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Litz Designing Calculations

Litz Design

Typically, the designing engineer that uses Litz knows the operating frequency and RMS current required for his application. Since the main advantage of a Litz conductor is the reduction of AC losses, the first thought in any Litz design is the operating frequency. The operating frequency not only influences the authentic Litz construction, it also determines the individual wire gauge.

Ratios of alternating-current resistance to direct-current resistance for an isolated solid round wire (S) 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
S	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.

$$X=0.271\ D_{M}\sqrt{F_{MHZ}}$$

Where: D_M = Wire Diameter in mils

F_{MHZ} = Frequency in Megahertz

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

Table 2				
Frequency	**Recommended Wire Gauge**	**Nominal Diameter over Copper**	**D.C. Resistance Ohms/M' (Max)**	**Single Strand R_{AC} / R_{DC} "S"**
60 HZ - 1 KHZ	28 AWG	0.0126	66.37	1.0000
1 KHZ – 10 KHZ	30 AWG	0.0100	105.82	1.0000
10 KHZ – 20 KHZ	33 AWG	0.0071	211.70	1.0000
20 KHZ – 50 KHZ	36 AWG	0.0050	431.90	1.0000
50 KHZ – 100 KHZ	38 AWG	0.0040	681.90	1.0000
100 KHZ – 200 KHZ	40 AWG	0.0031	1152.3	1.0000
200 KHZ – 350 KHZ	42 AWG	0.0025	1801.0	1.0000
350 KHZ – 850 KHZ	44 AWG	0.0020	2873.0	1.0003
850 KHZ – 1.4 MHZ	46 AWG	0.0016	4544.0	1.0003
1.4 MHZ – 2.8 MHZ	48 AWG	0.0012	7285.0	1.0003

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

$$\frac{\text{Resistance to Alternating Current}}{\text{Resistance to Direct Current}} = S + K\left(\frac{N\,D_1}{D_O}\right)^2 G$$

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

G =Eddy Current basis factor = $\left(\frac{D_I\sqrt{F}}{10.44}\right)^4$

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. Individual strands AWG.
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 standard 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 roughly correct.

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

$$R_{DC} = \frac{R_S\,(1.015)^{N_B}\,(1.025)^{N_C}}{N_S}$$

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 400 strands of 38 AWG single-film polyurethane-coated wire operating at 500 KHZ. This construction, designed with two bunching operations and one cabling operation, would be written 5 x 5 / 16 / 40 AWG (HM Wire 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.

$$R_{DC} = \frac{681.90\,(1.015)^2\,(1.025)^1}{400} = 1.80 \text{ ohms / 1000 ft.}$$

2. Calculate the A.C. to D.C. Resistance Ratio using Formula 2.

$$\frac{R_{AC}}{R_{DC}} = 1.000 + 2\left(\frac{400 \times 0.0045}{0.1040}\right)^2 \times \left(\frac{0.0045\sqrt{50000}}{10.44}\right)^4 = 1.2068$$

3. The A.C. resistance is, therefore, 1.2068 x 1.80 ohms/1000ft.