# Tricks of the Trade: Guesstimating Inductance of Wire Loops

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Parasitic inductance can drastically affect the operation of high-speed power electronics circuits. For instance, in MOSFET switching the gate and source inductance can lower the switching speed and increase switching losses. High gate inductance can cause ringing in the gate circuit which exceeds the maximum gate-source voltage specification. Drain inductance can overstress the MOSFET due to induced voltage spikes. In amplifier circuits, parasitic inductance can result in bandwidth reduction and/or oscillation. Therefore, a method for estimating these various inductances is a valuable tool.

Guesstimating the inductance of a length of wire and its return path, or of a wire loop can be done by applying a useful rule-of-thumb. This note provides a brief theoretical background in order to get order-of-magnitude estimates of wiring inductance, and points the user to several references that can be used if more accurate results are needed. The bottom line is that a wire loop has approximately 0.5-1 microhenries of inductance per meter of length, depending on the wire-wire spacing, wire diameter, shape of the loop, etc. For wire spacing large compared to the wire diameter, the inductance of the loop is a weak function of wire diameter (which makes physical sense, if you think about it).

For instance, a circular loop of wire with loop radius $a$ and wire radius $R$ has the approximate inductance [Wheeler]:

$$L_0 = \mu_0 a(\ln(8a/R) - 2) \text{ in H}$$

Using this formula, the inductance of a 1 meter circumference loop of 14-gauge wire is 1.07 $\mu$H; for 16-gauge wire it is 1.12 $\mu$H; and for 18-gauge wire it's 1.16 $\mu$H. Note the weak dependence of inductance on wire diameter. This is due to the natural log in the expression. So our guesstimate of 0.5-1 $\mu$H per meter of length is a pretty good starting point. A crude approximation to the Wheeler formula for circular loops is [Lee, p. 56]

$$L_0 = \mu_0 \pi a \text{ in H}$$

which predicts an inductance of 0.63 $\mu$H for a 1-meter circumference wire loop.

For two parallel wires, spaced $d$ meters apart, each wire with radius $R$ and with line length $l$ meters the inductance of the loop is [Wheeler]:

$$L_0 = (\mu_0 l/\pi) \ln(d/R-1) \text{ in H}$$

For $l$= 0.5 meter and a wire-to-wire spacing $d$ =1 cm, results are $L_0$= 0.485 $\mu$H for 14 gauge; $L_0$= 0.53 $\mu$H for 16 gauge and $L_0$= 0.58 $\mu$H for 18 gauge. Therefore, for the parallel-wire line with closely-spaced conductors, the inductance is approximately 0.5 $\mu$H per meter of total wire length.

We can hone the guesstimate further by applying a little physical reasoning. For the parallel-wire case with close wire-to-wire spacing, the close magnetic coupling between the wires reduces the inductance of the loop; (this is why twisted-pairs have lower inductance than parallel wires). So, for wires that are close together (i.e. our parallel line case, 0.5 meter long with total wire length 1 meters) the inductance will be approximately 0.5 $\mu$H/meter or less. For "fat" loops, there is more area enclosed by the loop and the inductance is higher.

An excellent reference (which, unfortunately is now out of print) is the Frederick Grover book listed below. Grover spent most of his professional life calculating inductances, and many useful examples and tables are given for loops of interesting shapes and sizes.

The goal of these rules-of-thumb is to get order-of-magnitude estimates of inductance. If more accurate results are required, you can use the more complicated closed-form solutions, or in the last resort, use finite-element analyses (FEA). How ever, it's difficult to do FEA analysis on the back of a napkin at lunchtime!

## REFERENCES

F. W. Grover, Inductance Calculations: Working Formulas and Tables, Dover Publications, Inc., New York, 1946.

Thomas H. Lee, The Design of CMOS Radio Frequency Integrated Circuits, Cambridge University Press, 1998.

F. E. Terman, Radio Engineers' Handbook, McGraw-Hill, New York, 1943.

Harold A. Wheeler, "Formulas for the Skin Effect," Proceedings of the I.R.E., September 1942, pp. 412-424.