SFU School of Engineering Science

ENSC 220 Electric Circuits I

Inductor Construction

Materials, Supplies and Equipment

You supply

1. Basic lab hand tools (diagonal cutters, needle-nosed pliers, wire strippers)
2. Breadboard
3. Small ruler

Cardboard winding form

Lab Supplies (issued per group at Lab Resource Office ASB9876)

1. Magnet wire, enameled, 9.4 m (~30 ft – 6.5 workstation bench lengths), #26AWG (O.D. typ. = 16.6-17.3mils[1])
2. Wire, hookup, #22AWG, solid, 75 mm/3 inches
3. Coil form (for inductor), plastic 15ml centrifuge tube with cap removed: ~96mm L x 16.2mm O.D.[2]
4. Emery or sand paper, Fine (320) or Medium (240) grit
5. Cardboard winding form *(please return to Resource office ASB9876 – slide under door)*
6. Cardboard piece to protect work-surfaces (provided for use at soldering stations).

Centrifuge tube coil form

Extra Materials (openly accessible in Lab1)

1. Soldering station/iron with medium tip & tip cleaning sponge/brass pad
2. Solder, rosin core, 63/37SnPb standard, 0.75mm Dia., ~3 inches (75mm) L
3. Tape, masking, ½" inch wide x 12" (30cm) *(supplied at wire rack)*

Test Equipment

1. Digital Multimeter (DMM), Fluke 45

Other Resources

1. Soldering video; Desktop > Reference Materials > Tutorials > 220 > CI_How_To_Solder
2. Additional excellent references on soldering Desktop > Reference Materials > Tutorials > Soldering > PACE
3. http://en.wikipedia.org/wiki/American_wire_gauge
4. *Lab1 computers > Desktop > Reference Material > Tutorials & App Notes > Lab Handbook* sections 2.4.2-Soldering; 2.3.5-Inductors

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[1] 1mil = 1/1000 inch. O.D. = Outside Diameter. Parameters given are Imperial units (inches), referenced to the NEMA (national Electrical Manufacturers Association) parameters established in the USA. The O.D. of enameled wire varies between batches depending on enamel type and chemical formulation, number of coats, manufacturer, etc. Enameled wire data may be found:
Lab1 computers > Desktop > Reference Materials > Parts Data\Wire & Cable\Enameled Copper Magnet Magnet Wire Data-AWG26.pdf and Magnet Wire Table-NEMA-inch.pdf

[2] O.D. = Outside Diameter. Measured at centrifuge tube centre. *Note: The tube has a 1mm taper over its supplied length.*

I Objective

Using the supplied materials, you will design and construct a single-tap air-core inductor. This will involve a group effort to carefully wind a length of enameled magnet wire onto a plastic coil form, then insulation-strip and prepare wire ends for breadboard testing using basic soldering techniques. The data you collect will be entered onto a designated Worksheet[3] that you will submit for marking.
Care during construction is important! Your group will only be permitted one set of materials. Upon completion, in a separate upcoming lab assignment, you will explore the electrical characteristics of your inductor.

Your inductor may be used in the AM radio project in a subsequent (optional) lab.

II Preparation & Time

Read this document and your assignment carefully in its entirety before commencing.

Your instructor will arrange for a lab technician to provide a preliminary practical demonstration for inductor winding, lead preparation, soldering techniques as well as safe handling practices. Materials will be issued to y*our group upon completion of the practical tutorial.*

Construction Time: 30-45 minutes to wind the inductor and solder the 3 connections.

III Safety

During the inductor construction phase, you will be working with potentially hazardous tools and materials. Please heed these important safety warnings.

1. Solder contains lead that is a known human toxin. Wash you hands carefully with soap and warm water immediately after handling.
2. Use the soldering station fume hood to draw off fumes created during soldering. Avoid inhaling fumes.
3. Hot soldering irons or molten solder can cause serious burns. Familiarize yourself with the appropriate first aid measures beforehand.
4. It is a good idea to wear some form of protective eyewear while soldering.
5. Exercise appropriate caution when using and transporting sharp knives.

IV Inductor Design & Construction

Follow the design method prescribed by your instructor.

Design – Calculated Method

The inductance L of a single-layer air-core inductor is approximated using Wheeler's Formula

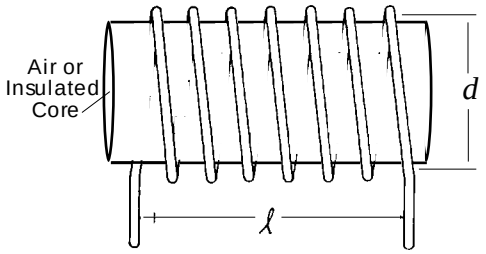
$$L = \frac{(d^2 n^2)}{18d + 40l} \quad \text{or} \quad L = \frac{(d^2 n^2)}{18d + 40nw}$$

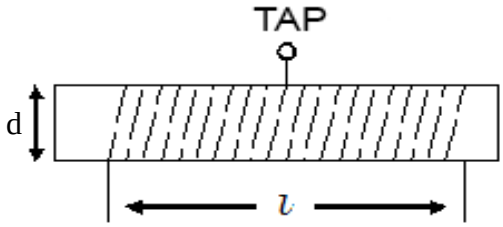
[3] Your instructor shall advise you where to acquire the necessary Worksheet.

where:

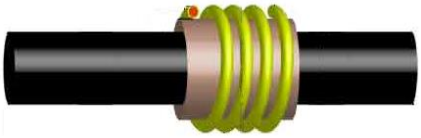
L = inductance (measured in µH)
d = coil diameter (inches)
l = coil length (inches)
n = number of turns
w = wire diameter (inches)

Please observe that because the supplied magnet wire is specified in AWG (American Wire Gauge), its parameters are given in imperial units (inch/fractional inch), hence the formulas are based accordingly.

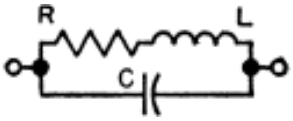




Your course syllabus may use this inductor later for an AM radio experiment. When calculating your coil's finished inductance, it may be helpful to consider that the AM radio broadcast band covers 520-1610kHz. Our variable capacitor tuning range is nominally between 12-235pF. Or, we may experiment with a fixed capacitor, such as the 47pF or 470pF capacitor in your main lab parts kit and make the inductor variable by sliding a ferrite rod inside the coil core to change its inductance and Q permitting us to tune between various radio stations.



$$f_r = \frac{1}{2\pi}\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)^{\frac{1}{2}}$$



Design – Practical Method

This is by far the simplest method. You will make only one tap in the centre. Start and terminate winding as close to each end of the coil form as possible, winding only on the smooth surface, and use ½" wide masking tape to secure the wire ends. Each turn of wire must be placed tightly against its neighbour with no air gaps or pigtail niggles between. In most cases, you can use the graduation marks on the centrifuge tube as a guide – '8' is typically the centre for the Corning CentriStar tubes. Start winding from the threaded end of the tube, keeping accurate record of the turn-count to the centre mark and place the tap. Continue winding the same number of turns to the finished end. The taps should fall in-line with the initial wire entry and exit point on the coliform.

Construction

Included with the supplied materials is a length of enameled wire and a plastic centrifuge tube (coil form) with which to construct your inductor. The specifications for these items are defined in the materials subsection. **Wind all of the wire given,** unless the windings exceed the length of the coil-form (in which case you can cut it off)**.**

Please, return any remaining wire on the notched cardboard to Lab Tech or to the Resource Office (ASB9876).

Tips *(answers to the common questions)*

a) **A ballpark guide**. 10m of #26AWG magnet wire wound will yield an air-core inductance of around 90µH +/-10%. With the ferrite rod inserted, you may realize upwards of 3.5mH.

b) **Style**. Be creative – there's no absolute *right* or *wrong* way to wind your coil. Essentially, as long as the turns are evenly spaced and the wire is electrically good/undamaged (continuous - no breaks, or shorted turns) and that the insulation is cleanly removed from the connection ends – it'll work. This grants you some creative latitude and flexibility in the winding, tapping and termination styles.

c) **Creating a tap**. A "tapped" inductor can be built by inserting a twisted wire loop "tap" at one or more sites along the length of the inductor. *For this lab, make only one tap in the approximate centre – typically at the '8' mark on the tube*. Try to keep the number of turns equal on either side of the tap. Finished tap(s) should be about 7 to 9 cm long.

> ***Be careful not to over-twist taps***. The soft copper wire will break – usually in the worst spot, at the coil form. Repairs can be challenging and time consuming. Practice first!

d) **Form hand windings** with firm, steady tension. Keep turns tucked tightly side-by-side all the way around. Constantly push gaps together with your fingernail.

e) ***Pigtails* or kinks** in the wire are bad news. The enameled wire provided to you must be kept free of these aberrations. The notched cardboard winder will help prevent accidents. Enlist a helper to 'pay' out the wire while another person forms the windings.

f) **Use masking tape** to secure wire ends and temporarily hold-fast windings in progress. Do this every dozen turns or so – hand muscles tend to get tired; one slip and your hard work will come undone.

g) **Free end space**. For the centrifuge tube, free-end (unwound) space will be very minimal. Masking tape can be used with careful placement at the coil-form ends to ensure that wire is held securely. Be careful to ensure that the tube's inner hollow core remains completely smooth and free of obstructions so that the ferrite tuning rod can be inserted and able to move freely from end to end.

h) **Practice.** You've been given an adequate length of enameled wire – probably a bit more than you really need. Cut off a couple of 8 cm pieces. Working on a protective cardboard section (i), experiment with the sandpaper and knife/needlenose pliers (inner-jaw edges)/diagonal cutting pliers (cutting head outer edges) to hone your enamel stripping and soldering skills.

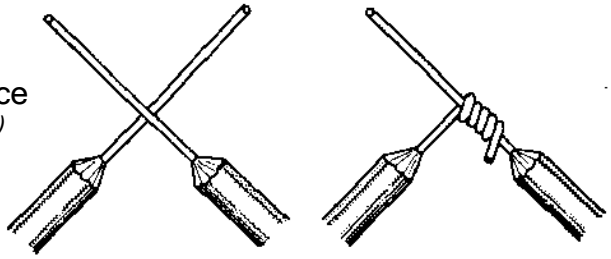
i) **Don't sand, cut or scrape directly on the benchtops - PLEASE!!!** Rather, place a piece of cardboard or similar protective material under your work for work-surface/benchtop protection.

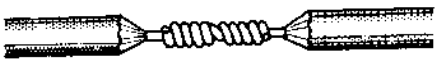
j) **Enamel insulation removal from magnet wire** is necessary to make an electrical connection to the copper underneath. Because bare copper oxidizes quickly, creating a solder tinned termination is important. Strip the enamel all around the desired point using the emery cloth provided on a protected work surface. Also, *the inner-jaw edges of your needle-nosed pliers or cutting head outer edges of your diagonal cutting pliers make nice tools for scraping; be gentle!*

k) **An interface wire** is generally the preferred method of joining the enameled wire to an electrically and mechanically reliable breadboard connection. First, strip the plastic PVC insulation completely from the #22AWG PVC insulated wire given. Make the first splice and solder the electrical connection to the magnet wire using the uncut length of given #22AWG interface wire. Once the joint has cooled, cut to about 7-8mm length for the breadboard receptacles. Repeat for the other two coil leads. Prepare the connections as pictured below.

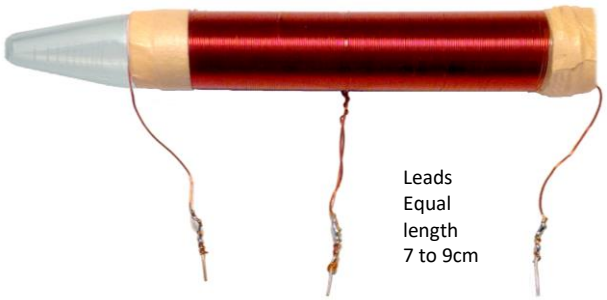
Tap Splice

Western Union Splice
(use for coil end leads)

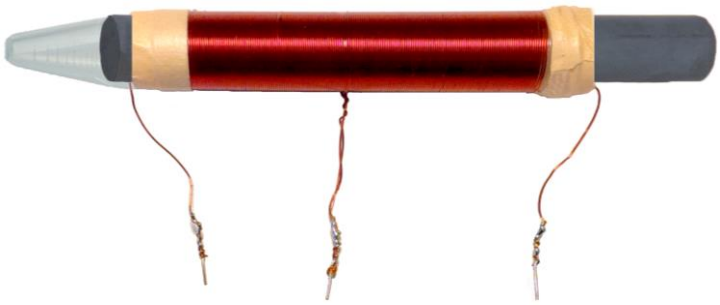




Western Union Splice
(finished step)



Finished inductor with breadboard interface wires



Inductor with instructor-supplied ferrite tuning rod

Inductor Verification Procedure

It's a good idea to perform a careful preliminary check of the inductor to ensure that excellent electrical continuity is present at all connections. You may use the workstation DMM in either the Ω mode or continuity-beeper (on the Fluke 45 select the button to the right of the Ω). Check for good and stable continuity indication from the tap to both outside end connections.