Litz Wire

For optimum performance, the Litz constructions covered in this section are made with individually insulated strands. Common magnet wire film insulations such as: polyvinylformal, polyurethane, polyurethane/nylon; solderable polyester, solderable polyester/nylon, polyester/polyamide-imide, and polyimide are normally used. The outer insulation and the insulation on the component conductors, in some styles, may be servings or braids of nylon, cotton, Nomex[1], fiberglass or ceramic. Polyester, heat sealed polyester, polyimide and PTFE tape wraps along with extrusions of most thermoplastics are also available as outer insulation if the applications dictate special requirements for voltage breakdown or environmental protection.

Litz Design

Typically, the design engineer requiring the use of Litz knows the operating frequency and RMS current required for the application. Since the primary benefit of a Litz conductor is the reduction of A.C. losses, the first consideration in any Litz design is the operating frequency. The operating frequency not only influences the actual Litz construction, but is also used to determine the individual wire gauge.

Ratios of alternating-current resistance to direct-current resistance for an isolated solid round wire (H) in terms of a value (X) are shown in Table 1.

Table 1

X	0	0.5	0.6	0.7	0.8	0.9	1.0
H	1.0000	1.0003	1.0007	1.0012	1.0021	1.0034	1.005

The value of X for copper wire is determined by Formula 1.

FORMULA 1

$$X = 0.271\, D_M \sqrt{F_{MHZ}}$$

Where: D_M = Wire diameter in mils

F_{MHZ} = Frequency in Megahertz

From Table 1 and other empirical data the following table of recommended wire gauges vs. frequency for most Litz constructions has been prepared.

Table 2

FREQUENCY	RECM'D WIRE GAUGE	NOM. DIA. OVER COPPER	DC RES. OHMS/M' (MAX)	SINGLE STRAND R_{AC}/R_{DC} "H"
60 HZ to 1 KHZ	28 AWG	.0126	66.37	1.0000
1 KHZ to 10 KHZ	30 AWG	.0100	105.82	1.0000
10 KHZ to 20 KHZ	33 AWG	.0071	211.70	1.0000
20 KHZ to 50 KHZ	36 AWG	.0050	431.90	1.0000
50 KHZ to 100 KHZ	38 AWG	.0040	681.90	1.0000
100 KHZ to 200 KHZ	40 AWG	.0031	1152.3	1.0000
200 KHZ to 350 KHZ	42 AWG	.0025	1801.0	1.0000
350KHZ to 850 KHZ	44 AWG	.0020	2873.0	1.0003
850 KHZ to 1.4 MHZ	46 AWG	.0016	4544.0	1.0003
1.4MHZ to 2.8 MHZ	48 AWG	.0012	7285.0	1.0003

After the individual wire gauge has been determined and assuming that the Litz construction has been designed such that each strand tends to occupy all possible positions in the cable to approximately the same extent, the ratio of A.C. to D.C. resistance of an isolated Litz conductor can be determined from the following formula.

FORMULA 2[2]

$$\frac{\text{Resistance to Alternating Current}}{\text{Resistance to Direct Current}} = H + K\left(\frac{N D_I}{D_O}\right)^2 G$$

[1] DuPont Registered Trademark

[2] See Radio Engineers Handbook - Terman, pp. 30-83.

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Where: H = Resistance ratio of individual strands when isolated (taken from Table 1 or 2)

G = Eddy-current basis factor $= \left(\dfrac{D_I \sqrt{F}}{10.44} \right)^4$

F = Operating frequency in HZ

N = Number of strands in the cable

D_I = Diameter of the individual strands over the copper in inches

D_O = Diameter of the finished cable over the strands in inches

K = Constant depending on N, given in the following table

N	3	9	27	Infinity
K	1.55	1.84	1.92	2

The D.C. resistance of a Litz conductor is related to the following parameters:

1. AWG of the individual strands.

2. Number of strands in the cable.

3. Factors relating to the increased length of the individual strands per unit length of cable (take-up). For normal Litz constructions a 1.5% increase in D.C. resistance for every bunching operation and a 2.5% increase in D.C. resistance for every cabling operation are approximately correct.

The formula derived from these parameters for the D.C. resistance of any Litz construction is:

FORMULA 3

$$R_{DC} = \frac{R_S (1.02)^{N_B} (1.03)^{N_C}}{N_S}$$

Where: R_{DC} = Resistance in Ohms/1000 ft.

R_S = Maximum D.C. resistance of the individual strands (taken from Table 2)

N_B = Number of bunching operations

N_C = Number of cabling operations

N_S = Number of individual strands

Following is an example of the calculations required to evaluate a Type 2 Litz construction consisting of 450 strands of 40 AWG single-film polyurethane-coated wire operating at 100 KHZ. This construction, designed with two bunching operations and one cabling operation, would be written 5x3/30/40 (NEW uses "x" to indicate a cabling operation and "/" to indicate a bunching operation.)

1. Calculate the D.C. resistance of the Litz construction using formula 3.

$$R_{DC} = \frac{1152.3 \times (1.015)^2 \times (1.025)^1}{450} = 2.70 \text{ ohms}/1000'$$

2. Calculate the A.C. to D.C. resistance ratio using formula 2.

$$\frac{R_{AC}}{R_{DC}} = 1.0000 + 2 \left(\frac{450 \times 0.0031}{0.094} \right)^2 (7.8 \times 10^{-6}) = 1.0344$$

3. The A.C. resistance is, therefore, 1.0344 x 2.70 or 2.79 ohms/1000 ft.

The value of Litz can easily be seen if the above example is compared with a solid round wire with equivalent cross sectional area, 65.8 mils in diameter. Using the same operating parameters, the D.C. resistance is 2.395 ohms/1000 ft. However, the A.C./D.C. resistance ratio increases to approximately 21.4 making the A.C. resistance 51.3 ohms/1000 ft.

The following tables list examples of Litz constructions which can be manufactured by New England Wire Technologies. These are categorized by operating frequency and by equivalent AWG size. Round, braided and rectangular Litz conductors are shown separately to provide the greatest possible selection for any design application.