Formulas for Tesla Coils
v. 3.0

Ohm's Laws

\[
\begin{align*}
V &= I \times R &= P / I &= \sqrt{P \times R} \\
I &= V / R &= \sqrt{P / R} &= P / V \\
R &= V / I &= P / (I^2) &= V^2 / P \\
P &= I \times V &= I^2 \times R &= V^2 / R
\end{align*}
\]

Where:
V = Voltage in Volts
I = Current in Amps
R = Resistance in Ohms
P = Power in Watts

Resonate Frequency

\[
Fo = \frac{1}{2 \times \pi \times \sqrt{L \times C}}
\]

Where:
Fo = Resonant frequency in Hertz
\pi = 3.14159...
\sqrt{} = Square root function
L = Inductance in Henries
C = Capacitance in Farads

Reactance

\[
\begin{align*}
X_l &= 2 \times \pi \times F \times L \\
X_c &= \frac{1}{2 \times \pi \times F \times C}
\end{align*}
\]

Where:
Xl = Inductive reactance in Ohms
Xc = Capacitive reactance in Ohms
\pi = 3.14159...
F = Frequency in Hertz
L = Inductance in Henries
C = Capacitance in Farads

**RMS**

\[ V_{peak} = V_{rms} \times \text{SQRT}(2) \] For sine waves only

Where:
Vpeak = Peak voltage in volts
Vrms = RMS voltage in Volts RMS
SQRT = Square root function

**Energy**

\[ E = \frac{1}{2} \times C \times V^2 = \frac{1}{2} \times L \times I^2 \]

Where:
E = Energy in Joules
L = Inductance in Henries
C = Capacitance in Farads
V = Voltage in Volts
I = Current in Amps

**Power**

\[ P = \frac{E}{t} \]

Where:
P = Power in Watts
E = Energy in Joules
t = Time in Seconds
**Helical Coil**

\[
L_h = \frac{(N \times R)^2}{(9 \times R + 10 \times H)}
\]

Where:
- \(L_h\) = Inductance in micro-Heneries
- \(N\) = number of turns
- \(R\) = Radius in inches
- \(H\) = Height in inches

**Flat spiral**

\[
L_f = \frac{(N \times R)^2}{(8 \times R + 11 \times W)}
\]

Where:
- \(L_f\) = Inductance in micro-Heneries
- \(N\) = number of turns
- \(R\) = Average radius in inches
- \(W\) = Width in inches

**Conical Primary**

\[
\begin{align*}
L_1 &= \frac{(N \times R)^2}{(9 \times R + 10 \times H)} \\
L_2 &= \frac{(N \times R)^2}{(8 \times R + 11 \times W)} \\
L_c &= \sqrt{\frac{(L_1 \times \sin(x))^2 + (L_2 \times \cos(x))^2}{\sin(x) + \cos(x)}}
\end{align*}
\]

Where:
- \(L_c\) = Inductance in Microhenries
- \(L_1\) = helix factor
- \(L_2\) = spiral factor
- \(\sqrt{}\) = Square root function
- \(N\) = number of turns
- \(R\) = average radius of coil in inches
- \(H\) = effective height of the coil in inches
- \(W\) = effective width of the coil in inches
- \(X\) = rise angle of the coil in degrees
Resonant Primary Capacitance

\[ C_{lr} = \frac{I}{2 \times \pi \times F_l \times V} \]

Where:
- \( C_{lr} \) = Resonant capacitor value in Farads
- \( I \) = NST rate current in Amps
- \( \pi \) = 3.14159...
- \( F_l \) = AC line frequency in Hertz
- \( V \) = NST rated voltage in Volts

Static Gap Primary LTR Capacitance

\[ C_{rs} = \frac{I}{4 \times F_l \times V} \]

Where:
- \( C_{rs} \) = Resonant capacitor value in Farads
- \( I \) = NST rate current in Amps
- \( F_l \) = AC line frequency in Hertz
- \( V \) = NST rated voltage in Volts

Sync Gap Primary LTR Capacitance

\[ C_{lr} = 0.83 \times \frac{I}{BPS \times V} \]

Where:
- \( C_{lr} \) = The LTR cap size in Farads
- \( I \) = The NST rated current in Amps
- \( V \) = The NST rated voltage in Volts
- \( BPS \) = The break rate (120 or 100 BPS)

Top Voltage

\[ V_t = V_f \times \sqrt{\frac{L_s}{2 \times L_p}} \]

Where:
- \( V_t \) = Peak top voltage in Volts
Vf = gap firing voltage in Volts
SQRT = Square root function
Ls = Secondary inductance in Henries
Lp = Primary inductance in Henries

**PFC Capacitors**

\[ Cpfc = \frac{Vo \times Io}{2 \times \pi \times Fl \times Vi^2} \]

Where:
Cpfc = Power factor correction capacitance in Farads
Vo = NST output voltage in Volts
Io = NST output current in Amps
\( \pi = 3.14159... \)
Fl = AC line frequency in Hertz
Vi = NST input voltage in Volts

**Power-BPS**

\[ P = BPS \times \frac{1}{2} \times Cp \times Vf^2 \]

Where:
P = Coil power in Watts
BPS = Breaks per second
Cp = Primary capacitance in Farads
Vf = Gap firing Voltage

**Transformers**

\[ Vi \times li = Vo \times Io \]

Where:
Vi = Input voltage in Volts
li = Input current in Amps
Vo = Output voltage in Volts
Io = Output current in Amps
**Primary Peak Current**

\[ IP_{peak} = \frac{V_f}{\sqrt{L_p / C_p}} \]

Where:
- \( IP_{peak} \) = Peak primary loop current Amps
- \( V_f \) = Firing Voltage in Volts
- \( L_p \) = Primary inductance in Henries
- \( C_p \) = Primary capacitance in Farads

**Surge Impedance**

\[ Z_s = \sqrt{\frac{L_p}{C_p}} \]

Where:
- \( Z_s \) = Surge impedance in Ohms
- \( L_p \) = Primary inductance in Henries
- \( C_p \) = Primary capacitance in Farads

**Secondary "Q" Factor**

\[ Q = 2 \times \pi \times F_o \times L_s / R_{ac} \]

Where:
- \( Q \) = "Q" factor
- \( F_o \) = Fundamental frequency in Hertz
- \( L_s \) = Secondary inductance in Henries
- \( R_{ac} \) = Secondary "AC" resistance in Ohms

**Freau Spark Length Formula**

\[ L = 1.7 \times \sqrt{P} \]

\( L \) = Maximum spark length in Inches
\( \sqrt{ } \) = Square root function
\( P \) = Wallplug Watts
## Appendix

### Wire Chart

<table>
<thead>
<tr>
<th>Gauge No. B. &amp; S.</th>
<th>Diam in Mils</th>
<th>Circular Mil Area</th>
<th>Turns Per Linear Inch</th>
<th>Feet per Lb.</th>
<th>Ohms per 1000ft. 250 C.</th>
<th>Current Carrying Capacity @ 1500 C.M. per Amp</th>
<th>Diameter in mm</th>
</tr>
</thead>
</table>
## Capacitor Chart

### MMC Capacitor Chart

<table>
<thead>
<tr>
<th>NST Type</th>
<th>Capacitor Value (μF)</th>
<th>60Hz</th>
<th>50Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Resonant</td>
<td>Static Gap LTR</td>
</tr>
<tr>
<td>7.5/30</td>
<td>0.0106</td>
<td>0.0159</td>
<td>0.0277</td>
</tr>
<tr>
<td>7.5/60</td>
<td>0.0212</td>
<td>0.0318</td>
<td>0.0533</td>
</tr>
<tr>
<td>7.5/90</td>
<td>0.0318</td>
<td>0.0477</td>
<td>0.0830</td>
</tr>
<tr>
<td>7.5/120</td>
<td>0.0424</td>
<td>0.0637</td>
<td>0.1107</td>
</tr>
<tr>
<td>9/30</td>
<td>0.0088</td>
<td>0.0133</td>
<td>0.0231</td>
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<tr>
<td>9/60</td>
<td>0.0177</td>
<td>0.0265</td>
<td>0.0461</td>
</tr>
<tr>
<td>9/90</td>
<td>0.0265</td>
<td>0.0398</td>
<td>0.0692</td>
</tr>
<tr>
<td>9/120</td>
<td>0.0354</td>
<td>0.0531</td>
<td>0.0922</td>
</tr>
<tr>
<td>10/23</td>
<td>0.0061</td>
<td>0.0092</td>
<td>0.0159</td>
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<td>12/30</td>
<td>0.0066</td>
<td>0.0099</td>
<td>0.0173</td>
</tr>
<tr>
<td>12/60</td>
<td>0.0133</td>
<td>0.0199</td>
<td>0.0346</td>
</tr>
<tr>
<td>12/90</td>
<td>0.0195</td>
<td>0.0298</td>
<td>0.0519</td>
</tr>
<tr>
<td>12/120</td>
<td>0.0265</td>
<td>0.0398</td>
<td>0.0692</td>
</tr>
<tr>
<td>15/30</td>
<td>0.0053</td>
<td>0.0080</td>
<td>0.0138</td>
</tr>
<tr>
<td>15/60</td>
<td>0.0106</td>
<td>0.0159</td>
<td>0.0277</td>
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<td>15/90</td>
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<tr>
<td>15/120</td>
<td>0.0212</td>
<td>0.0318</td>
<td>0.0553</td>
</tr>
</tbody>
</table>

## Metric Prefixes

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Decimal</th>
<th>Exponential</th>
</tr>
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<tbody>
<tr>
<td>pico</td>
<td>p</td>
<td>0.000000000000001</td>
<td>1e-12</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>0.000000001</td>
<td>1e-9</td>
</tr>
<tr>
<td>micro</td>
<td>μ</td>
<td>0.00001</td>
<td>1e-6</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>0.001</td>
<td>1e-3</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>1000.0</td>
<td>1e+3</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>1,000,000</td>
<td>1e+6</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>1,000,000,000</td>
<td>1e+9</td>
</tr>
</tbody>
</table>
### Cornell Dubilier 942 Series polypropylene Metal Foil Caps (Recommended)

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Cap. µF</th>
<th>D inches (mm)</th>
<th>L inches (mm)</th>
<th>d inches (mm)</th>
<th>Typical ESR milliOhms</th>
<th>Typical ESL nH</th>
<th>dV/dt V/µs</th>
<th>I Peak A</th>
<th>IRMS A</th>
</tr>
</thead>
<tbody>
<tr>
<td>942C20S1K</td>
<td>0.01</td>
<td>0.472 (12.0)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>50</td>
<td>20</td>
<td>5137</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>942C20S15K</td>
<td>0.015</td>
<td>0.571 (14.5)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>40</td>
<td>21</td>
<td>5137</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>942C20S22K</td>
<td>0.022</td>
<td>0.650 (16.5)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>20</td>
<td>22</td>
<td>5137</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>942C20S33K</td>
<td>0.033</td>
<td>0.768 (19.5)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>12</td>
<td>23</td>
<td>5137</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>942C20S47K</td>
<td>0.047</td>
<td>0.709 (18.0)</td>
<td>1.811 (46.0)</td>
<td>0.040 (1.0)</td>
<td>10</td>
<td>28</td>
<td>2879</td>
<td>7.1</td>
<td></td>
</tr>
<tr>
<td>942C20S68K</td>
<td>0.068</td>
<td>0.807 (20.5)</td>
<td>1.811 (46.0)</td>
<td>0.040 (1.0)</td>
<td>6</td>
<td>29</td>
<td>2879</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>942C20P1K</td>
<td>0.1</td>
<td>0.965 (24.5)</td>
<td>1.811 (46.0)</td>
<td>0.047 (1.2)</td>
<td>5</td>
<td>30</td>
<td>2879</td>
<td>12.1</td>
<td></td>
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<tr>
<td>942C20P15K</td>
<td>0.15</td>
<td>1.161 (29.5)</td>
<td>1.811 (46.0)</td>
<td>0.047 (1.2)</td>
<td>5</td>
<td>32</td>
<td>2879</td>
<td>13.5</td>
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</tr>
</tbody>
</table>

Metal Foil caps are normally the best type to use for MMCs.

### Cornell Dubilier 940 Series polypropylene Metal Film Caps

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Cap. µF</th>
<th>Vdc</th>
<th>Vac</th>
<th>D inches (mm)</th>
<th>L inches (mm)</th>
<th>d inches (mm)</th>
<th>Typical ESR milliOhms</th>
<th>Typical ESL nH</th>
<th>dV/dt V/µs</th>
<th>I Peak A</th>
<th>IRMS A</th>
</tr>
</thead>
<tbody>
<tr>
<td>940C20S22K</td>
<td>0.022</td>
<td>2000</td>
<td>630</td>
<td>0.453 (11.5)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>35</td>
<td>6</td>
<td>1712</td>
<td>38</td>
<td>2.6</td>
</tr>
<tr>
<td>940C20S33K</td>
<td>0.033</td>
<td>2000</td>
<td>630</td>
<td>0.531 (13.5)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>20</td>
<td>21</td>
<td>1712</td>
<td>57</td>
<td>3.8</td>
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<tr>
<td>940C20S47K</td>
<td>0.047</td>
<td>2000</td>
<td>630</td>
<td>0.591 (15.0)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>12</td>
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<td>5.2</td>
</tr>
<tr>
<td>940C20S68K</td>
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<td>2000</td>
<td>630</td>
<td>0.689 (17.5)</td>
<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>8</td>
<td>23</td>
<td>1712</td>
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<td>6.9</td>
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<tr>
<td>940C20P1K</td>
<td>0.1</td>
<td>2000</td>
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<td>1.339 (34.0)</td>
<td>0.040 (1.0)</td>
<td>7</td>
<td>24</td>
<td>1712</td>
<td>171</td>
<td>8.3</td>
</tr>
<tr>
<td>940C20P15K</td>
<td>0.15</td>
<td>2000</td>
<td>630</td>
<td>0.768 (19.5)</td>
<td>1.811 (46.0)</td>
<td>0.040 (1.0)</td>
<td>7</td>
<td>29</td>
<td>960</td>
<td>144</td>
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<td>2000</td>
<td>630</td>
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<td>960</td>
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<td>9.0</td>
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<tr>
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<td>2000</td>
<td>630</td>
<td>1.063 (27.0)</td>
<td>1.811 (46.0)</td>
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<td>960</td>
<td>317</td>
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</tr>
<tr>
<td>940C20P47K</td>
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<td>2000</td>
<td>630</td>
<td>1.260 (32.0)</td>
<td>1.811 (46.0)</td>
<td>0.047 (1.2)</td>
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<td>940C20P56K</td>
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<tr>
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<td>630</td>
<td>1.339 (34.0)</td>
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<td>0.047 (1.2)</td>
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<td>754</td>
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<td>42</td>
<td>754</td>
<td>754</td>
<td>17.7</td>
</tr>
</tbody>
</table>

Metal Film caps are normally not recommended for MMCs unless the primary peak current is well within the capacitor's ability.