

# Take another look at the Noise Bridge:

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Diagrams:

1. Circuit diagram.
2. PCB layout
3. Front panel layout
4. Internal layout diagram
5. Inductance chart

## Introduction

There are many amateurs who are not familiar with the Noise Bridge, and this article serves to explain the design and operation of them. Some would say the most important piece of test equipment in the amateur shack is the Noise Impedance Bridge, and certainly it is very versatile for such a simple instrument. To those not familiar with Noise Bridges, this statement can bewilder them even more, so let us start with an explanation. The Noise Bridge, in its simplest form, is an instrument to measure impedances (combinations of resistance, capacitance and inductance) over a wide frequency band, and it consists of two parts: The Bridge and the Noise generator.

### 1. The Bridge part.

The Bridge is like a Wheatstone bridge, as shown in Figure 1, This shows a pair of resistors RA & RB of equal value and a pair of impedances - X (unknown, sometimes called the *unknown leg* here) and Z (variable). Also a detector across the bridge centre points, and an AC source supplying a balanced voltage across the bridge.

The principle of operation - if the variable Z is adjusted so the detector reads zero, the voltage at A is the same as B, and the bridge is balanced.

We know that RA is the same as RB, then the unknown impedance X must equal the known impedance "Z". By *knowing* the value of the variable impedance, we can find the value of the unknown one.

In simple bridges, the known impedance Z is just a variable resistor, and restricts the bridge to only measure unknown resistances.

If the known impedance Z is made of a combination of resistance and capacitance, the bridge can measure complex impedances, made up of capacitance or inductance.

### 2. The Noise generator.

If the unknown impedance is not pure resistance, the bridge balance will depend on the frequency of the voltage source mentioned above. A signal generator on a frequency of your choice could supply the AC voltage source. However, if the detector is a sensitive radio receiver tuned to the frequency of interest it is more useful if the AC voltage source provided signal at ALL frequencies simultaneously. This is possible by using a noise generator, as noise contains energy over a wide band of frequencies, and allows the user to make measurements at any frequency by tuning the detector receiver to the frequency of interest. In other words, by using a sensitive receiver as the detector, a built in noise source will suffice as the AC voltage for the bridge.

The bridge circuit developed.

The bridge of Figure 1 can be developed into the practical arrangement in Figure 2. Balun T1, driven from the noise generator, implements the voltage source. The voltage divider RA & RB of Figure 1 is implemented with the centre tapped secondary of T1, and the detector receiver is connected from the centre to ground. The known impedance Zv, is made up of VR1 and CV1, and the bridge will balance when this combination matches the series combination of the "unknown impedance" and C7.

When the unknown impedance contains only *resistance*, bridge balance can be achieved by adjusting the calibrated resistance VR1, while the capacitor C7 in series with the unknown leg makes the bridge balance with variable capacitance CV1 at approximately mid range, 120pF.

When the unknown impedance contains series *capacitance*, it combines with C7 and results in a capacitance less than 120pF, therefore capacitance in the unknown impedance will cause CV1 to be adjusted to less than 120pF and it can be calibrated to read the series capacitance of the unknown impedance.

To balance the bridge with *inductance* in the unknown impedance, again the combined impedance of VR1 and CV1 must equal the unknown leg.

The total reactance of the unknown leg XT, is the sum of the inductive reactance XL, and the reactance of C7 we can call XC, but remember the reactance of capacitance is treated as negative.

$$X_T = X_L + (-X_C) \text{ therefore } X_T = X_L - X_C \quad (1)$$

Of course for the bridge to balance, the “unknown leg” reactance must be matched by the variable capacitor CV1, so XT must be capacitive, ie negative. The formulae says to achieve this XC must always be greater than XL, so for any one frequency there is a limited range of inductances that can be measured. (See chart 1). To sum up, inductance will always make the unknown leg appear more capacitive than C7 alone (120pF) and so cause CV1 to be adjusted to greater than 120pF. This half of its dial is calibrated in “equivalent negative capacitance” of the unknown leg, (no, this is not the April edition of Breakin!). With the aid of the Chart 1 shown here, or using the formulae stated in the calibration section, this reading can be used to measure the unknown inductance.

A practical design of the bridge circuit.

The practical circuit of this noise bridge is shown in Figure 3. It can be seen there are the two parts described above, and a third part, a modulator. The noise source uses a reversed biased base emitter junction Q3 to generate a low level noise signal, which is amplified by the three stages Q4, Q5, Q6. This noise voltage has a much higher level at low frequencies, so to achieve the required noise output at VHF, the later stages may be overdriven at the lower frequencies.

The modulator.

The modulator here consists of a two transistor audio oscillator, and a diode switch to modulate the signal on the collector of Q5.

When measuring the impedance of large aerials, the noise generated by the Noise Bridge has to compete with the noise coming from the aerial, and sometimes the latter is overwhelming. This design modulates the bridge generated noise, and gives the ability to discern which is bridge noise, to be tuned to a minimum, and which is aerial noise. This also gives the bridge a second use, as a modulated wide band signal generator for fault finding on receivers!

This section of the bridge, namely Q1, Q2, R1, R2, R3, R4, C1, C2 and D1, can be omitted if no modulation is required.

The design of this noise bridge.

The design has concentrated on using parts readily available from the suppliers listed or the trusty old junk box. The transistors Q4, Q5 and Q6 can be those listed or any high speed switching transistor, and should have good gain at VHF frequencies, but Q1, Q2 and Q3 can be audio types. C7 has one special aspect; it should be silver mica or some composition that maintains low loss, a ceramic will be OK but have lower Q at VHF, so the nulls will be broader.

The variable resistor, VR1.

This is mounted direct onto the PCB and should be insulated from the chassis and front panel knobs. The value of 1K will allow the bridge to cover 600ohm balanced line, and the logarithmic law gives a good dial spread in the region zero to 100ohms. The resistance track should be carbon or cermet, but not wire wound. The Omeg type comes with a convenient plastic shaft, long enough to pass through the front panel. A small plastic bracket was made to give the pot extra support, fixed to the PCB using the two holes provided.

The variable capacitor, CV1.

In series with the variable resistor is the variable capacitor CV1. Air spaced variable capacitors are not readily available as new parts these days, but the supplier shown below may have them available. Solid dielectric capacitors as used in miniature transistor radios are not suitable. I used a junk box part originally from an old broadcast radio. If a bigger box is used, this widens the choice of useable variable caps. Use the best quality here, as it will affect the repeat-ability of measurements. To allow the bridge to balance on resistance with CV1 mid range, the maximum capacitance should be approximately 250pF. Other values of CV1 can be used, but try to make C7 about half the maximum value of CV1. The front panel calibration and inductance chart shown here assumes a value of 120pf for C7 and 250pF for CV1.

The builder has the choice of not using a variable capacitor at all. In this case connect pad3 straight to chassis and short out C7. This will allow the bridge to just measure resistance.

The transformer balun.

The heart of the Noise Bridge, the transformer, should really be called a balun, as it converts the unbalanced output of the noise generator to a perfectly balanced noise source across the bridge. It will be noted that this design has an unused winding on pin 7. This is to completely balance the capacitance coupling between primary and secondary. Some experimentation took place to determine the best ferrite, and this type provided a good noise level up to 145MHz.

A little care should be taken in winding this component.

1. Twist together 4 x180mm strands of 0.18mm enamel copper wire. Aim to have a twist of about 40 rotations over this length.
2. Wind ten turns of the twisted bundle through the centre hole, note one turn is equivalent to one pass through the centre hole. Evenly wind the turns around the toroid so that the start is very close to the finish.
3. Separate the ends and remove the insulating enamel. This can be done with a soldering iron on most wire types now.
4. Use a buzzer or ohmmeter to identify the four pairs of windings. Arrange them as in the diagram Figure 4. This is the lead out pattern needed for the PCB.

I used masking tape to keep the strand ends together throughout the twisting and winding process, and a marking on the tape shows the pair orientation for placing into the PCB.

The PCB tracks connect the windings in the correct phase as long as the pair groups are maintained as in Figure 4.

The case preparation and other bits.

A suitable case is available from Branch 05 projects group, price \$12.00, inclusive PP, and the external connections use flange mounted BNC sockets. The variable capacitor CV1 is best mounted in close proximity to the rear of the bridge, as close as possible to the BNC connectors. It will need a metal bracket to hold it to the floor of the case, and an extension shaft to bring the control through the front panel. It is a good idea to make the control shafts a close fit in the front panel to give reliable dial calibrations. Drill a hole in the front panel for the power switch, and an indicator if required.

Assembling and testing the PCB.

No special problems here, as long as care is taken soldering the component leads and avoiding soldering shorts. A thorough visual inspection before power up is the best prevention of faults. Double check the polarity of D1 and the orientation of all the transistors. The circuit can be tested outside the case without CV1. Connect a receiver from pad2 to ground, a 47ohm resistor from pad1 to ground and earth pad3, then apply 9V-battery power. A loud hiss should be heard on frequencies from 1Mhz to 30Mhz, and if the receiver can demodulate AM, an audio tone should be received. The received noise should drop to a minimum by adjusting VR1. If no hiss is heard, check the collector voltages of Q4, 5, and 6. They should all be around 4v, and the bases around 0.7v. Approximately 5v should be on the emitter of Q3. To test the audio modulation oscillator, a pair of headphones connected through 100nF to the collector of Q1 or Q2 should produce a load audio note.

When the PCB has been tested, insert into the case and connect the BNC connectors, the receiver port to Pad2, The bridge input BNC is connected to the PCB by C7. Th connection between Pad3 and VC1 should be as short as possible, as should a braid between the frame of CV1 and the BNC grounds. I have found no need to earth the negative rail of the circuit.

Method of calibration.

Once the unit has been proved to be working, the calibration can begin. If a 250pF capacitor is used for CV1, and 120pF for C7, the front panel calibrations shown here will probably be accurate enough.

However, if the builder wishes to calibrate his own front panel, here is the method.

Connect a receiver tuned to 14MHz to the receiver output connector. Connect a 20ohm resistor to the bridge input and adjust VR1 and CV1 for minimum noise in the receiver. Mark the CV1 position as "0" and VR1 with the corresponding resistance value. Repeat this dial marking procedure for 50,70,100,150,200 ohms etc up to 800 ohms

To calibrate the positive capacitance half of the CV1 dial, connect a 20ohm resistor in series with a 10pF capacitor to the bridge input, and adjust VR1 and CV1 for a receiver null. The position of CV1 will be near to minimum capacitance. Mark the dial of CV1 with +10pF, and repeat with 20,50,100,200,400pF, which should fill one half of the dial. To calibrate the negative capacitance of the dial, short the bridge input and connect the same capacitors temporarily in parallel with C7, marking each position of the receiver null on the dial. The maximum negative capacitance will be about 130pF.

Using the bridge.

Once we have calibrated the dial of CV1 we can measure inductances by rearranging the formulae (1) to make it friendlier, and we get

$$L = 1/(2\pi F)^2 + (1/CF) + (1/CN) \quad (2)$$

Where F is the frequency, CF is the value of C7 in pF, and CN is the -C value in pF (read from the calibration dial of CV1).

Component values can be measuring by connecting the unknown component to the bridge input, and nulling the receiver noise. An advantage of using a bridge here is that the component can be measured at the frequency that it will be used, but remember to make all connections as short as possible.

Aerial impedances can be measured using the bridge, and this can tell the user at what frequency the aerial is resonant, and what additional components are needed to bring it into band. Do not be fooled by the coax connection to the aerial, which can change the impedance seen at the shack end of the cable. However, if the cable is an exact number of half wavelengths long then no impedance change takes place. The AM modulated noise of this bridge will stand out when the noise from the aerial is oppressive.

Remember the two readings given by the bridge represent the *series* combination in the unknown impedance, and the formulae to convert this to a parallel combination can be found in many electronics textbooks.

The bridge is a fine way to tune your aerial tuner unit *before* transmitting. Set the bridge to 50ohms, 0 reactance and adjust the ATU for a null on the receiver tuned to the operating frequency.

The output matching of a power amplifier can be set up with the bridge "looking back" into the amplifier output with no power coming out. The impedance can be measured first on the final transistors, then on the amplifier output, so checking the final matching network is correct.

The noise bridge circuit can be permanently built into an aerial tuning unit for the purpose of aerial matching. VR1 in this case should be replaced with a 50ohm resistor, and both CV1 and C7 shorted out. A relay should be used to bring the bridge into circuit when needed.

Although it is not recommended, my prototype of this Noise Bridge has survived several accidental exposures to a 100w transmission into its "receiver" connection. It is all too easy to do when using a transceiver!

#### **Notes on this kit of parts for the ZL3KB Noise Bridge:**

This is not a complete kit of parts, but should provide enough for the experienced home brewer to get something going. The Variable capacitor has not been included as stock of such items cannot be supported by Branch 05. However a suitable capacitor can be rescued from scrap broadcast receivers, especially early transistor models which tended to use smaller tuning capacitors. A supplier in the USA has been found and the address is given under "Suppliers".

The front panel of the supplied case has a large cut out, and this will accommodate a wide variety of Variable capacitor shaft positions. Once the variable capacitor has been chosen it is suggested a sub plate is fitted behind the front panel to support the shaft, and this could extend over to the pot shaft to support that as well.

Please note the supplied front panel overlay will only be relevant if a 250pF variable capacitor is used. The BNC connectors will each need four mounting holes drilled in the rear panel.

#### **Changes made since the Breakin article "Take A Look At The Noise Bridge" was published:**

Component changes - All 10nF capacitors changed to 1nF to reduce noise levels at lower frequencies. The PCB has an extra pad added Pad 3 "MODOFF". Grounding this pad will turn off the modulation to the audio, and can be used if pure noise is required. An extra switch can be fitted for this function. 2N2222A transistors have been substituted for PH2369 types

Parts list

Used	PartType	Designators
2	1K	R7
1	1K log pot, 20mm, PCB mount.	VR1
4	10K	R3 R4 R5 R6
1	15K	R11
3	100K	R1 R2 R10
2	470K	R8 R9
7	1nF Ceramic	C1 C2 C3 C4 C5 C6 C8
1	120pF* Silver Mica or ceramic	C7
3	BC337 or any audio NPN	Q1 Q2 Q3
3	PH2369 or 2N2222A etc	Q4 Q5 Q6
1	1N4148	D1
1	Ferrite toroid type Amidon FT50-61	T1
1	Air spaced variable cap, 250pF	CV1
2	BNC connectors Flange mount.	S1, S2
1	Battery connector clip	
1	Power switch	SW1

\*This capacitor should be half the value of the variable capacitor.

Suppliers:

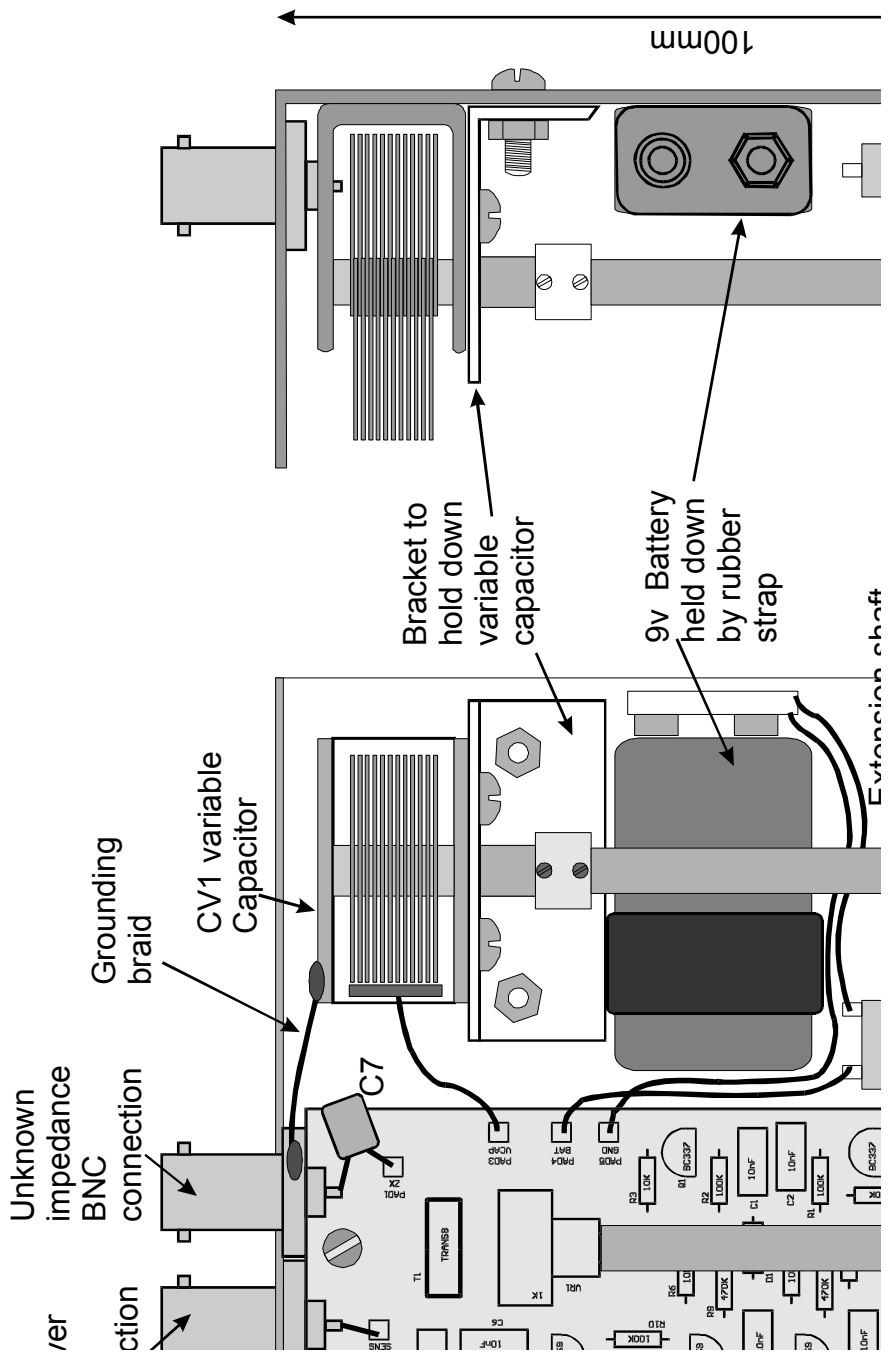
Sources of components not supplied:

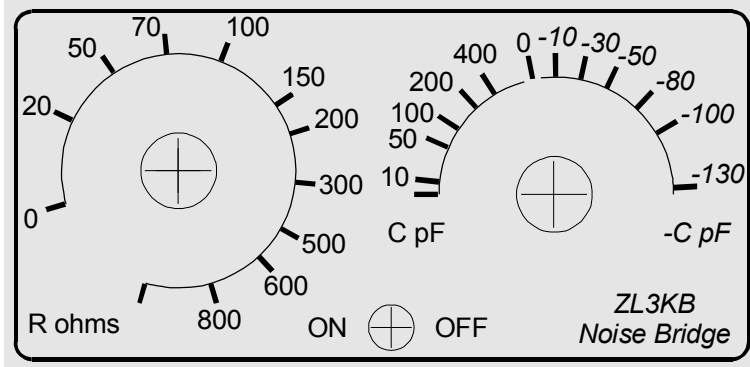
1. RS Components, PO Box 71-151, Auckland. (Silver Mica Capacitors.)
2. Oren Elliot, POBox 638, 128 W.Vine, Ederton, OH 43517, USA. (variable capacitors, product code N50).

References:

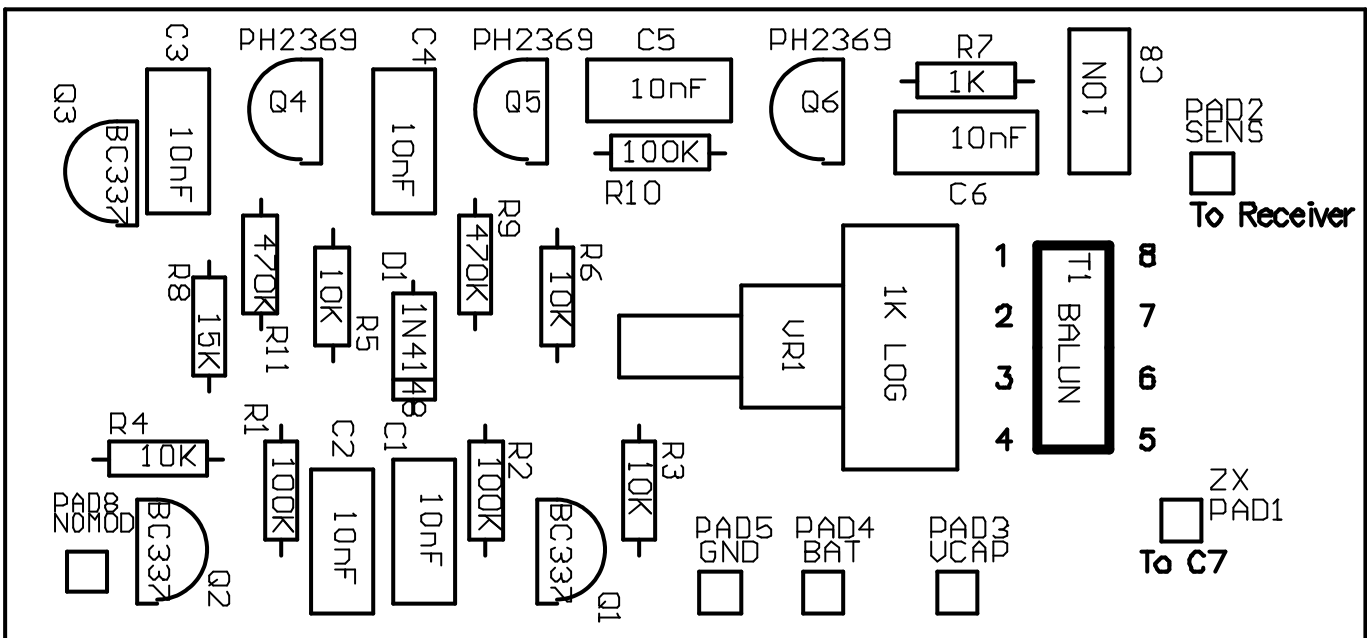
1. Galbraith Noise bridge.
2. Noise Bridge, ARRL Handbook, 1988.
3. Noise Bridge, RSGB VHF handbook.

Technical notes from ZL3AO





Caption:  
 Layout of front panel of Noise Bridge. Note these calibrations only  
 apply when using the potentiometer and capacitor listed in the text.



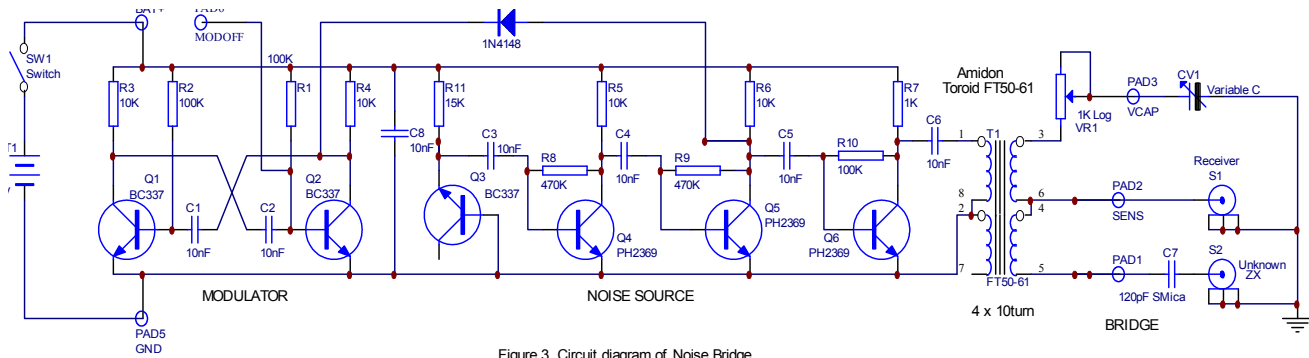


Figure 3. Circuit diagram of Noise Bridge

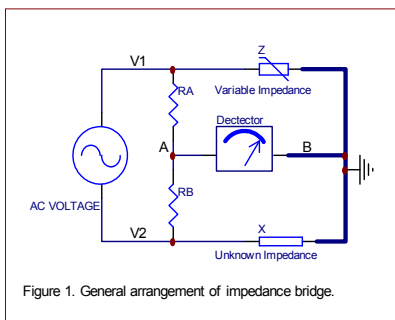
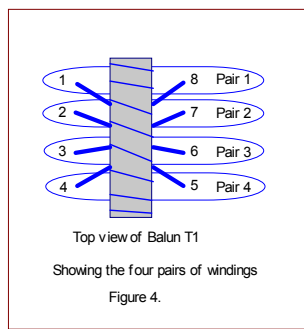


Figure 1. General arrangement of impedance bridge.



Top view of Balun T1  
Showing the four pairs of windings  
Figure 4.

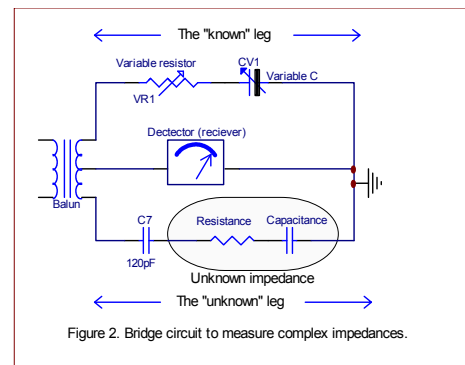


Figure 2. Bridge circuit to measure complex impedances.

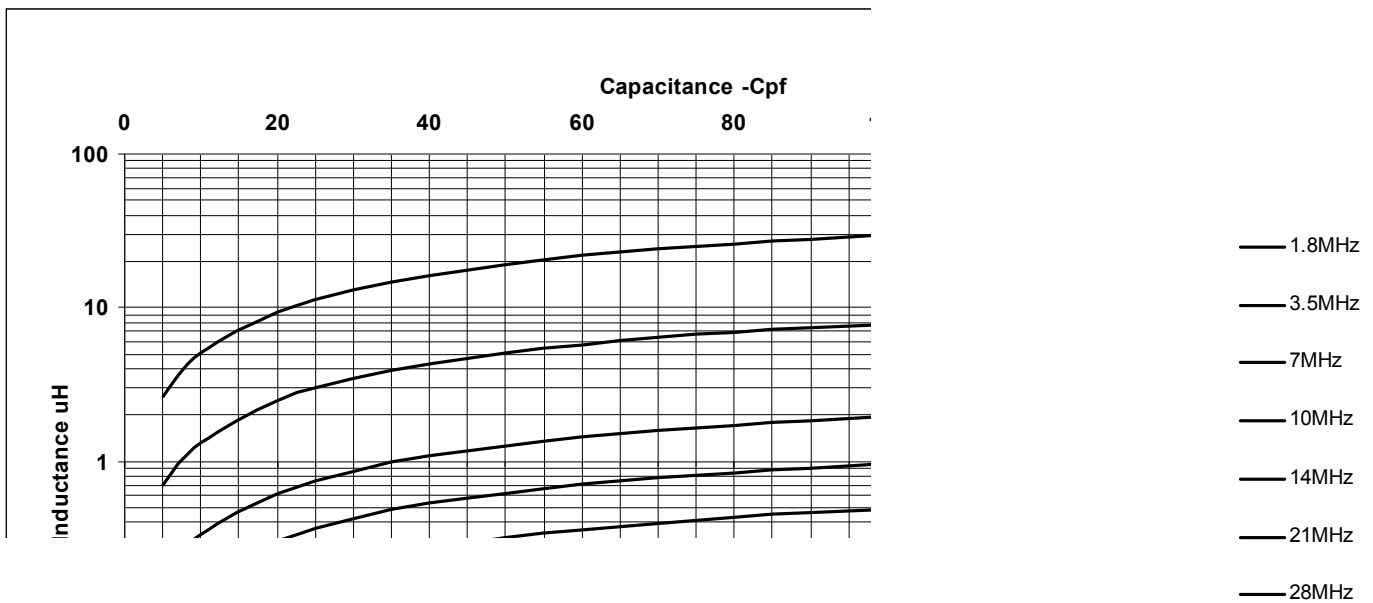


Chart 1. Inductance versus -CpF reading. Note this chart is valid for C7 =120pF