SOLEN INC.

AIR CORE INDUCTORS
PERFECT LAY HEXAGONAL WINDING

SOLEN was the first electronic passive components manufacturing company to design air core inductors using the high precision honeycomb structured *perfect lay hexagonal winding technique*. This advance concept was introduced to design and manufacture the most complete line of highest quality close tolerance self supporting air core inductors for the specific application of the loudspeaker industry. The range of values is from 0.10 mH to 30 mH with solid conductor sizes from 0.8 mm Ø (20AWG) to 2.6 mm Ø (10AWG) with a tolerance of ±0.5 %.

▸ **Inductor**

Inductor, also called coil, is a passive device consisting of a number of turns of conductor that introduce an inductive reactance due to inductance into an electrical circuit to produce a magnetic flux. The parameters that characterize an inductor are the inductance (L) and the quality factor (Q). In addition the d.c. resistance (R) and the a.c. resistance (R f) can also be useful parameters as well.

▸ **Inductance** L (H)

The inductance of an inductor depends on the number of turns, diameter of the inductor, the length of the inductor and the nature of the core. The electrical size of an inductor is called inductance (L) and is expressed in Henrys (H). It is the property of a circuit that tends to oppose any change of current because of magnetic field associated with the current itself.

▸ **Inductive Reactance** $X_L = 2 * \pi * f * L$

It is a positive reactance due the inductance of an inductor

▸ **Quality Factor** Q

The quality factor is the ratio of the reactance to the resistance and therefore is unit less. The higher the quality factor, the fewer the losses there are in the inductor. The dissipation factor (D) can be referred to as the total loss within a components and it is defined as 1 / Q. The total loss (D) of an air core inductor is comprised of winding copper loss, winding eddy-current loss and conductor skin effect loss. The total loss (D) of a magnetic core inductor is comprised of winding copper loss, winding eddy-current loss and conductor skin effect loss with the addition the magnetic core eddy-current loss and magnetic core hysteretic loss.

▸ **Impedance** Z (Ω / f)

The opposition that an inductor offers to alternating current is called impedance (Z) and it is expressed in ohms (Ω f). The impedance of an inductor increases with frequency.

▸ **Air Core Inductors**

Air core inductors are the only one that can achieve pure inductance ideal inductive reactance behavior. They have the highest stability, the tightest tolerance, a linear inductance under dynamic signal condition, greater power handling and less distortion. They have relatively low d.c. resistance, linear a.c. resistance, better and more linear quality factor at high frequency and linear phase characteristics. They also have no magnetic core hysteretic distortion, no magnetic core saturation distortion, no magnetic core non-linear inductance and no magnetic core phase distortion. They produce no harmonics frequency. Air core also means larger inductors and a higher d.c. resistance compare to magnetic core inductor.

‣ **Wheeler's Formula** $L\ (\mu H) = (0.0315 * a^2 * N^2) / (6 * a + 9 * l + 10 * c)$ $l_W = 2 * \pi * N * a$

N = number of turns, (mm) a = average coil radius, l = coil length, c = coil thickness, l_W = length of wire

This accurate formula that calculate the inductance in micro henries, for multi layer air core inductors was used and integrated in a computer program to efficiently evaluate each specific inductor design for optimum size and lowest possible d.c. resistance for any given inductance value and wire size. After the most promising designs were identified, they were merged and incorporated in a series of 12 different optimum inductor dimensions (l x d x D were l = coil length, were the inside diameter d = 2c and were the outside diameter D = 4c) in order to cover the whole range of the inductance values and wire size ranges. The accuracy is within 1% when the three terms in the denominator are about equal.

‣ **Winding D.C. Resistance** $R_{dc}\ (\Omega) = 4 * \rho_C * N * 2 * \pi * a / \pi * d_W^2$

ρ_C = conductor resistivity (copper = 1.709×10^{-8} Ωm), d_W = diameter of wire

This general formula calculates the d.c. resistance in ohms for the above multi layer air core inductor. Another formula, $R_{dc}\ (\Omega) = 7.67 * a * N^2 / 10^6 * l * c$, calculates the d.c. resistance in ohms for the above multi layer air core inductor with a single enamel coating circular copper conductor and a space factor of 90% for the winding.

‣ **Hexagonal Winding**

The standard air core inductor using low precision machine wound type which produces either a random or a square type loose winding, self supporting or not, was not acceptable. Close tolerance proprietary custom designed winding tooling were research and developed as the only way to achieve the high precision honeycomb structured *perfect lay hexagonal winding technique*. The finish product is a multi layer self supporting air core inductor with an extremely tight hexagonal honeycomb structured maximum filled winding area that delivers the best possible winding space factor for any given inductor value with the highest possible quality factor.

‣ **Electro Mechanical Vibration**

The alternating current passing through an inductor will induce an alternating magnetic field, which will produce a mechanical vibration in each turn of wire corresponding the applied audio frequency. This mechanical vibration generates an acoustic radiation that will cause a non-linear loss and distortion under the form of an audio frequency noise. The high precision *perfect lay hexagonal winding technique* with its tight hexagonal honeycomb structured winding cut most of these electro mechanical vibration losses. Furthermore, each inductor is dipped in an industrial varnish that impregnates perfectly and totally solidifies all the outside turns.

‣ **Perfect Layer Winder**

Advance technology, state of the art, perfect layer winding equipments along with a complete set of 12 proprietary high precision self-supporting winding types tooling were custom designed, developed and manufactured by *SOLEN*. With this sophisticated manufacturing equipment and tooling, each turn of each layer is precisely winded side by side and each turn of all subsequent layers are alternatively offset from the underlying layer turn by a distance equal to the radius of the wire used, which means that each overlying turn of the second layer fits in the groove made by the underlying turn of the first layer, hence the term *perfect lay*.

‣ **Nec Plus Ultra**

All those optimized factors combine to give a much superior air core inductor with the best possible specifications: a higher quality factor, lower d.c. resistance, more linear a.c. resistance, lower electro mechanical vibration losses, closer tolerance, lower stray capacitance, longer stability, higher power handling, lowest distortion and the best sonic quality for any given inductor value. They are the *nec plus ultra* of today inductors because they were originally designed has a cost no object project and as a no compromise achievement.

SOLEN 2008

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AIR CORED INDUCTORS
PERFECT LAY HEXAGONAL WINDING

● GENERAL INFORMATION

Type	: Air Cored Inductor.
Conductor	: Pure Copper Solid Round Type.
Dielectric	: Red Polyurethane Polyamide Enamel.
Construction	: Hollow Cylindrical Type, Radial Leads.
Winding	: Perfect Layer Hexagonal Self-Supporting Type.
Coating	: Varnish Dip With Four Black Nylon Ties.
Leads	: Pure Copper

● TECHNICAL DATA

Inductance Range/Tolerance	: 0.10 mH ... 30 mH, E24 series, ±1 %. (see specifications for details)
Conductor Material	: ≥ 99.99 % Purity Annealed Copper.
Electrical Conductivity	: ≥ 101.5 %.
DC resistance	: Very Low (see specifications for details)
Oxygen Content	: ≤ 200 ppm on surface.
Temperature Coefficient	: 0.00393 / °C.
Temperature Range	: -55 °C to +85 °C.
Insulation Temperature	: 130 °C.
Solderable Temperature	: 360 °C.
Test Voltage	: 1000 VAC
Conductor Diameter	: S20 = 0.8, S18 = 1.0, S16 = 1.3, S14 = 1.6, S12 = 2.0, S10=2.6mmØ
Skin Effect Rac = Rdc	: S20 = 7.0, S18 = 4.0, S16 = 2.5, S14 = 1.7, S12 = 1.0, S10 = 0.7 KHz
Skin Effect Rac = Rdc +10%	: S20 = 27, S18 = 17, S16 = 10, S14 = 7.0, S12 = 4.0, S10 = 2.5 KHz
Winding Space Factor	: S20 = 84, S18 = 86 , S16 = 87, S14 = 88, S12 = 90, S10 = 92 %

● FEATURE

Integral Wheeler Formula Application.
Computer Optimized Inductor Dimension.
Linear AC Resistance
Very Low Magnetostriction Distortion.
Constant Inductance with Voltage Variation.
Constant Inductance with Current Variation.
No Saturation Distortion.
No Hyteresis Distortion.

● ELECTRICAL PERFORMANCE

High Quality Factor.
Very Low DC Resistance
Low AC Resistance.
Low Skin Effect Losses.
Low Proximity Effect Losses.
Low Self Capacitance.

DC Resistance (Ohms) +5%
Dimensions (mm) +10%

S20 0.80 mm Ø / 20 AWG

P/N	Inductance/DCR		LxdxD
S20.16	.16 mH	.24	10x19x38
S20.18	.18 mH	.26	10x19x38
S20.20	.20 mH	.27	10x19x38
S20.22	.22 mH	.29	10x19x38
S20.24	.24 mH	.31	10x19x38
S20.27	.27 mH	.34	10x19x38
S20.30	.30 mH	.36	10x19x38
S20.33	.33 mH	.38	11x22x45
S20.36	.36 mH	.40	11x22x45
S20.39	.39 mH	.42	11x22x45
S20.43	.43 mH	.44	11x22x45
S20.47	.47 mH	.47	11x22x45
S20.51	.51 mH	.49	11x22x45
S20.56	.56 mH	.51	11x22x45
S20.62	.62 mH	.54	11x22x45
S20.68	.68 mH	.57	13x25x51
S20.75	.75 mH	.60	13x25x51
S20.82	.82 mH	.63	13x25x51
S20.91	.91 mH	.66	13x25x51
S201.0	1.0 mH	.70	13x25x51
S201.1	1.1 mH	.75	13x25x51
S201.2	1.2 mH	.80	13x25x51
S201.3	1.3 mH	.85	13x25x51
S201.5	1.5 mH	.91	13x25x51
S201.6	1.6 mH	.96	14x29x57
S201.8	1.8 mH	1.01	14x29x57
S202.0	2.0 mH	1.05	14x29x57
S202.2	2.2 mH	1.14	14x29x57
S202.4	2.4 mH	1.20	14x29x57
S202.7	2.7 mH	1.28	14x29x57
S203.0	3.0 mH	1.36	14x29x57

S18 1.02 mm Ø / 18 AWG

P/N	Inductance/DCR		LxdxD
S18.10	.10 mH	.12	10x19x38
S18.11	.11 mH	.13	10x19x38
S18.12	.12 mH	.14	10x19x38
S18.13	.13 mH	.15	10x19x38
S18.15	.15 mH	.16	10x19x38
S18.16	.16 mH	.16	11x22x45
S18.18	.18 mH	.17	11x22x45
S18.20	.20 mH	.18	11x22x45
S18.22	.22 mH	.19	11x22x45
S18.24	.24 mH	.21	11x22x45
S18.27	.27 mH	.22	11x22x45
S18.30	.30 mH	.24	11x22x45
S18.33	.33 mH	.26	13x25x51
S18.36	.36 mH	.27	13x25x51
S18.39	.39 mH	.28	13x25x51
S18.43	.43 mH	.29	13x25x51
S18.47	.47 mH	.31	13x25x51
S18.51	.51 mH	.33	13x25x51
S18.56	.56 mH	.35	13x25x51
S18.62	.62 mH	.36	13x25x51
S18.68	.68 mH	.38	14x29x57
S18.75	.75 mH	.40	14x29x57
S18.82	.82 mH	.43	14x29x57
S18.91	.91 mH	.45	14x29x57
S181.0	1.0 mH	.47	14x29x57
S181.1	1.1 mH	.50	14x29x57
S181.2	1.2 mH	.54	14x29x57
S181.3	1.3 mH	.57	14x29x57
S181.5	1.5 mH	.60	14x29x57
S181.6	1.6 mH	.63	16x32x64
S181.8	1.8 mH	.68	16x32x64
S182.0	2.0 mH	.70	16x32x64
S182.2	2.2 mH	.76	16x32x64
S182.4	2.4 mH	.81	16x32x64
S182.7	2.7 mH	.87	16x32x64
S183.0	3.0 mH	.93	16x32x64

S16 1.29 mm Ø / 16 AWG

P/N	Inductance/DCR		LxdxD
S16.10	.10 mH	.08	11x22x45
S16.11	.11 mH	.08	11x22x45
S16.12	.12 mH	.09	11x22x45
S16.13	.13 mH	.09	11x22x45
S16.15	.15 mH	.10	11x22x45
S16.16	.16 mH	.11	13x25x51
S16.18	.18 mH	.11	13x25x51
S16.20	.20 mH	.12	13x25x51
S16.22	.22 mH	.13	13x25x51
S16.24	.24 mH	.14	13x25x51
S16.27	.27 mH	.15	13x25x51
S16.30	.30 mH	.16	13x25x51
S16.33	.33 mH	.16	14x29x57
S16.36	.36 mH	.17	14x29x57
S16.39	.39 mH	.18	14x29x57
S16.43	.43 mH	.19	14x29x57
S16.47	.47 mH	.21	14x29x57
S16.51	.51 mH	.22	14x29x57
S16.56	.56 mH	.23	14x29x57
S16.62	.62 mH	.24	14x29x57
S16.68	.68 mH	.25	16x32x64
S16.75	.75 mH	.27	16x32x64
S16.82	.82 mH	.28	16x32x64
S16.91	.91 mH	.30	16x32x64
S161.0	1.0 mH	.31	16x32x64
S161.1	1.1 mH	.33	16x32x64
S161.2	1.2 mH	.35	16x32x64
S161.3	1.3 mH	.38	16x32x64
S161.5	1.5 mH	.41	16x32x64
S161.6	1.6 mH	.44	19x38x76
S161.8	1.8 mH	.46	19x38x76
S162.0	2.0 mH	.48	19x38x76
S162.2	2.2 mH	.52	19x38x76
S162.4	2.4 mH	.56	19x38x76
S162.7	2.7 mH	.60	19x38x76
S163.0	3.0 mH	.63	19x38x76

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S203.3  3.3 mH 1.43  16x32x64    S183.3  3.3 mH  .98  19x38x76    S163.3  3.3 mH  .66  22x45x89
S203.6  3.6 mH 1.50  16x32x64    S183.6  3.6 mH 1.03  19x38x76    S163.6  3.6 mH  .70  22x45x89
S203.9  3.9 mH 1.57  16x32x64    S183.9  3.9 mH 1.09  19x38x76    S163.9  3.9 mH  .73  22x45x89
S204.3  4.3 mH 1.66  16x32x64    S184.3  4.3 mH 1.15  19x38x76    S164.3  4.3 mH  .77  22x45x89
S204.7  4.7 mH 1.75  16x32x64    S184.7  4.7 mH 1.22  19x38x76    S164.7  4.7 mH  .82  22x45x89
S205.1  5.1 mH 1.84  16x32x64    S185.1  5.1 mH 1.29  19x38x76    S165.1  5.1 mH  .86  22x45x89
S205.6  5.6 mH 1.93  16x32x64    S185.6  5.6 mH 1.36  19x38x76    S165.6  5.6 mH  .91  22x45x89
S206.2  6.2 mH 2.02  16x32x64    S186.2  6.2 mH 1.43  19x38x76    S166.2  6.2 mH  .96  22x45x89
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                                 S186.8  6.8 mH 1.51  22x45x89   S166.8  6.8 mH 1.01  25x51x102
                                 S187.5  7.5 mH 1.59  22x45x89   S167.5  7.5 mH 1.07  25x51x102
                                 S188.2  8.2 mH 1.67  22x45x89   S168.2  8.2 mH 1.12  25x51x102
                                 S189.1  9.1 mH 1.75  22x45x89   S169.1  9.1 mH 1.18  25x51x102
                                 S1810   10  mH 1.84  22x45x89   S1610   10  mH 1.24  25x51x102
                                 S1811   11  mH 1.98  22x45x89   S1611   11  mH 1.38  25x51x102
                                 S1812   12  mH 2.12  22x45x89   S1612   12  mH 1.52  25x51x102
                                 S1813   13  mH 2.27  22x45x89   S1613   13  mH 1.66  25x51x102
                                 S1815   15  mH 2.42  22x45x89   S1615   15  mH 1.70  25x51x102
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                                                                 S1616   16  mH 1.79  32x64x127
                                                                 S1618   18  mH 1.88  32x64x127
                                                                 S1620   20  mH 1.97  32x64x127
                                                                 S1622   22  mH 2.07  32x64x127
                                                                 S1624   24  mH 2.17  32x64x127
                                                                 S1627   27  mH 2.27  32x64x127
                                                                 S1630   30  mH 2.37  32x64x127
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DC Resistance (Ohms) ±5%
Dimensions (mm) ±10%

S14 1.63 mm Ø / 14 AWG

P/N	Inductance/DCR		LxdxD
S14.16	.16 mH	.07	14x29x57
S14.18	.18 mH	.08	14x29x57
S14.20	.20 mH	.08	14x29x57
S14.22	.22 mH	.09	14x29x57
S14.24	.24 mH	.10	14x29x57
S14.27	.27 mH	.10	14x29x57
S14.30	.30 mH	.11	14x29x57
S14.33	.33 mH	.11	16x32x64
S14.36	.36 mH	.11	16x32x64
S14.39	.39 mH	.12	16x32x64
S14.43	.43 mH	.12	16x32x64
S14.47	.47 mH	.13	16x32x64
S14.51	.51 mH	.14	16x32x64
S14.56	.56 mH	.15	16x32x64
S14.62	.62 mH	.16	16x32x64
S14.68	.68 mH	.17	19x38x76
S14.75	.75 mH	.18	19x38x76
S14.82	.82 mH	.19	19x38x76
S14.91	.91 mH	.20	19x38x76
S141.0	1.0 mH	.21	19x38x76
S141.1	1.1 mH	.23	19x38x76
S141.2	1.2 mH	.24	19x38x76
S141.3	1.3 mH	.26	19x38x76
S141.5	1.5 mH	.28	19x38x76
S141.6	1.6 mH	.29	22x45x89
S141.8	1.8 mH	.30	22x45x89
S142.0	2.0 mH	.31	22x45x89
S142.2	2.2 mH	.33	22x45x89
S142.4	2.4 mH	.36	22x45x89
S142.7	2.7 mH	.39	22x45x89
S143.0	3.0 mH	.42	22x45x89

S12 2.05 mm Ø / 12 AWG

P/N	Inductance/DCR		LxdxD
S12.33	.33 mH	.07	19x38x76
S12.36	.36 mH	.08	19x38x76
S12.39	.39 mH	.08	19x38x76
S12.43	.43 mH	.09	19x38x76
S12.47	.47 mH	.10	19x38x76
S12.51	.51 mH	.10	19x38x76
S12.56	.56 mH	.11	19x38x76
S12.62	.62 mH	.11	19x38x76
S12.68	.68 mH	.11	22x45x89
S12.75	.75 mH	.12	22x45x89
S12.82	.82 mH	.12	22x45x89
S12.91	.91 mH	.13	22x45x89
S121.0	1.0 mH	.14	22x45x89
S121.1	1.1 mH	.15	22x45x89
S121.2	1.2 mH	.16	22x45x89
S121.3	1.3 mH	.17	22x45x89
S121.5	1.5 mH	.19	22x45x89
S121.6	1.6 mH	.20	25x51x102
S121.8	1.8 mH	.21	25x51x102
S122.0	2.0 mH	.22	25x51x102
S122.2	2.2 mH	.24	25x51x102
S122.4	2.4 mH	.26	25x51x102
S122.7	2.7 mH	.28	25x51x102
S123.0	3.0 mH	.30	25x51x102

S10 2.59 mm Ø / 10 AWG

P/N	Inductance/DCR		LxdxD
S10.68	.68 mH	.08	25x51x102
S10.75	.75 mH	.09	25x51x102
S10.82	.82 mH	.09	25x51x102
S10.91	.91 mH	.10	25x51x102
S101.0	1.0 mH	.10	25x51x102
S101.1	1.1 mH	.11	25x51x102
S101.2	1.2 mH	.11	25x51x102
S101.3	1.3 mH	.12	25x51x102
S101.5	1.5 mH	.13	25x51x102
S101.6	1.6 mH	.13	32x64x127
S101.8	1.8 mH	.14	32x64x127
S102.0	2.0 mH	.15	32x64x127
S102.2	2.2 mH	.16	32x64x127
S102.4	2.4 mH	.17	32x64x127
S102.7	2.7 mH	.18	32x64x127
S103.0	3.0 mH	.20	32x64x127

S143.3	3.3 mH	.45	25x51x102	S123.3	3.3 mH	.32	32x64x127	S103.3	3.3 mH	.21	38x76x152
S143.6	3.6 mH	.47	25x51x102	S123.6	3.6 mH	.34	32x64x127	S103.6	3.6 mH	.23	38x76x152
S143.9	3.9 mH	.49	25x51x102	S123.9	3.9 mH	.35	32x64x127	S103.9	3.9 mH	.24	38x76x152
S144.3	4.3 mH	.52	25x51x102	S124.3	4.3 mH	.37	32x64x127	S104.3	4.3 mH	.26	38x76x152
S144.7	4.7 mH	.56	25x51x102	S124.7	4.7 mH	.40	32x64x127	S104.7	4.7 mH	.27	38x76x152
S145.1	5.1 mH	.59	25x51x102	S125.1	5.1 mH	.42	32x64x127	S105.1	5.1 mH	.29	38x76x152
S145.6	5.6 mH	.63	25x51x102	S125.6	5.6 mH	.45	32x64x127	S105.6	5.6 mH	.30	38x76x152
S146.2	6.2 mH	.67	25x51x102	S126.2	6.2 mH	.47	32x64x127	S106.2	6.2 mH	.32	38x76x152
S146.8	6.8 mH	.71	32x64x127	S126.8	6.8 mH	.49	38x76x152	S106.8	6.8 mH	.34	45x89x178
S147.5	7.5 mH	.75	32x64x127	S127.5	7.5 mH	.52	38x76x152	S107.5	7.5 mH	.36	45x89x178
S148.2	8.2 mH	.79	32x64x127	S128.2	8.2 mH	.54	38x76x152	S108.2	8.2 mH	.38	45x89x178
S149.1	9.1 mH	.83	32x64x127	S129.1	9.1 mH	.57	38x76x152	S109.1	9.1 mH	.40	45x89x178
S1410	10 mH	.87	32x64x127	S1210	10 mH	.60	38x76x152	S1010	10 mH	.41	45x89x178
S1411	11 mH	.96	32x64x127	S1211	11 mH	.65	38x76x152	S1011	11 mH	.44	45x89x178
S1412	12 mH	1.03	32x64x127	S1212	12 mH	.70	38x76x152	S1012	12 mH	.47	45x89x178
S1413	13 mH	1.11	32x64x127	S1213	13 mH	.75	38x76x152	S1013	13 mH	.50	45x89x178
S1415	15 mH	1.17	32x64x127	S1215	15 mH	.79	38x76x152	S1015	15 mH	.53	45x89x178
S1416	16 mH	1.24	38x76x152	S1216	16 mH	.83	45x89x178	S1016	16 mH	.56	51x102x204
S1418	18 mH	1.29	38x76x152	S1218	18 mH	.88	45x89x178	S1018	18 mH	.59	51x102x204
S1420	20 mH	1.35	38x76x152	S1220	20 mH	.92	45x89x178	S1020	20 mH	.61	51x102x204
S1422	22 mH	1.44	38x76x152	S1222	22 mH	.99	45x89x178	S1022	22 mH	.66	51x102x204
S1424	24 mH	1.53	38x76x152	S1224	24 mH	1.06	45x89x178	S1024	24 mH	.71	51x102x204
S1427	27 mH	1.62	38x76x152	S1227	27 mH	1.13	45x89x178	S1027	27 mH	.76	51x102x204
S1430	30 mH	1.71	38x76x152	S1230	30 mH	1.20	45x89x178	S1030	30 mH	.81	51x102x204

Maximum d. c. resistance for series inductors for 8 ohms load: 0.6 Ohms total.
Maximum d. c. resistance for parallel inductors for 8 ohms load: 1.2 Ohms.