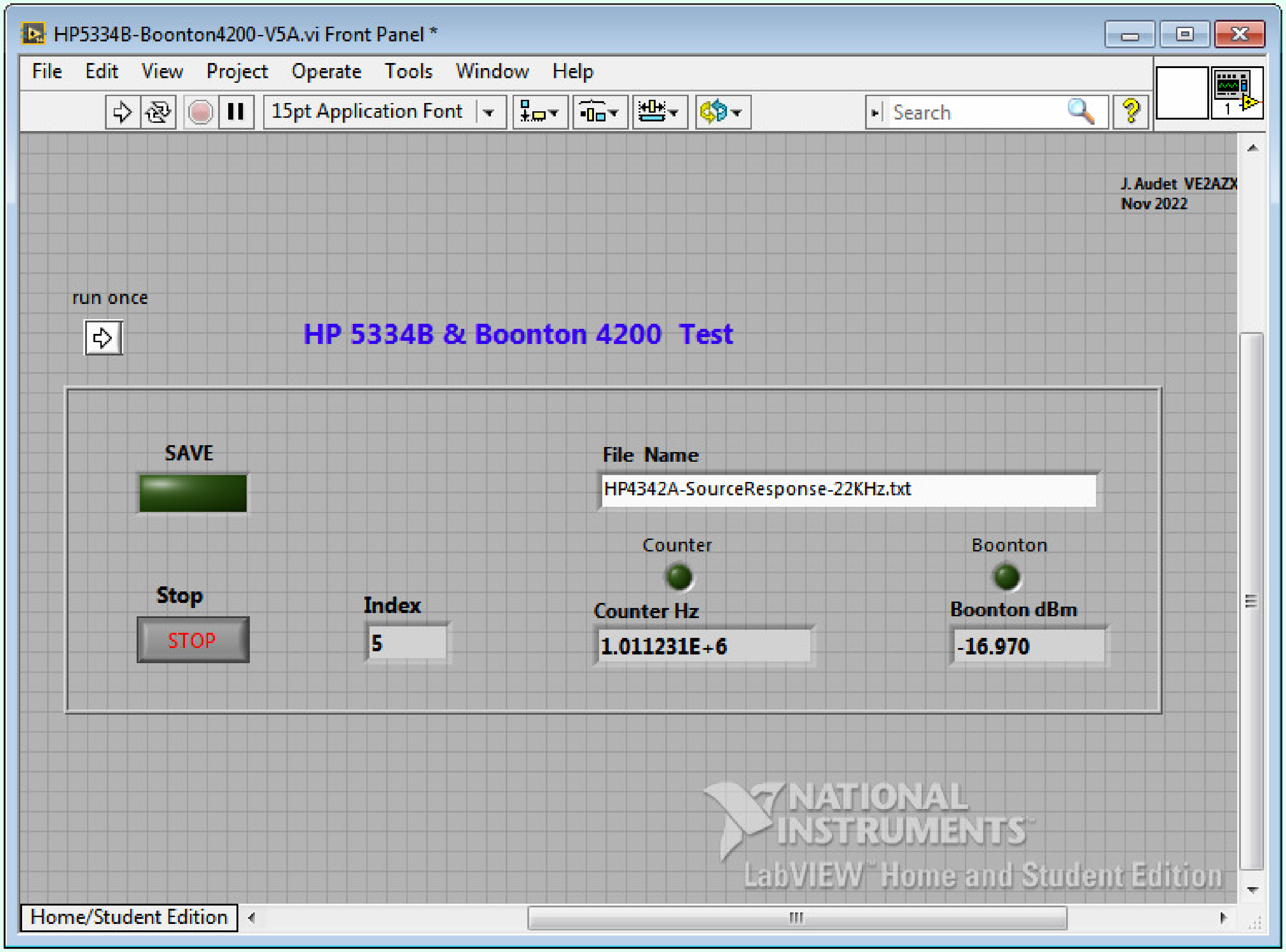


SETUP FOR MEASURING SOURCE FLATNESS

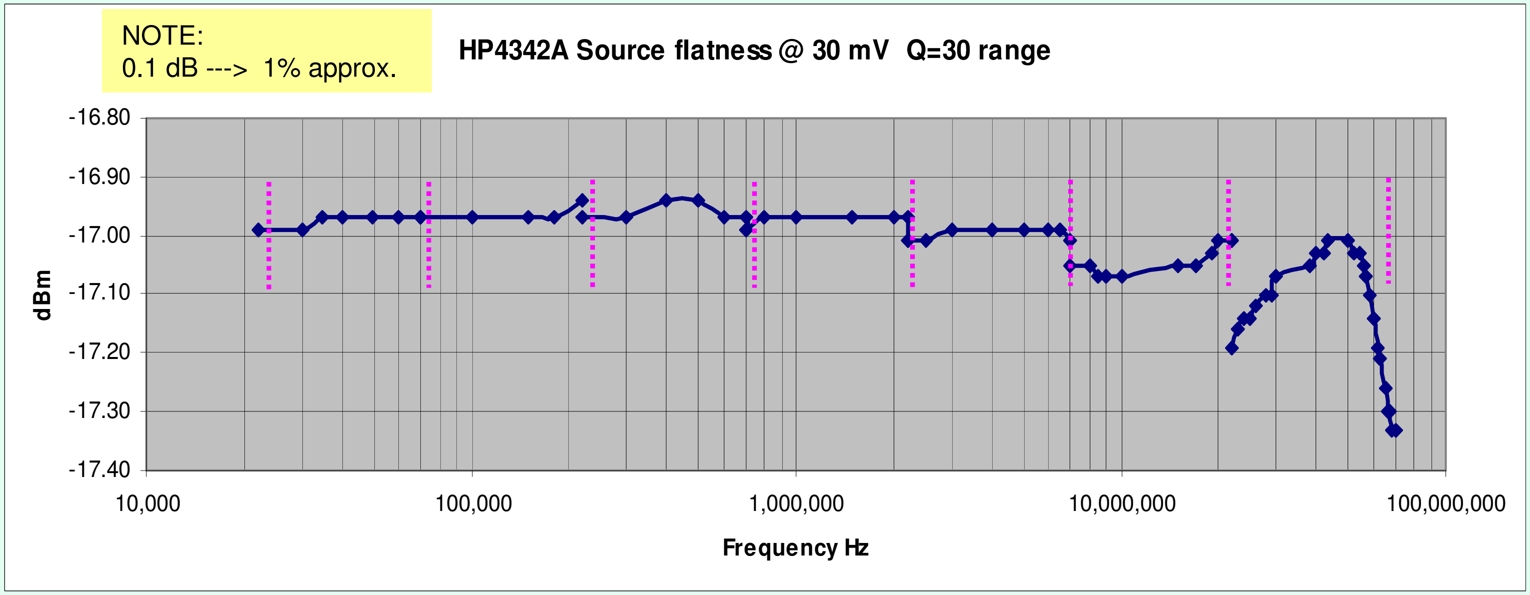
Injection Source Flatness

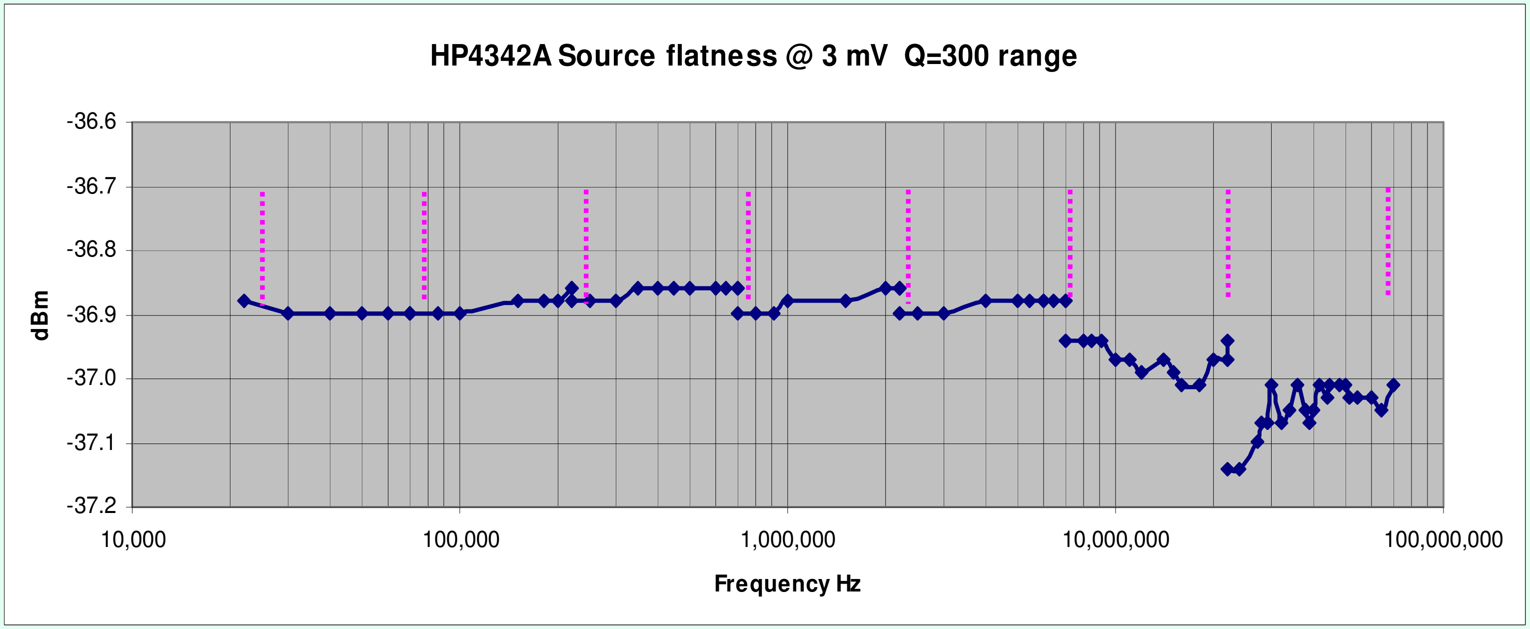
Mostly automated test, using Labview

Ref: HP5334B-Boonton4200-V5A.vi



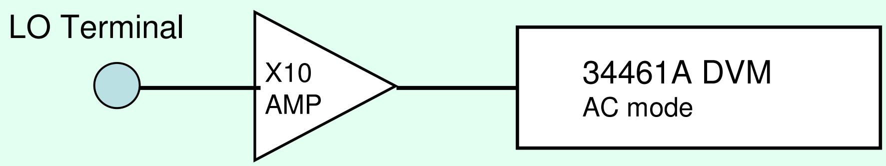
Injection Source Flatness





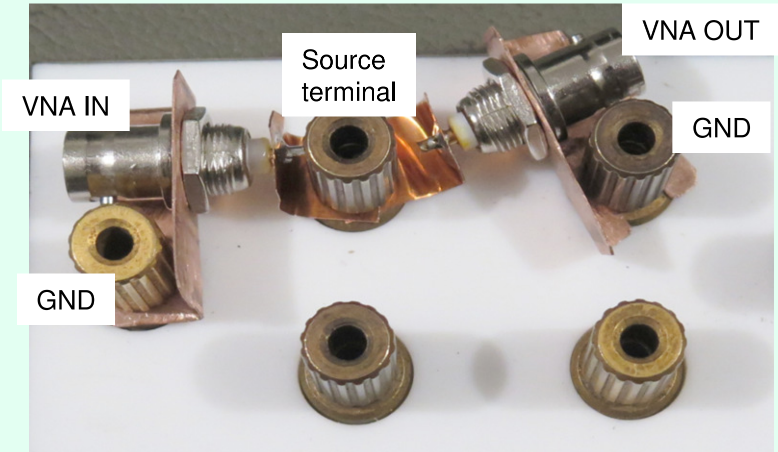
Test of the Internal Q Range Attenuator

HP 4342A set at 100 KHz

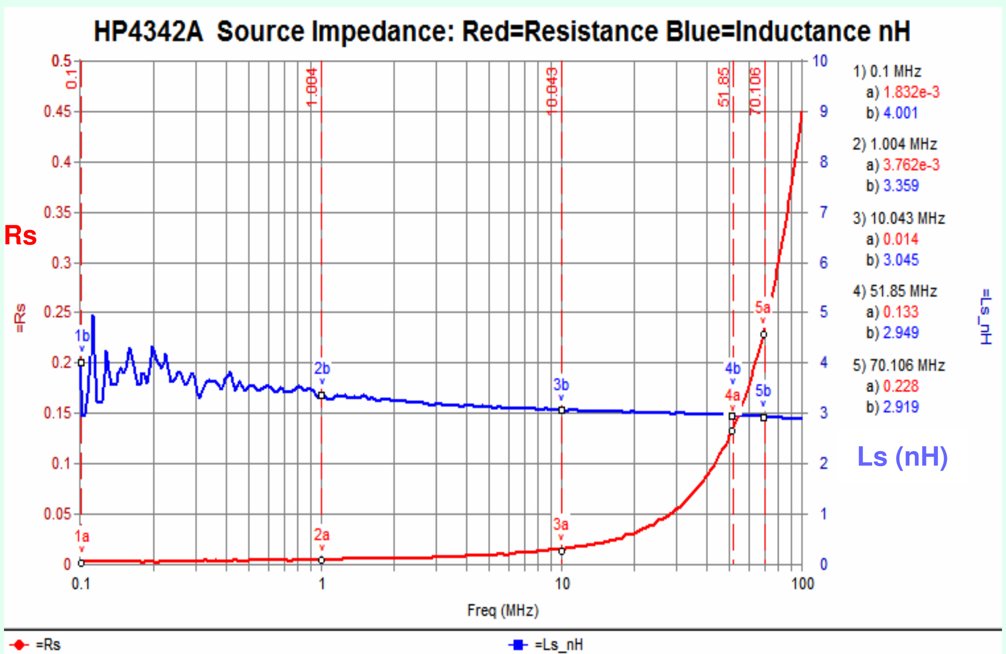


Q range	dB reading		Expected dB	Error dB
1000	0.00	Ref.		
300	10.40		10.46	- 0.06
100	20.00		20.00	0.00
30	30.38		30.46	- 0.08

Verification of the Source Resistance: Rs and Inductance: Ls (at the transformer secondary)



- The tests are done in S21 mode with the unknown impedance connected in shunt. (across the source terminal)
- Rs varies from 1.8 milliohm at 100 KHz, to 14 milliohm at 10 MHz, to 228 milliohm at 70 MHz. This comes from the transformer coupling coefficient which is below the ideal value of 1 (About 0.8)
- Ls value is around 3 nH, (blue curve).




```
' SERIES and SHUNT IMPEDANCE CALCULATIONS
' S21 mode is used. Data from .s2p file
Z0=50     ' Impedances of source and load.

R=.RE[S21]          ' Extract Re and IM parts of measured S21.
I=.IM[S21]
C=COMPLEX(R,I)      ' Convert to a complex number

' Select Z in SERIES connection. Not Used.
' Z=2*Z0*(1-C)/C        ' Calculate Z in serial mode.

' Select Z in SHUNT connection. Used here.
Z=0.5*Z0*C/(1-C)       ' Calculate complex Z in shunt mode.

MagZ=MAG(Z)            ' Computes Impedance magnitude
Rs=RE(Z)               ' Series Résistance
Xs=IM(Z)               ' Series Reactance
Ls_ µH=Xs/(2*PI*FREQ)          ' FREQ in MHz
Ls_nH=1000*Ls_µH
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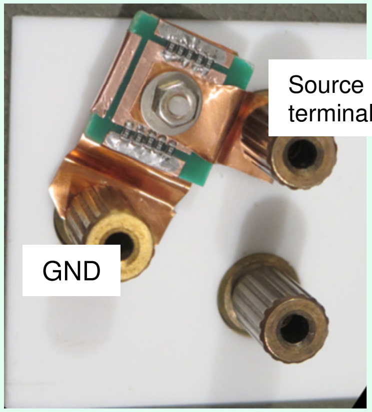
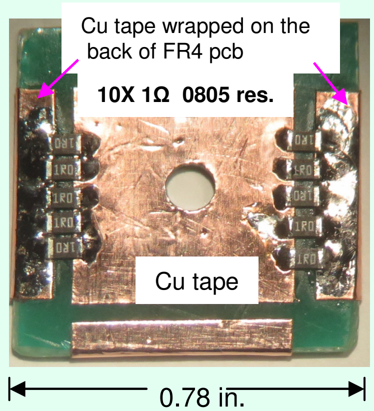
Verification of the Impedance Converter and Transformer Response

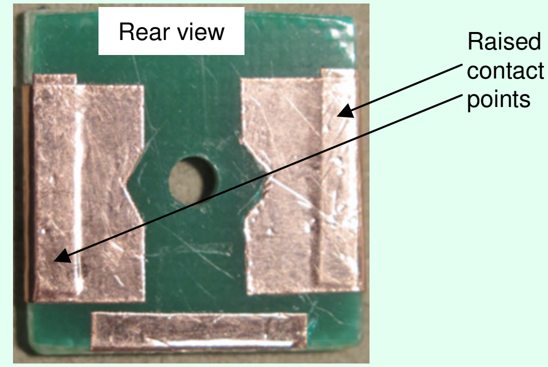
Measured transformer turns ratio @ 100 KHz: 51

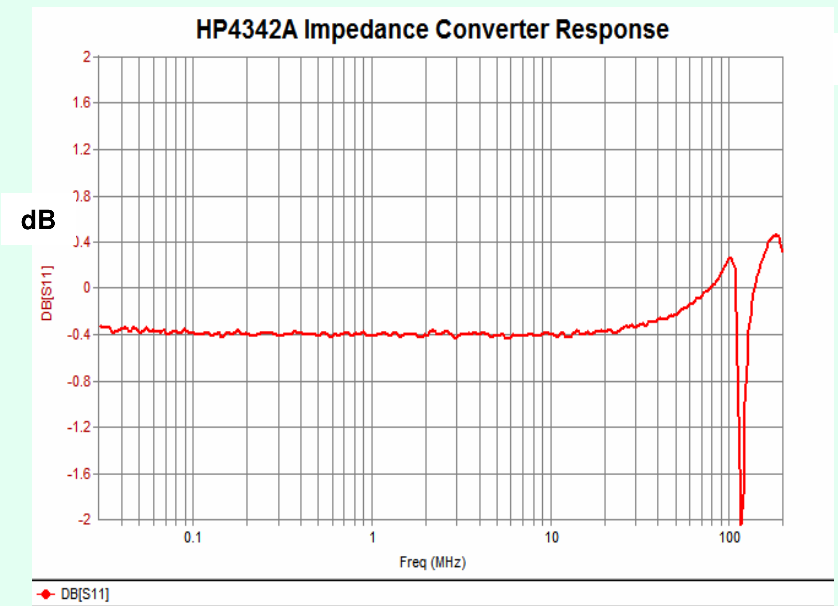


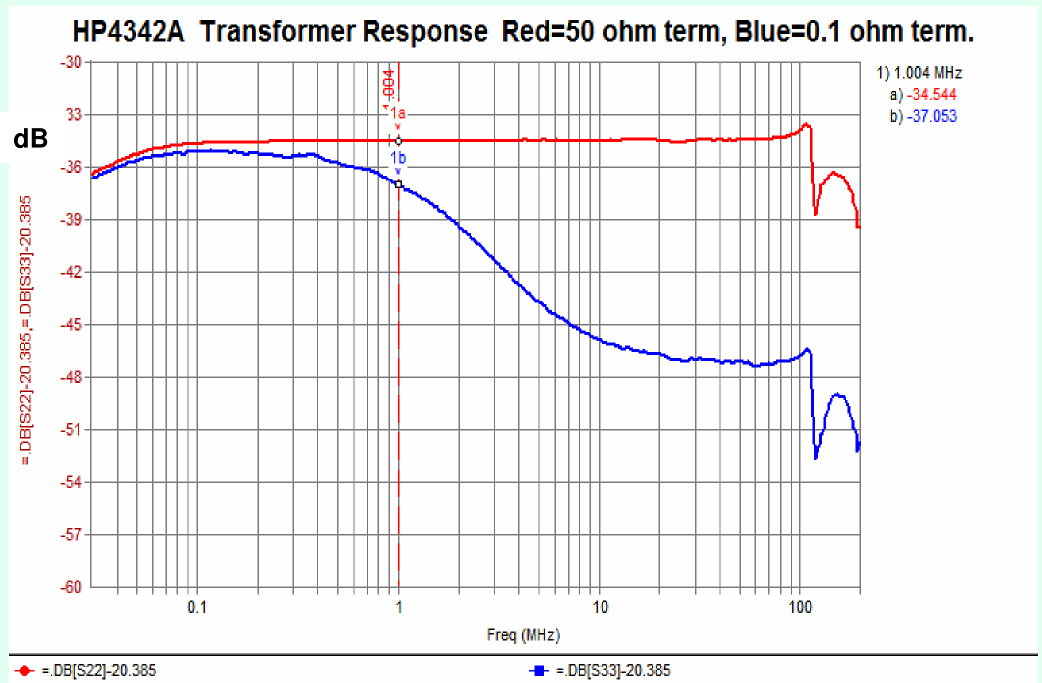
0.1 Ω load used to test transmission (S21)

0.1 Ω Resistor connected across source / gnd terminals







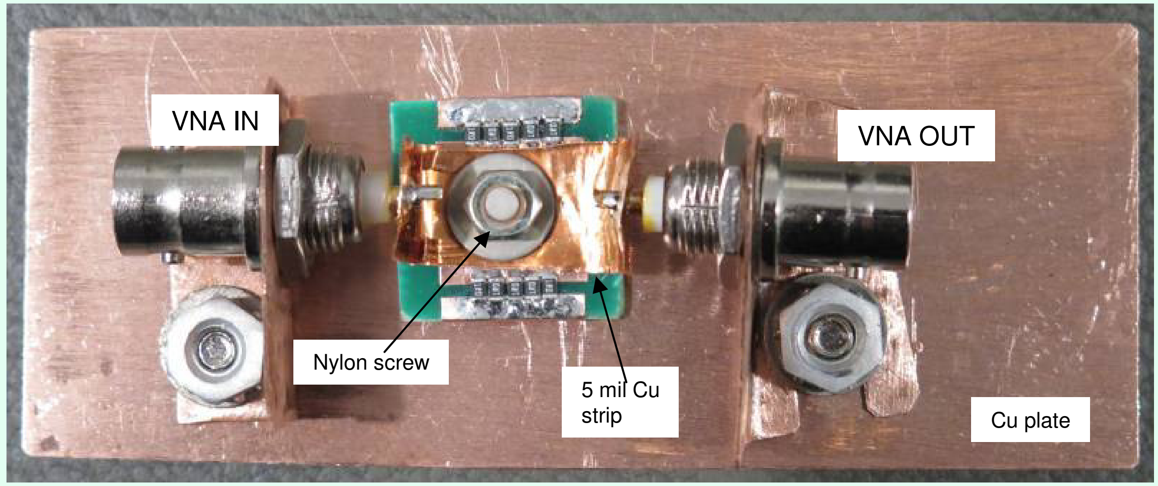


It uses two emitter followers in cascade.

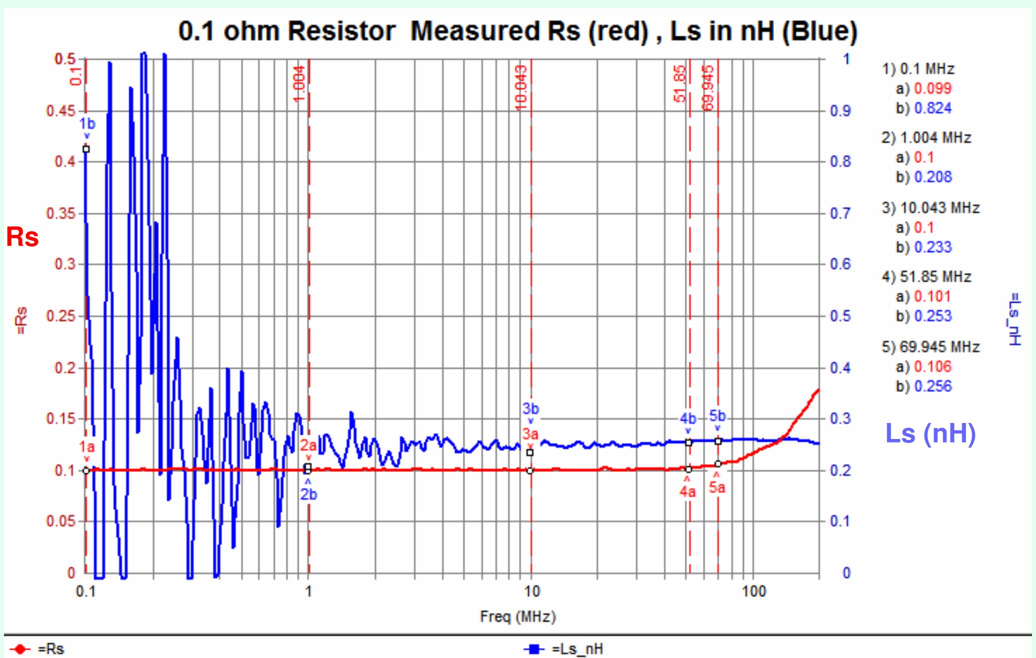
Note: **Transformer response includes the impedance converter**

Ref: HP4342A-Imped Cvtr and Xfrm Tests.wsp

Testing the Low Impedance 0.1 Ω Termination Resistor



Set-up to measure the resistance Rs and inductance Ls, in S21 mode with shunt connection

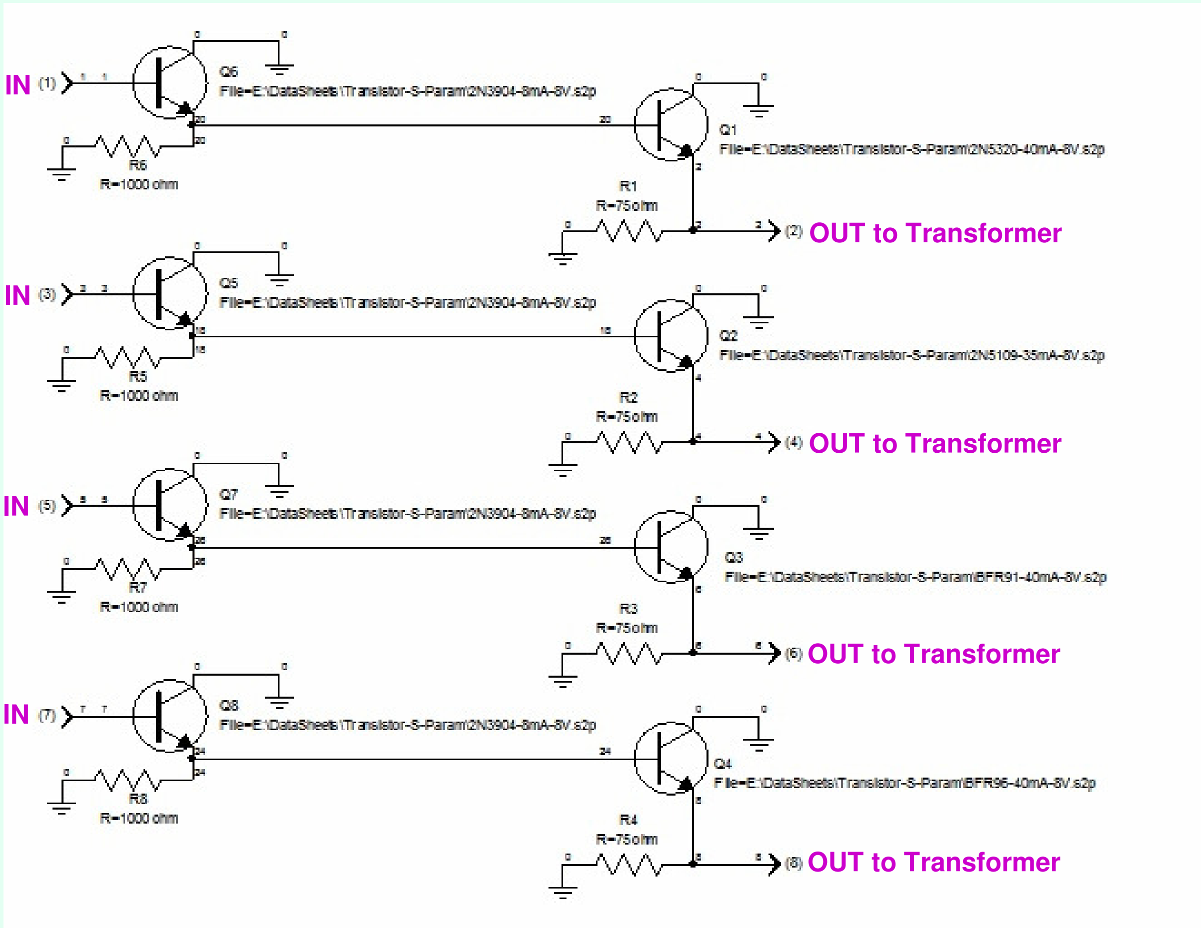


- Rs (red) is very constant up to ~ 70 MHz at 0.1 Ω

- Ls (blue) varies slightly between 0.20 and 0.25 nH
  Such a small value is difficult to measure below 1 MHz
  (XL = 1.6 milliΩ at 1 MHz).

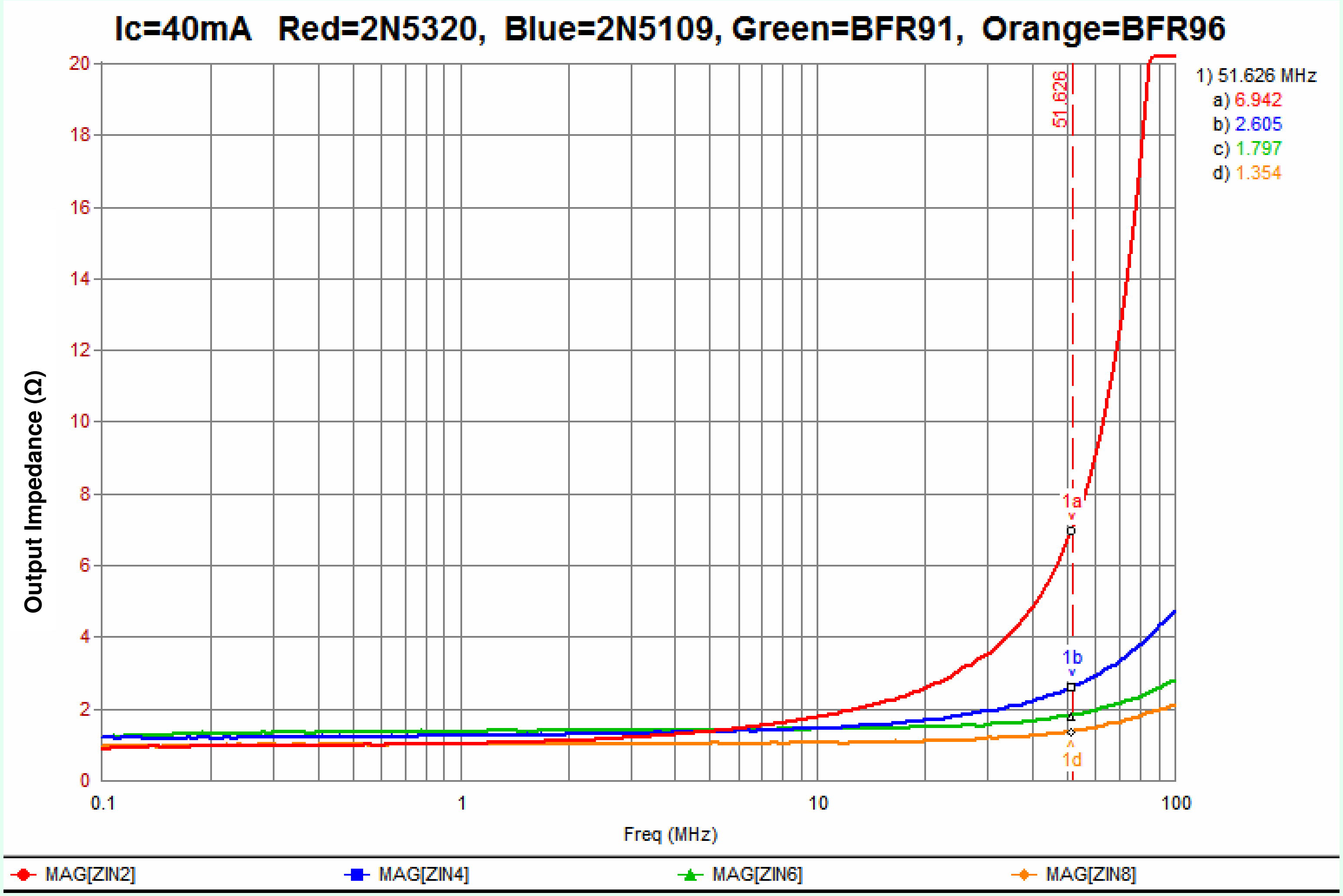
Simulations of Impedance Converter (Transformer Driver).

For four different Transistors.

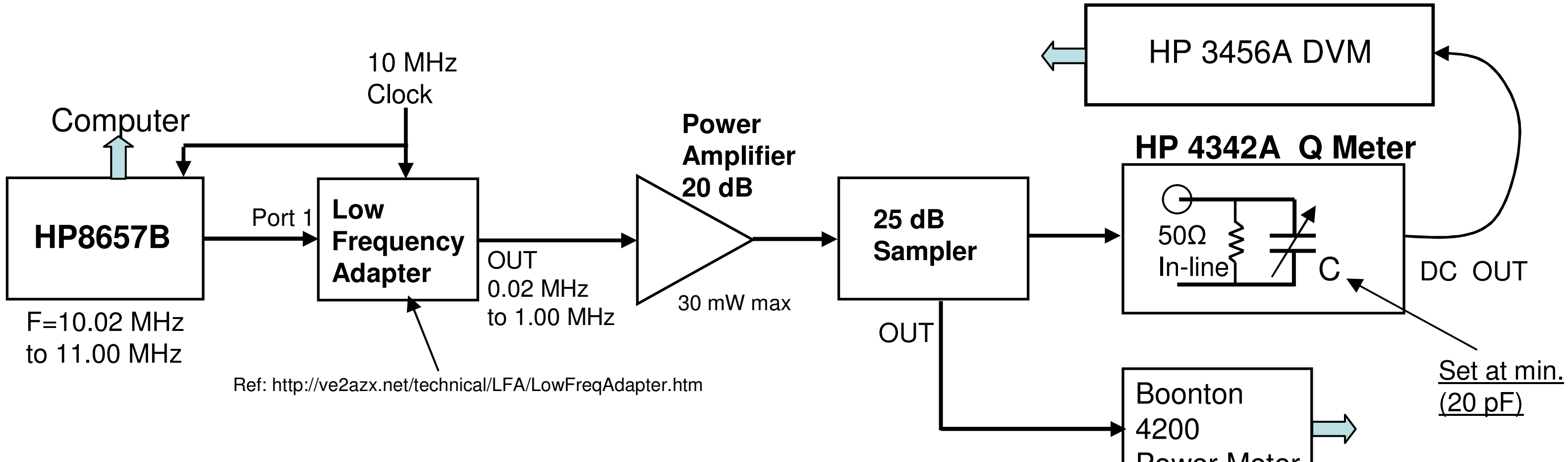


Simulations of Impedance Converter Output Impedance

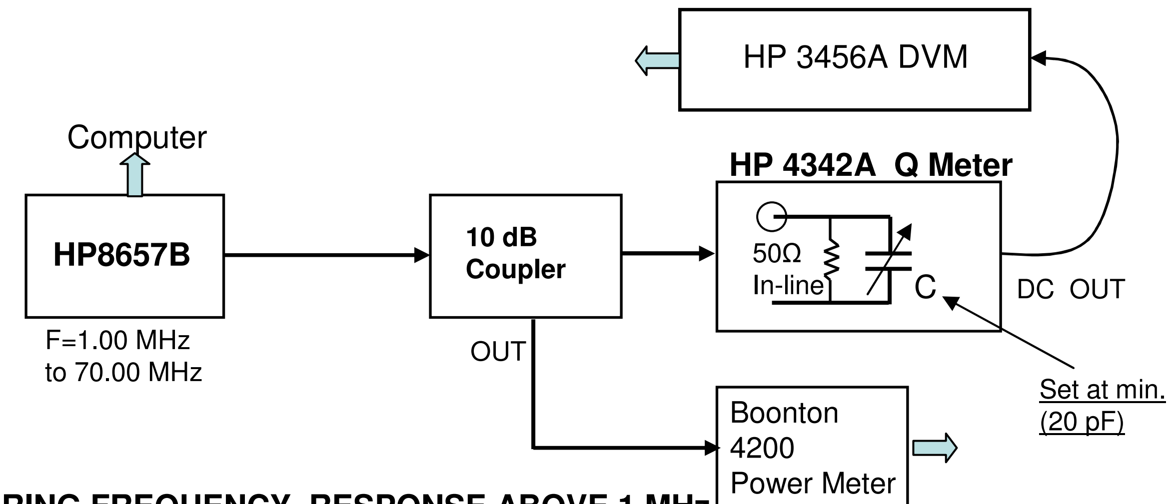
Using four different output transistors.



Measuring the HP4342A Voltmeter Frequency Response



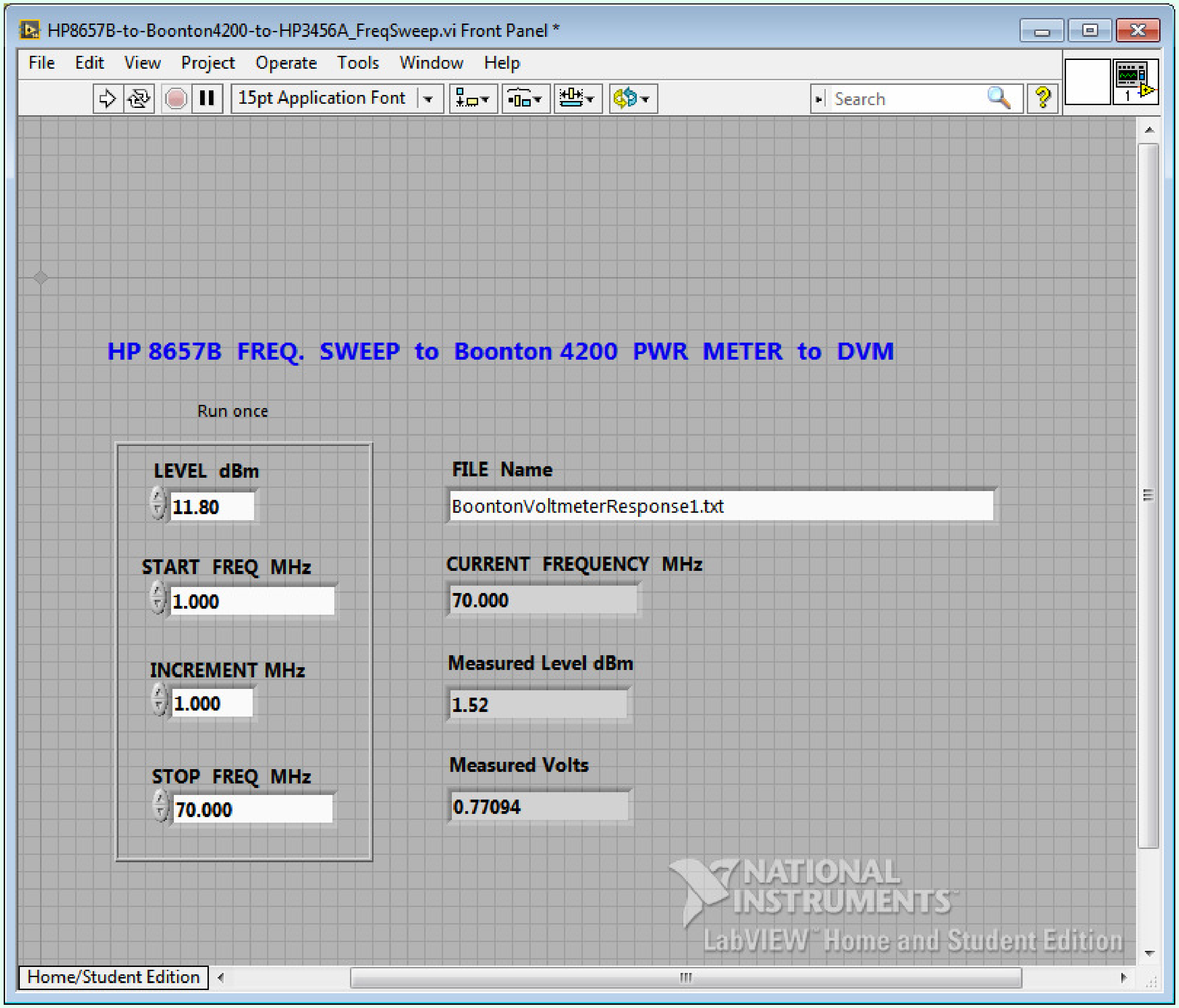
SETUP FOR MEASURING FREQUENCY RESPONSE BELOW 1 MHz



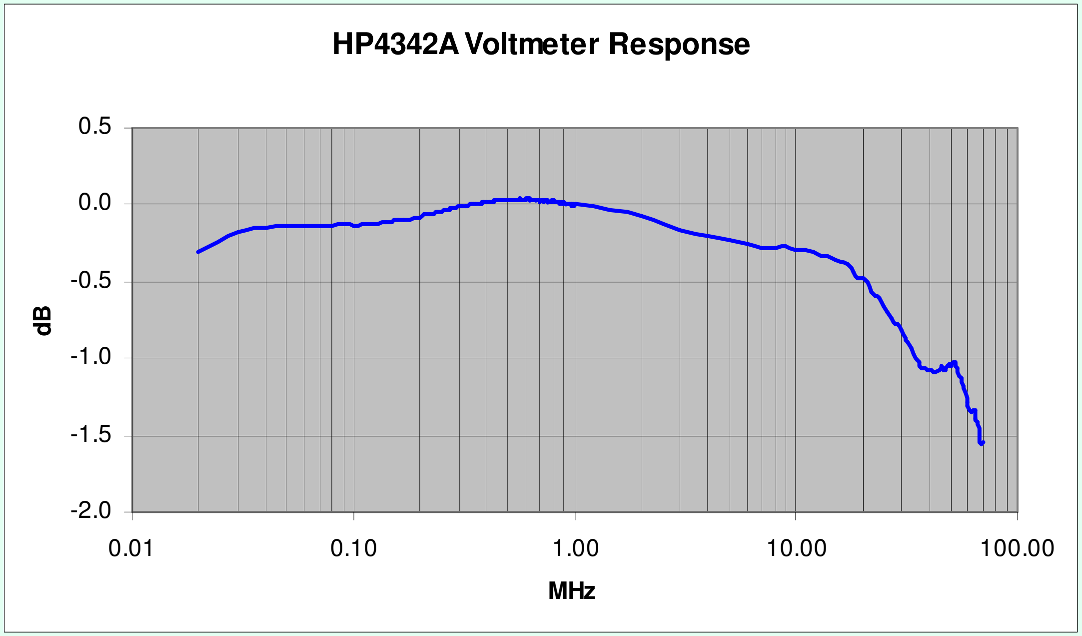
SETUP FOR MEASURING FREQUENCY RESPONSE ABOVE 1 MHz

Measuring the Q Voltmeter Frequency Response

Using Labview to automate the measurements

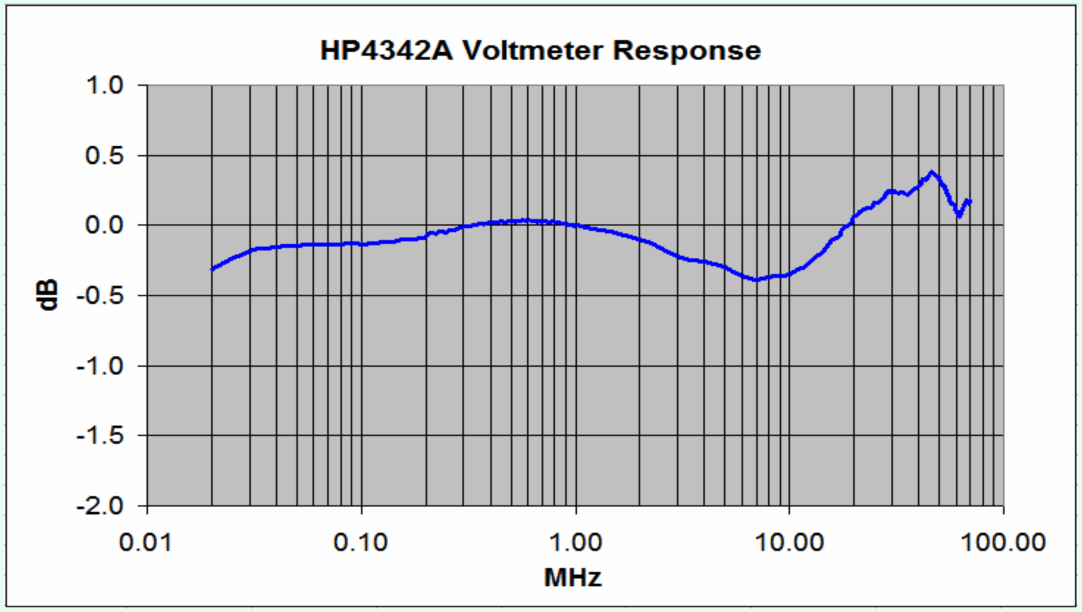


Before adjustments



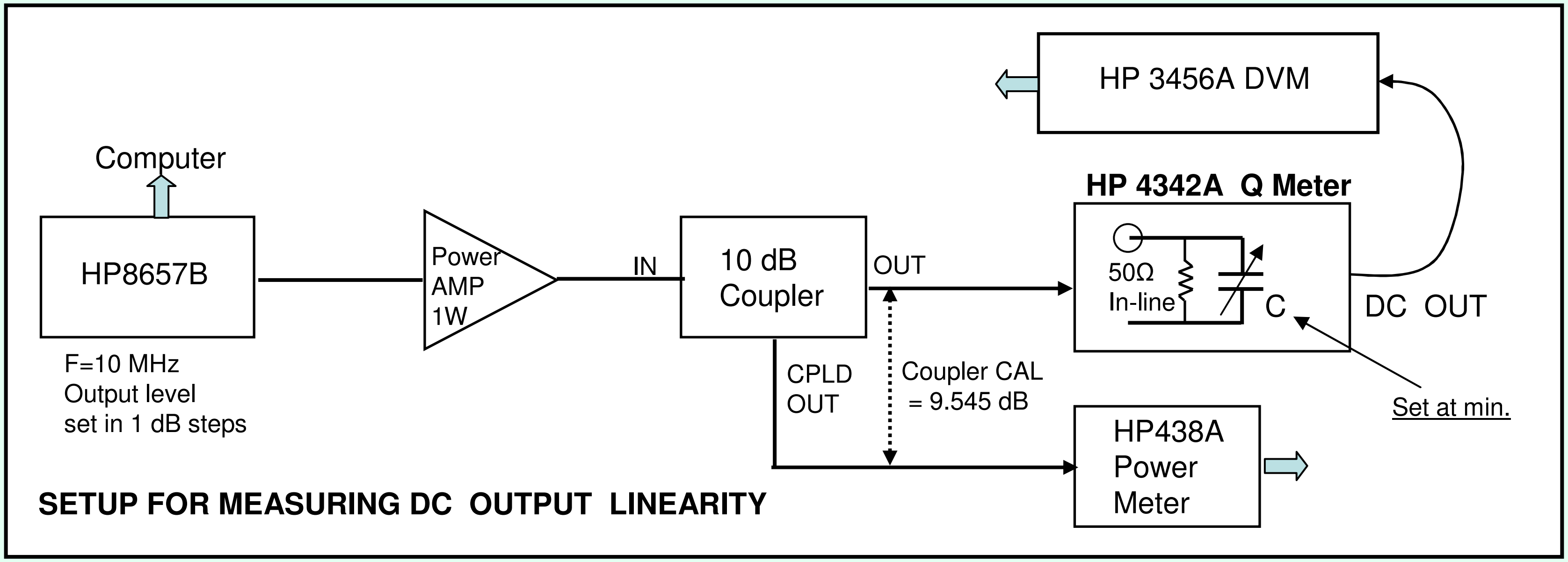
Note: 0.5 dB = 6%
1 dB = 12%
1.5 dB = 19%

After adjustments



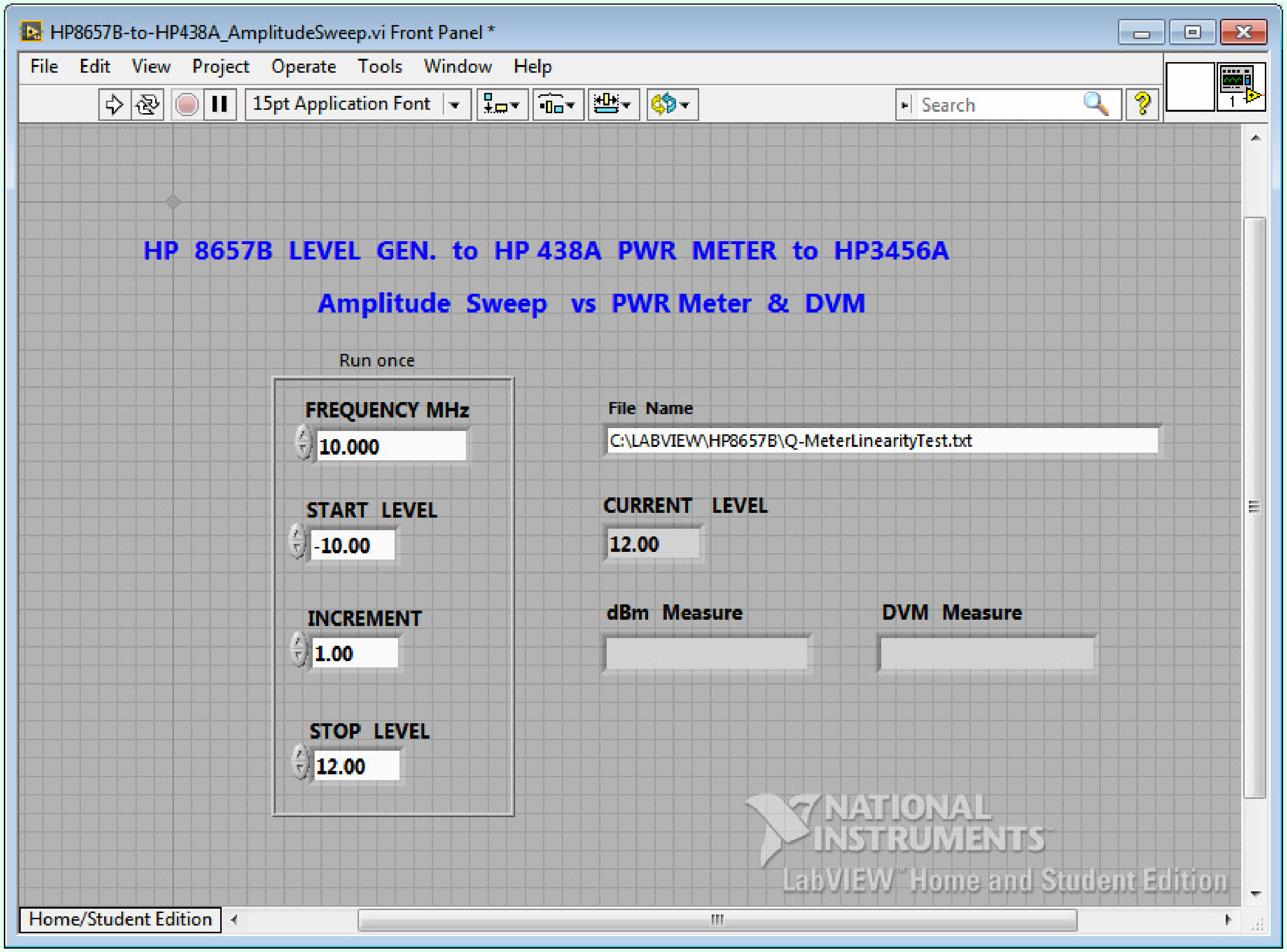
Measuring DC Output Linearity at Q's of 500 to 2000

NOTE: A DVM connected at the Q Meter DC Output increases the resolution in Q Measurements and allows measuring Q's above 1000. Insure the DC output is properly calibrated.

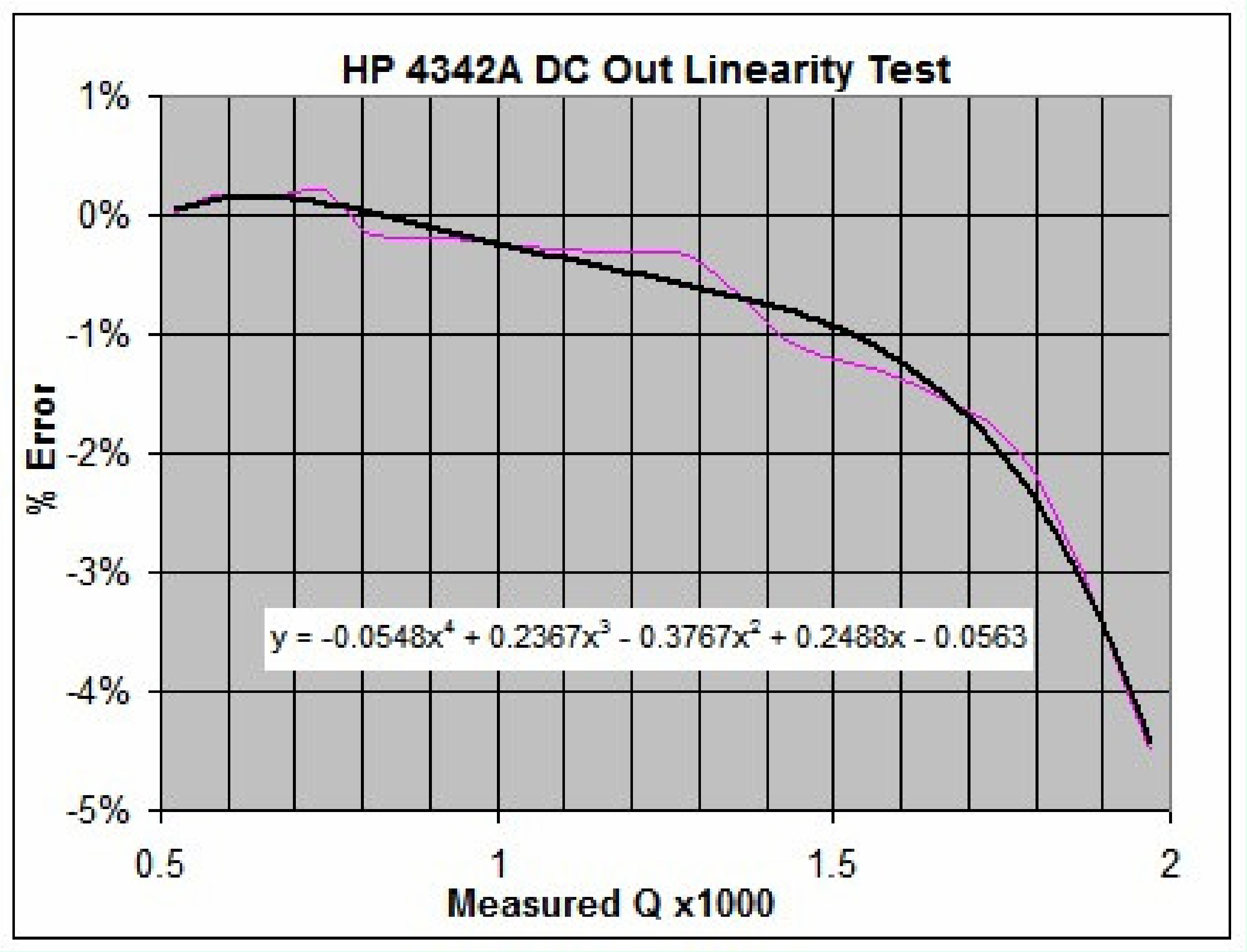


Measuring DC Output Linearity at Q's of 500 to 2000

Using Labview to automate the measurements



Measured DC Output Linearity

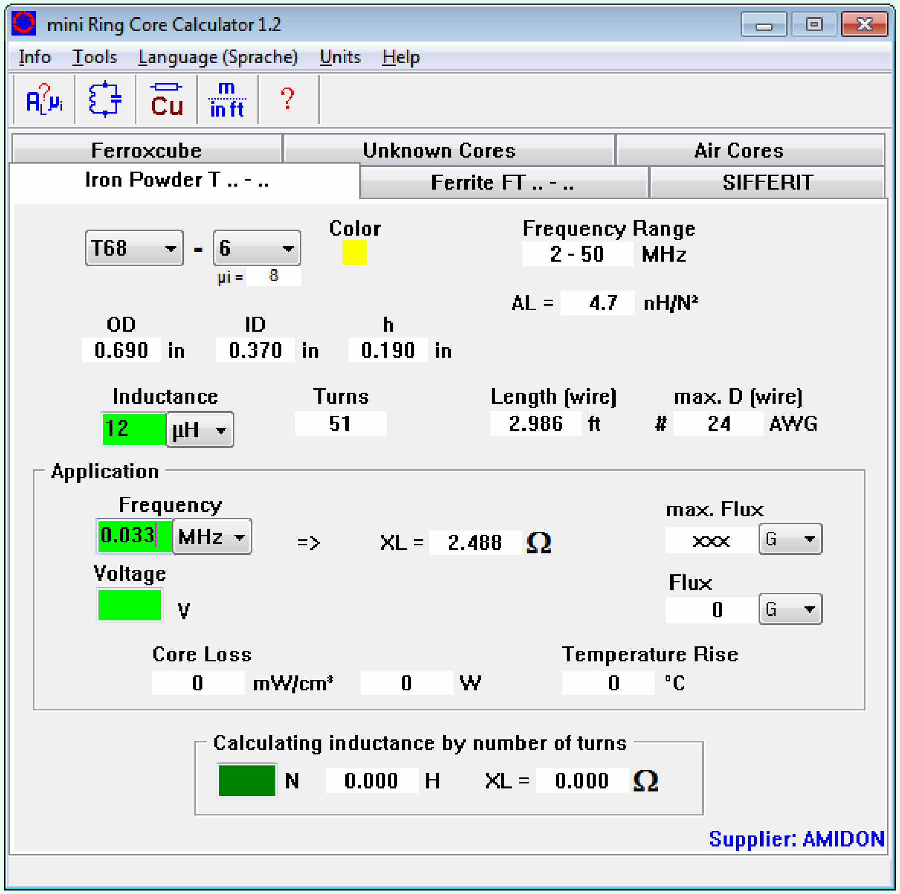


Measuring the HI Z Buffer Input Resistance (Rp)

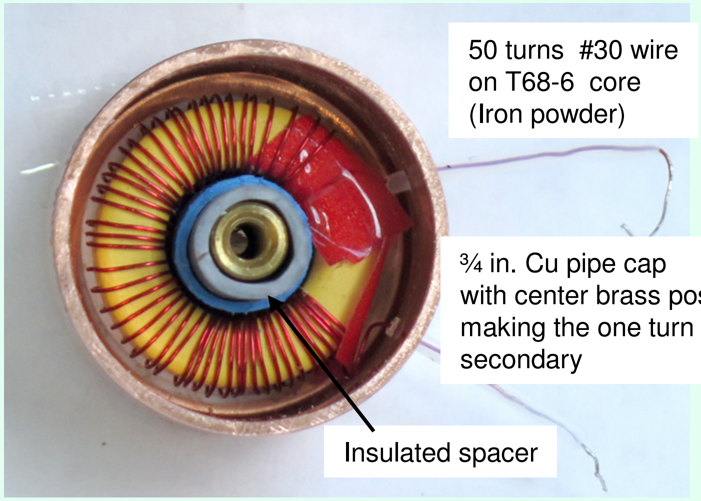
Requires another Q meter, using delta Q mode for this measurement !

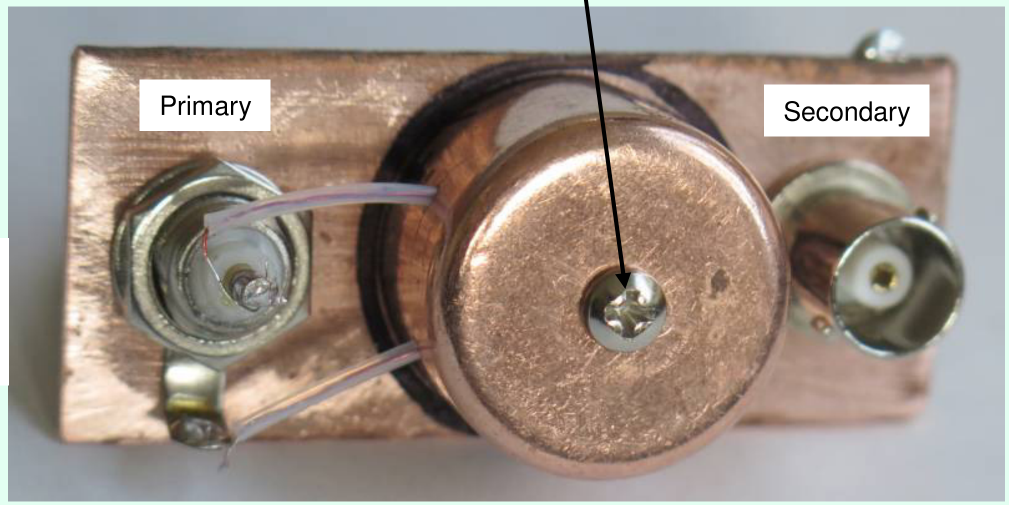
Building my own Transformer

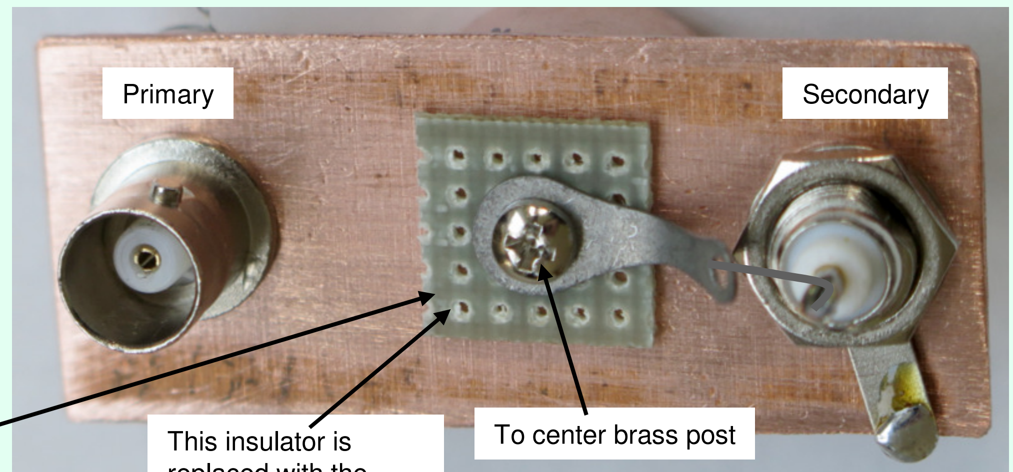
50:1 ratio needed: 50 turns and 1 turn will be used.
T68-6 Iron powder core provides L = 12 µH with 51 turns.
This will give -3 dB point at: 33 KHz when driven with a source resistance of 2.5 ohms.
$F_{-3dB} = 2.5 / (2*\pi*L)$
T68-6 frequency range is OK.   #30 AWG wire is OK

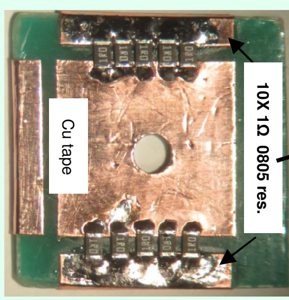


Building my own Transformer



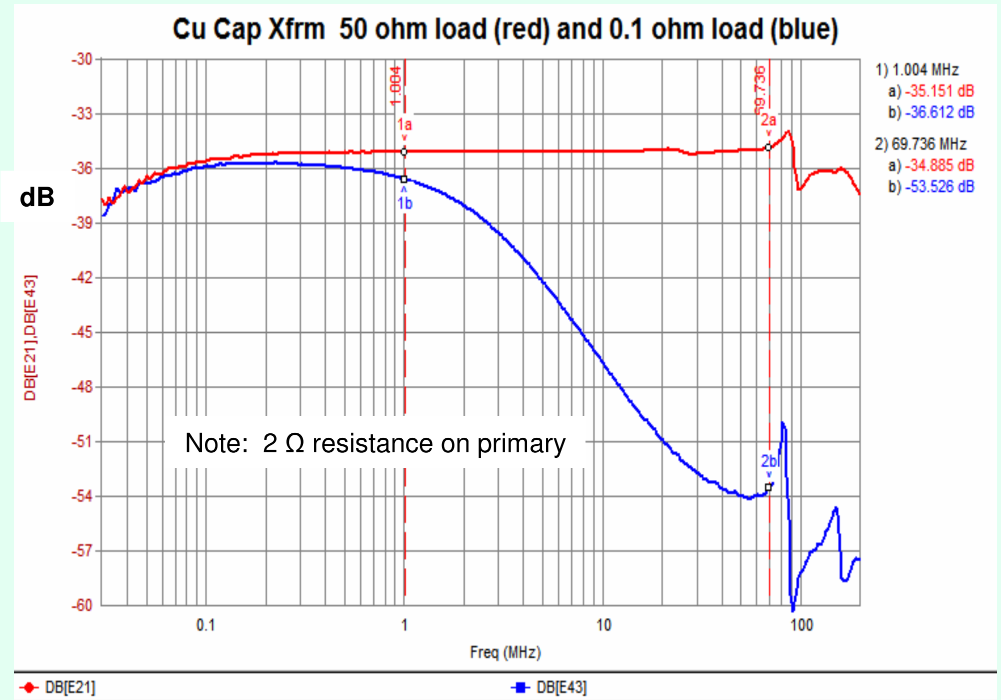




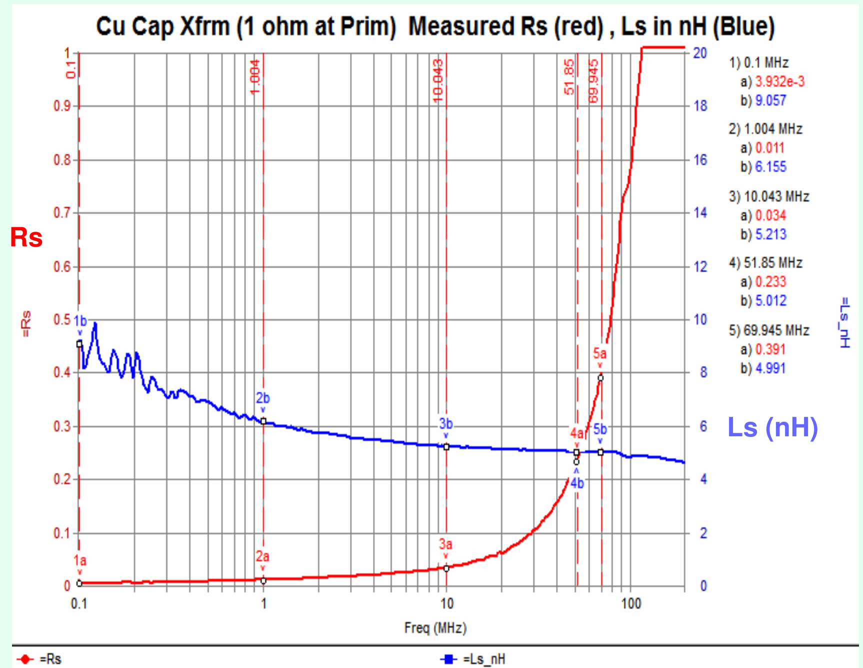


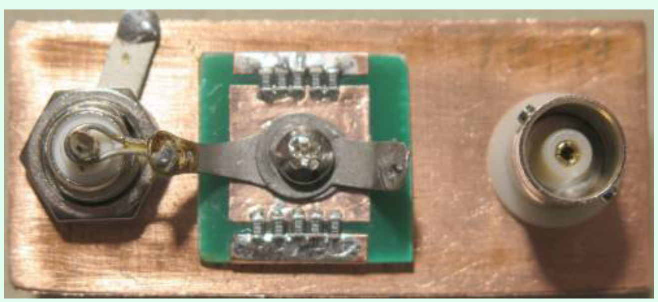
Building my own Transformer:
Frequency Response, Output Resistance and Inductance

Frequency Response



Output Resistance and Inductance

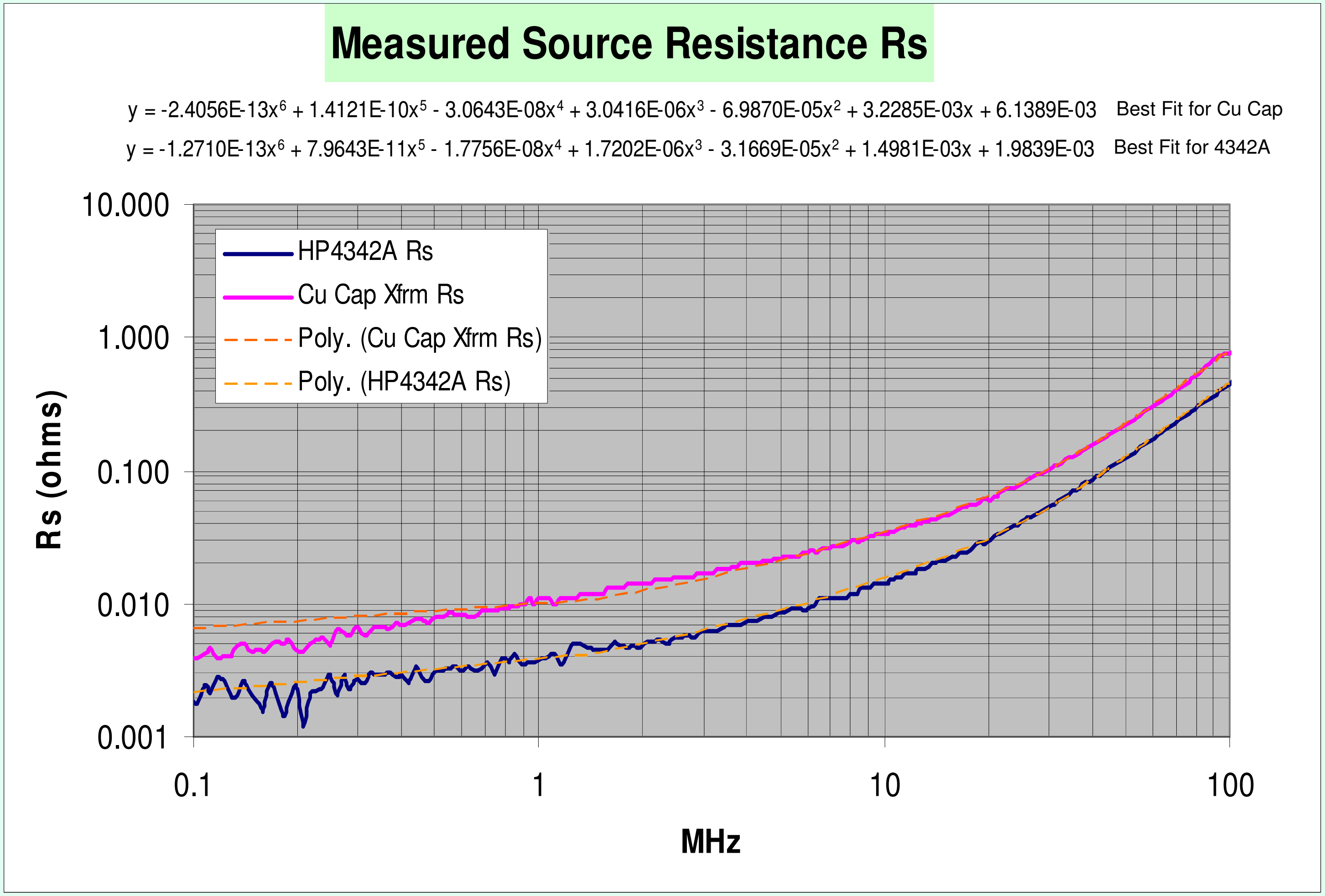




0.1 Ω load connected on the secondary

Comparing both Transformers

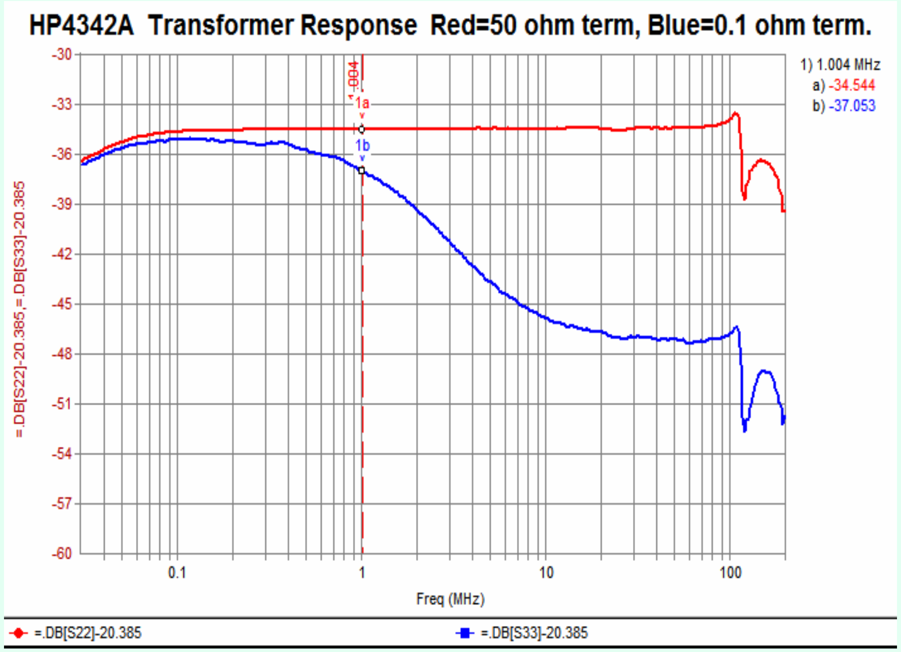
The Cu Cap Transformer has ~ 2.5 times higher resistance
The equations below predict the source resistance at all frequencies and may be used to correct the measured Q.
See: **HP 4342A Q Meter Corrections.xls**



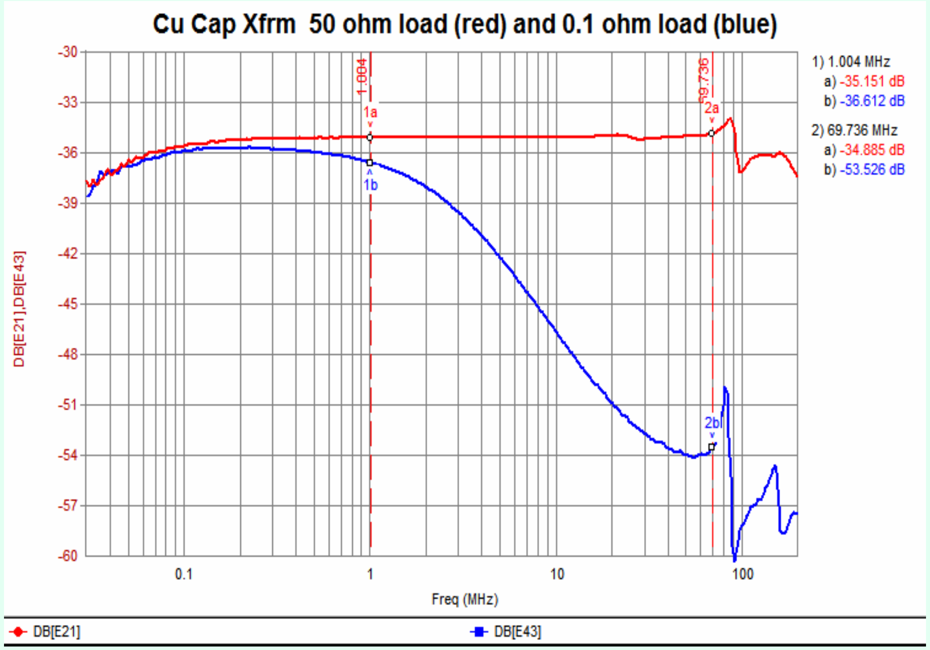
Ref: SourceFlatness-30 - 3 mV-VM_FreqResp_After Adjmt_Source_Zs.xls

Comparing both Transformers

Measured Frequency Response



Output Ls value ~ 3 nH.

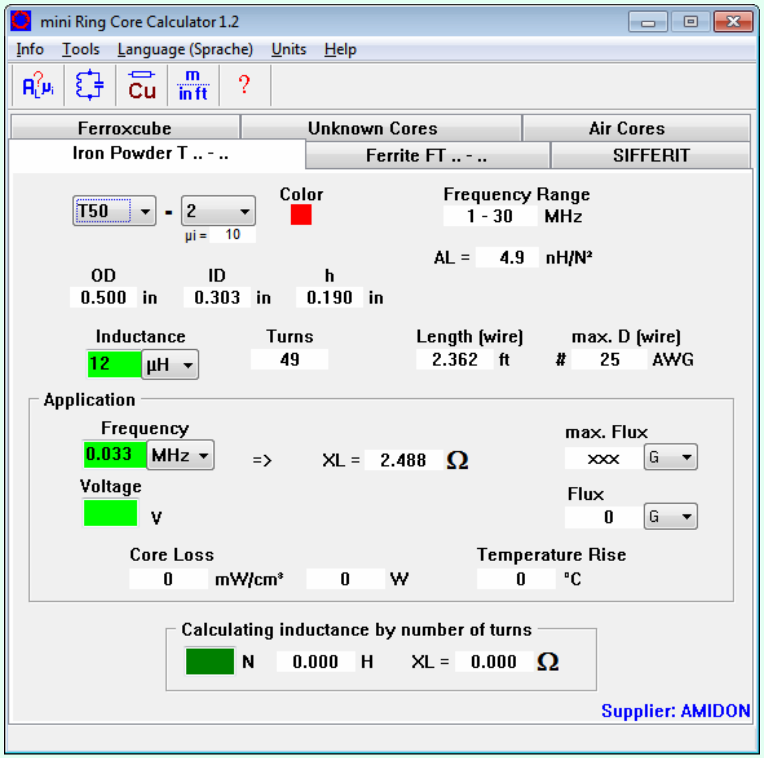


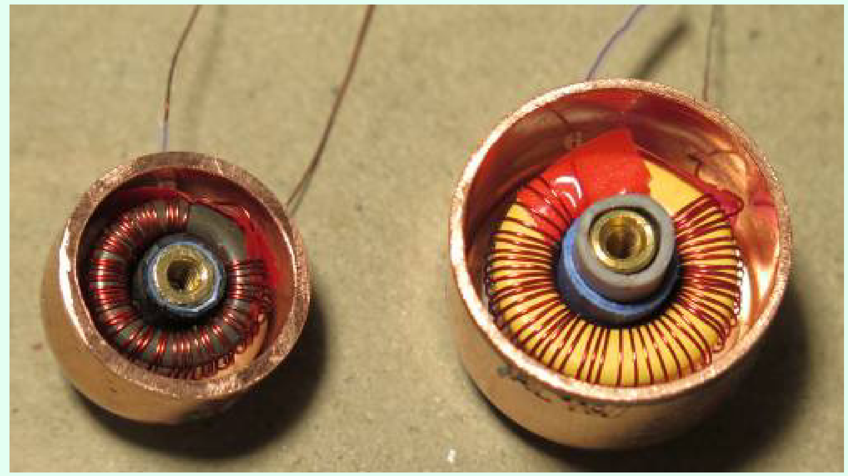
Output Ls value ~ 5 nH.

The higher source inductance Ls probably caused the increased S43 drop above 10 MHz

Building my own Transformer - Improved Version ?

Using a smaller core, µ =10 instead of 8, and a smaller pipe cap might help to increase coupling…
And provide a lower source resistance Rs.
Called the V2 transformer



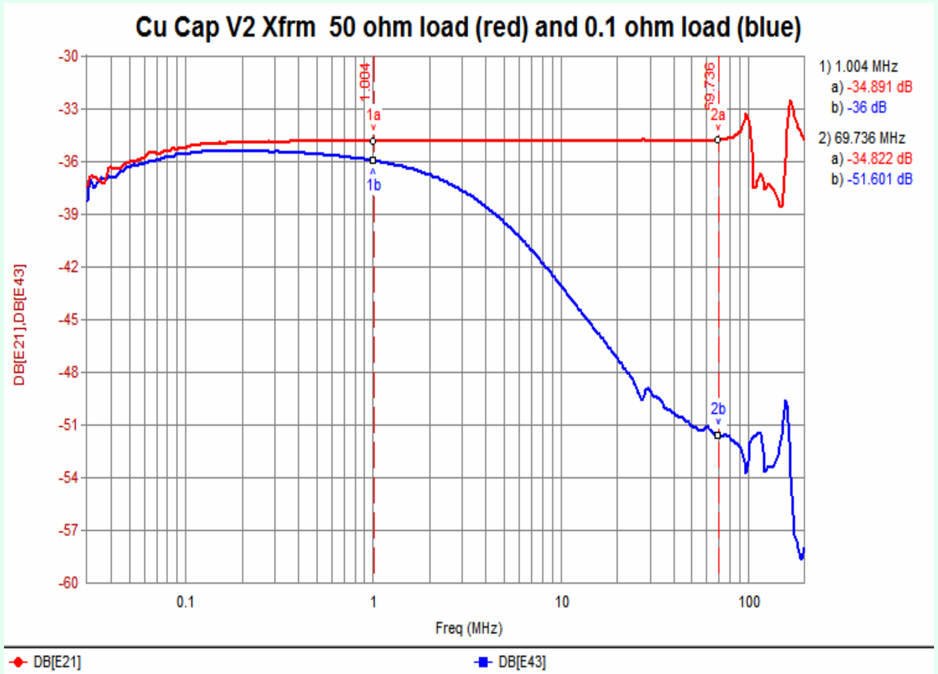


½ in. pipe cap
T50-2 core
AWG 30 wire
V2 transformer
turns=51
L-13.7 µH
Q=15 @ 100 KH
65 mil plastic spacer
at bottom & top

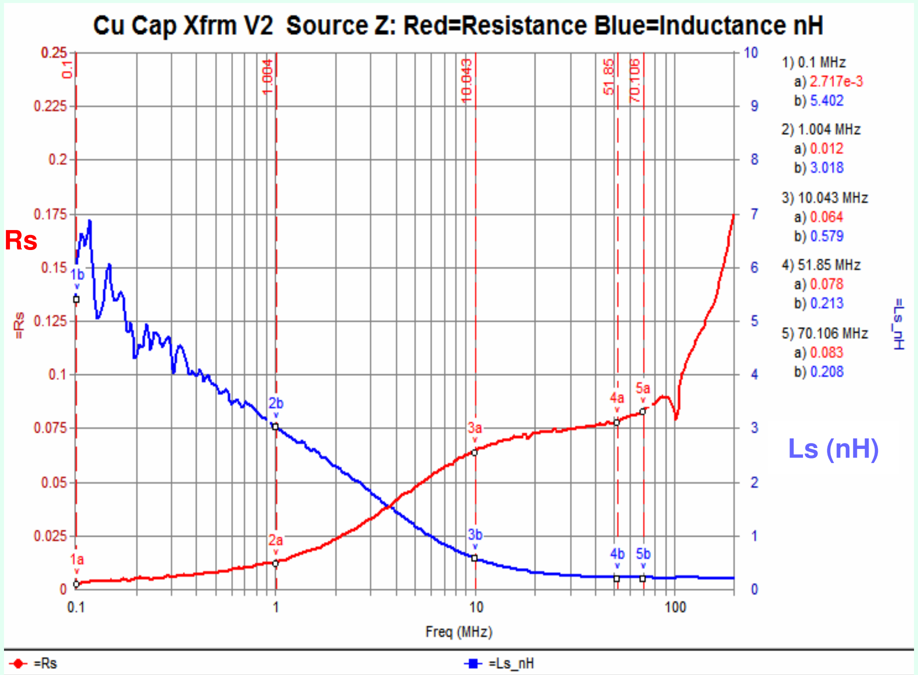
¾ in. pipe cap
T68-6 core
AWG 30 wire
turns=50
L-13.1 µH
Q=13 @ 100 KHz
65 mil plastic spacer
at bottom & top

V2 Transformer Tests

Frequency Response



Output Resistance and Inductance

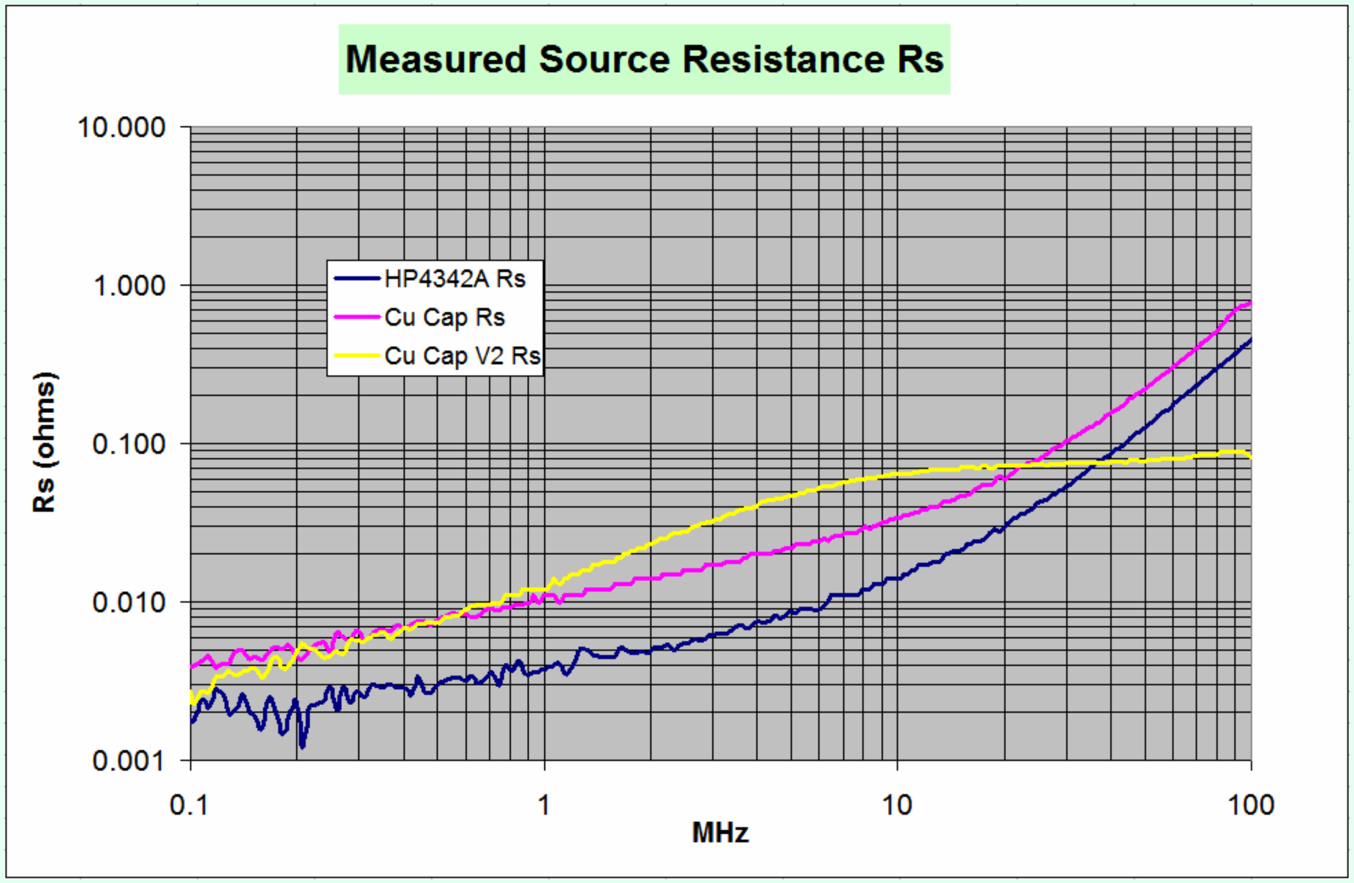


Very flat frequency response up to 70 MHz with 50Ω load
Response with 0.1 ohm is improved compared to previous xfrm.
But worse compared to HP4342A.

Output Ls value very low ~0.6 nH @ 10 MHz
Rs is ~ 80 mΩ from 10 to 70 MHz

All 3 Transformers Compared

HP documentation only mentions about 1 milliohm source resistance.
But the source resistance Rs goes up with frequency by a factor of 200 at 70 MHz, as shown below.
It is then important to apply proper corrections for the rising source resistance especially above 10 MHz.



Correcting the Q readings on the HP4342A

Ref: HP 4342A – Boonton 260A Q Meter Corrections1.xls

For the Source Resistance Rs and Ls values plus
Tuning Capacitor residual Inductance and Voltmeter parallel Rp

Q Factor Rs , Ls and Lc Corrections for the HP4342A Q Meter

Ref: Q Factor Corrections for the source resistance.xmcd

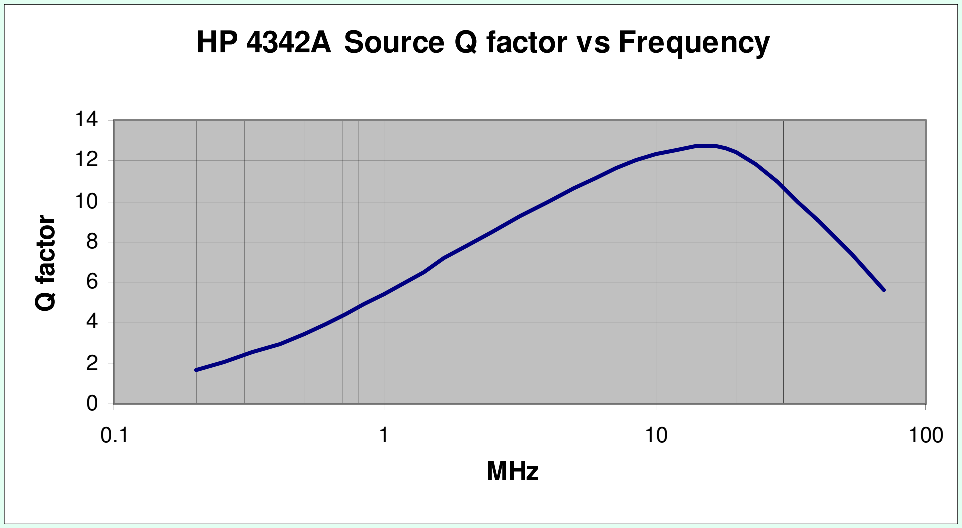
Jacques Audet
VE2AZX Dec-22
Rev 4 Feb 17 2023

Required Data
Ls = source Inductance (µH)
Ls= 0.003 µH

Resonating Capacitor Residual Inductance
Lc= 0.00122 µH

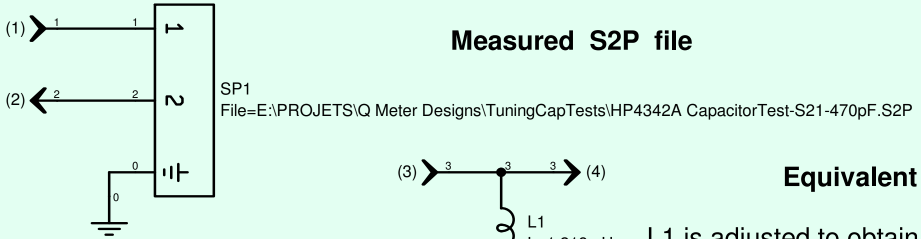
Frequency MHz	Q Reading	Capacitance pF	Reactance ohms (Calculations)	HP4342A Rs Curve (Calculations)	Corrected Q Reading (Calculations)	Corrected Inductance µH (Calculations)	Corrected Resonant Fr MHz (Calculations)	Inductor ESR Ω (Calculations)	Voltmeter Rp Curve MΩ (Calculations)
0.1	300	1000	1591.5	0.002	302.9	2533.025	0.1000	5.254	51.331
1	1000	400	397.9	0.003	1017.5	63.322	1.0000	0.391	46.459
10	400	400	39.7	0.015	473.0	0.629	10.0335	0.084	17.139
20	300	300	26.4	0.030	458.0	0.207	20.2030	0.057	5.660
30	200	200	26.3	0.052	331.6	0.137	30.4602	0.079	1.869
40	100	100	39.5	0.084	127.1	0.154	40.5440	0.309	0.617
48.82	200	100	32.2	0.119	855.1	0.102	49.8191	0.037	0.232

HP 4342A Source Q factor vs Frequency

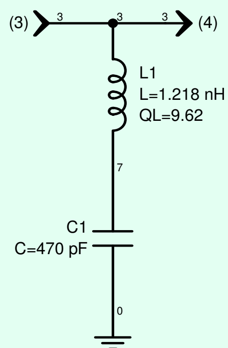


Measuring the RF voltage at the transformer output is not a good idea because its output impedance is not purely resistive.
The source impedance is more reactive than resistive. (At 10 MHz the measured Q is over 12).
This means that the source reactance will decrease the apparent source voltage when the coil ESR is low.
An auto leveling circuit at the transformer output will increase the drive voltage by a factor of 1 to 12 approx, which will throw out the Q measurement accuracy completely.
Note that the source inductance is small (3 nH) and that it only adds to the coil inductance being measured.
Only the source resistance will degrade the Q factor. HP documentation only mentions about 1 milliohm source resistance.
But the source resistance Rs goes up with frequency by a factor of 200 at 70 MHz, as I measured.
It is then important to apply proper corrections for the rising source resistance especially above 10 MHz.
This document summarizes the tests that I did on the HP4342A: http://ve2azx.net/technical/HP4342A_Q%20Meter_Tests1.pdf
It is much better to correct the Q readings.
Here is an Excel file that will help in doing the corrections:
http://ve2azx.net/technical/HP4342A_%20Boonton_260A_Q_Meter_Corrections.xls

HP 4342A Tuning Capacitor Residual Inductance, using S21 measurement



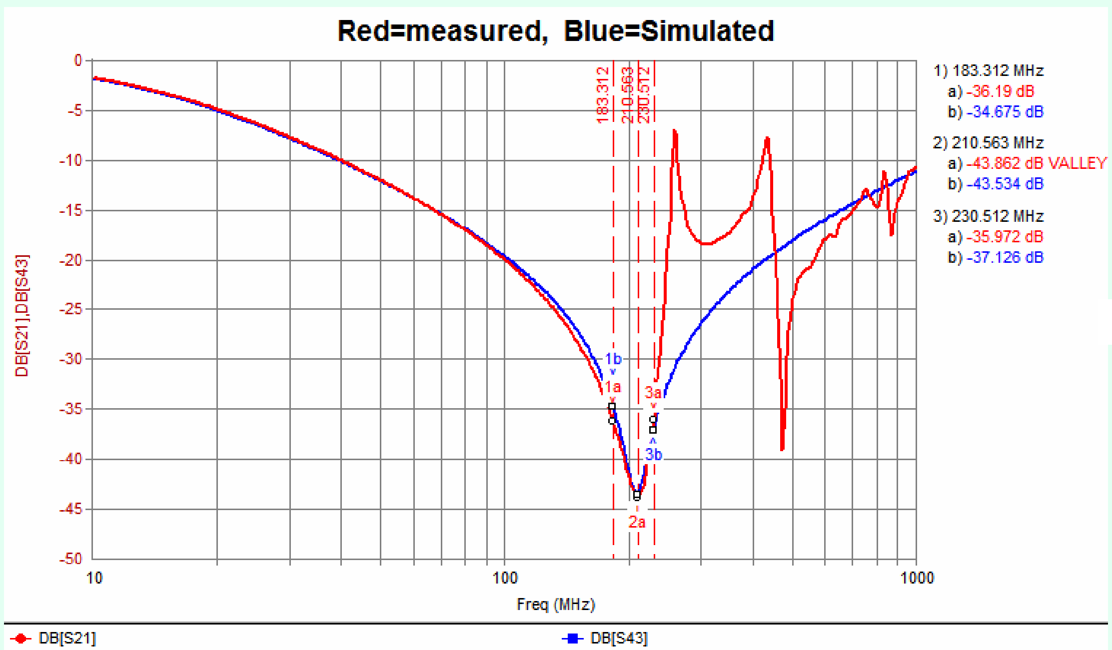
Measured S2P file

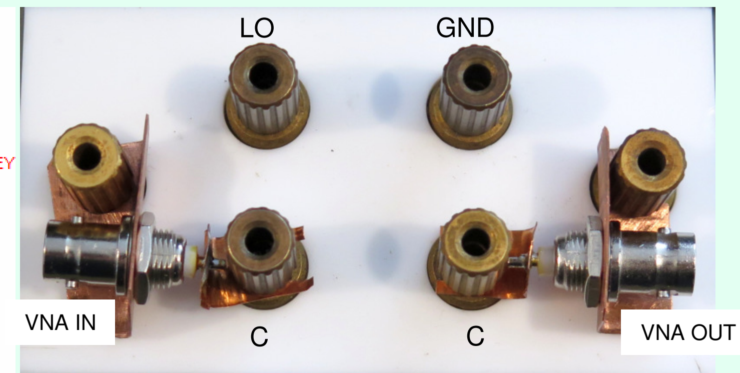


Equivalent Circuit

L1 is adjusted to obtain the same resonant frequency. (210.56 MHz)
L1 = 1.22 nH quite a low value !
QL is adjusted to obtain the same S43 depth, as with S21

C1 is the tuning capacitor





Q METER BASIC CALCULATIONS

$f := 1$ $C := 20$ $Q := 1000$ $Zs1 := 0.004$

f in MHz, C in pF, Q factor, Zs1 = Measured transfo series resistive impedance @ f (MHz)

$XC := \frac{10^6}{2 \cdot \pi \cdot f \cdot C}$ $XC = 7.958 \times 10^3$ Capacitive reactance of capacitor C

$Rp := Q \cdot XC = 7.958 \times 10^6$ Tuned circuit Parallel Resistance

$Zp := 100 \cdot Rp = 7.958 \times 10^8$ Impedance Converter Parallel Resistance for 1% error

$Rs := \frac{XC}{Q} = 7.958$ Tuned circuit Series Resistance

$Zs := \frac{Rs}{100} = 0.07958$ One turn transformer secondary highestest Series Impedance for 1% error

$Pe := \frac{100 \cdot Zs1}{Rs + Zs1} = 0.05$ Percent uncorrected error from the transformer secondary Impedance

==

$f := 1$ $C := 450$ $Q := 1000$ $Zs1 := 0.004$

f in MHz, C in pF, Q factor, Zs1 = Measured transfo series resistive impedance @ f (MHz)

$XC := \frac{10^6}{2 \cdot \pi \cdot f \cdot C}$ $XC = 353.678$ Capacitive reactance of capacitor C

$Rp := Q \cdot XC = 3.537 \times 10^5$ Tuned circuit Parallel Resistance

$Zp := 100 \cdot Rp = 3.537 \times 10^7$ Impedance Converter Parallel Resistance for 1% error

$Rs := \frac{XC}{Q} = 0.354$ Tuned circuit Series Resistance

$Zs := \frac{Rs}{100} = 3.537 \times 10^{-3}$ One turn transformer secondary highestest Series Impedance for 1% error

$Pe := \frac{100 \cdot Zs1}{Rs + Zs1} = 1.118$ Percent uncorrected error from the transformer secondary Impedance

==

$f := 50$ $C := 20$ $Q := 500$ $Zs1 := 0.130$

f in MHz, C in pF, Q factor, Zs1 = Measured transfo series resistive impedance @ f (MHz)

$XC := \frac{10^6}{2 \cdot \pi \cdot f \cdot C}$ $XC = 159.155$ Capacitive reactance of capacitor C

$Rp := Q \cdot XC = 7.958 \times 10^4$ Tuned circuit Parallel Resistance

$Zp := 100 \cdot Rp = 7.958 \times 10^6$ Impedance Converter Parallel Resistance for 1% error

$Rs := \frac{XC}{Q} = 0.318$ Tuned circuit Series Resistance

$Zs := \frac{Rs}{100} = 3.1831 \times 10^{-3}$ One turn transformer secondary highestest Series Impedance for 1% error

$Pe := \frac{100 \cdot Zs1}{Rs + Zs1} = 28.998$ Percent uncorrected error from the transformer secondary Impedance

==

$f := 50$ $C := 100$ $Q := 500$ $Zs1 := 0.130$

f in MHz, C in pF, Q factor, Zs1 = Measured transfo series resistive impedance @ f (MHz)

$XC := \frac{10^6}{2 \cdot \pi \cdot f \cdot C}$ $XC = 31.831$ Capacitive reactance of capacitor C

$Rp := Q \cdot XC = 1.592 \times 10^4$ Tuned circuit Parallel Resistance

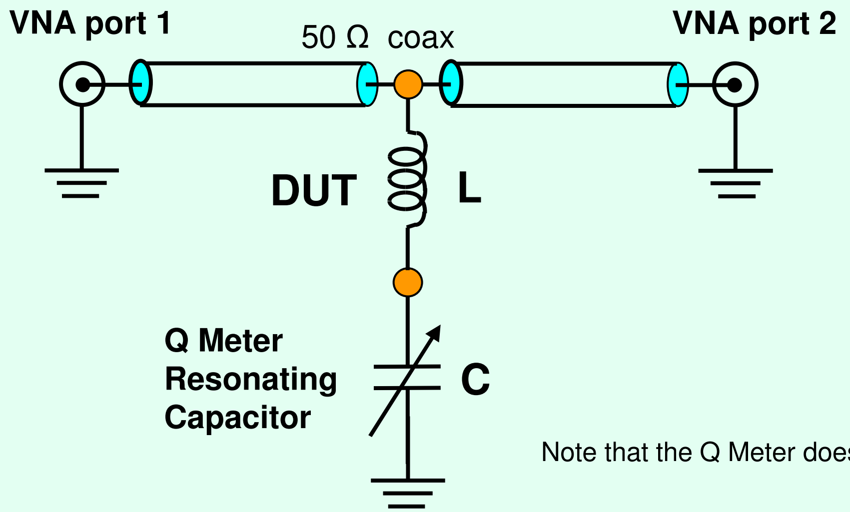
$Zp := 100 \cdot Rp = 1.592 \times 10^6$ Impedance Converter Parallel Resistance for 1% error

$Rs := \frac{XC}{Q} = 0.064$ Tuned circuit Series Resistance

$Zs := \frac{Rs}{100} = 6.3662 \times 10^{-4}$ One turn transformer secondary highestest Series Impedance for 1% error

$Pe := \frac{100 \cdot Zs1}{Rs + Zs1} = 67.127$ Percent uncorrected error from the transformer secondary Impedance

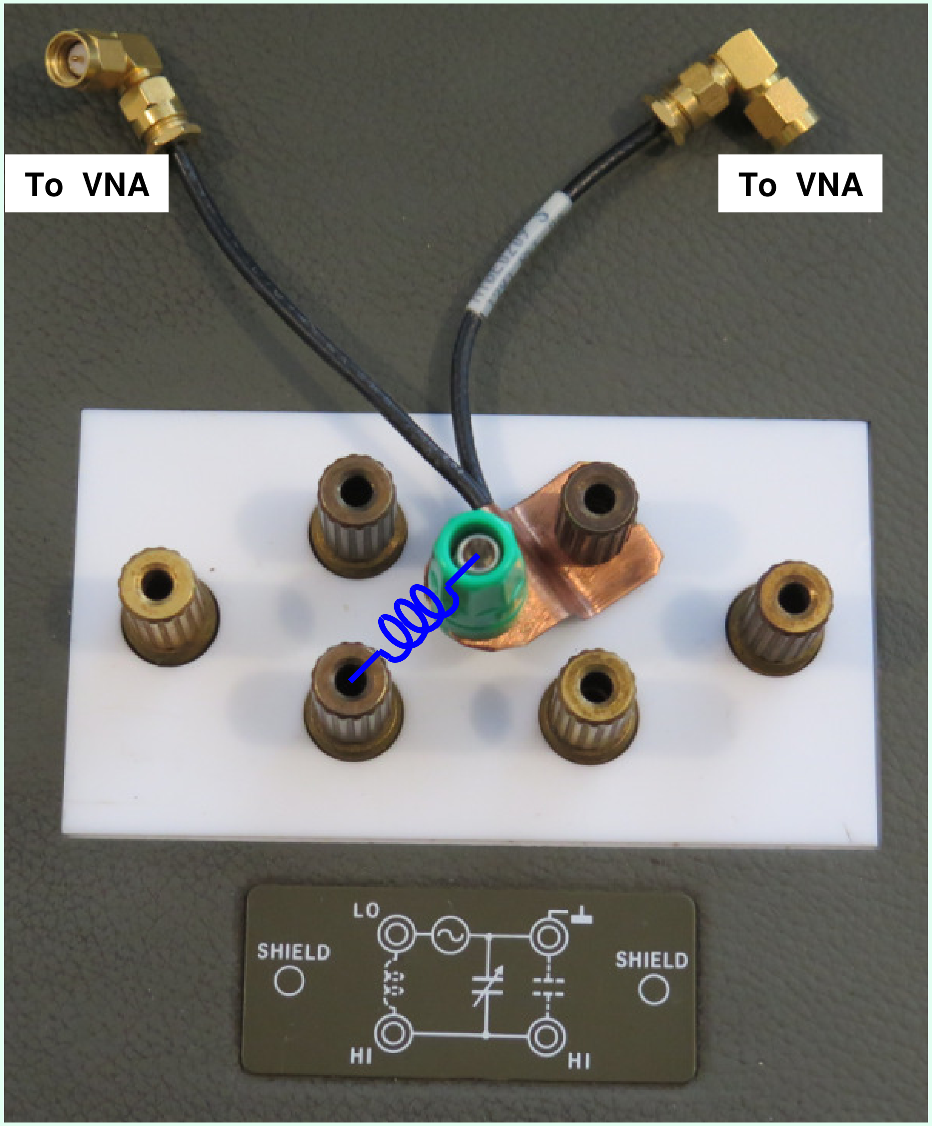
The Transmission Method for Measuring the Q Factor



Note that the Q Meter does NOT need to be turned ON.

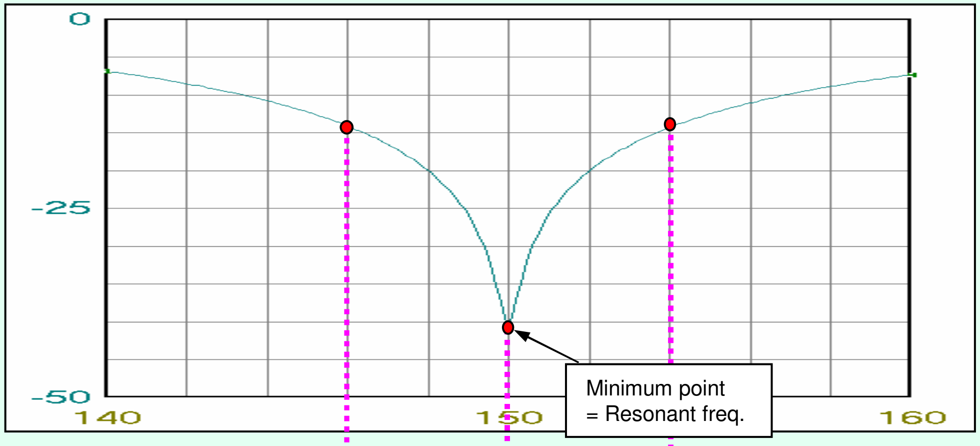
Calculations are used to derive the R, L and C components as seen from the three insertion loss measurements.
(R is the ESR associated with the inductor)
This means that the additional inductance of the connecting wires of the L and C components is taken into account
In the Q measurement.

The Transmission Method



The Transmission Method

See: http://ve2azx.net/technical/Calc_Series-Par_RLC.xls



DATA ENTRY ZONE				
	FREQUENCY (MHz)	7.079	7.118	7.156
	LOSS (dB)	19.935	28.297	20.023

GENERATOR / DETECTOR	IMPEDANCE (ohms)	50

Loss values in dB obtained after zeroing with RLC components removed.

SERIES MODE RESULTS	
SERIES Ls in nH	4999.66
SERIES Cs in pF	100.01
SERIES Rs ohms	1.000
SERIES Xs ohms	223.592

Q FACTOR =	223.53
3 dB BANDWIDTH (KHz)	32
CALC. RESONANT FREQ in MHz	7.1176
% OFF FROM MEAS. RESONNANCE	-0.005

Comments zone

PARALLEL MODE RESULTS	
PARALLEL Lp nH	250.02
PARALLEL Cp pF	1999.86
PARALLEL Rp ohms	2499.3
PARALLEL Xp ohms	11.181

An error of 0.1 dB will give give about 1% error in the calculated Q
(Tested with Q around 220)