Low-Pass RC Filter

Log $|V_{out}/V_{in}|$

Log $\omega$

$1/RC$

$\Phi = -\pi/2$

$V_{IN}$

$R$

$C$

$V_{OUT}$

$0$

Log $\omega$

$0$

Phase

$-\pi/2$

$1/RC$
For frequencies above $\omega = 1/RC$, the RC low-pass filters integrates the current on the capacitor.
For frequencies above $\omega = 1/RC$, the RC low-pass filters integrates the current on the capacitor.
High-Pass RC Filter

\[
\frac{V_{\text{out}}}{V_{\text{in}}} \propto \log(\omega) \quad \text{Phase} \approx \frac{\pi}{2} - \frac{1}{RC} \log(\omega)
\]

\[
\frac{V_{\text{out}}}{V_{\text{in}}} \propto \log(\omega) \quad \text{Phase} \approx \frac{\pi}{2} - \frac{1}{RC} \log(\omega)
\]
For frequencies below $\omega = 1/RC$, the RC high-pass filters differentiates the voltage on the resistor.
Capacitors perform better than inductors, and they’re cheaper to make.

Nevertheless, capacitors behave like inductors at high frequencies.

- Wire leads on capacitor have an inductance
- Maxwell’s equations (dE/dt \rightarrow B)
- \[ Z_{\text{inductor}} = j \omega L \]

Circuit diagram for a real capacitor:
Capacitors Spec Sheet

Type FCA  Acrylic Surface Mount Film Capacitors

Acrylic Stacked Metallized Film Capacitors for Filtering and Noise Attenuation

Type FCA acrylic film clips are non-inductive stacked metallized film capacitors which feature large capacitance values in standard surface mount case sizes.

Highlights
- Smallest film clips
- No piezoelectric effect
- Non-polarized, non-magnetic
- Low ESR
- 1.0 µF/10V in 1206 case

Filtering • Decoupling • Noise Attenuation • Distortion Free Audio

Type FCA acrylic film capacitors offer high capacitance values in standard surface mount case sizes. They excel in attenuating DC power bus noise, and as ripple filters in DC to DC power conversion circuits. As coupling capacitors in audio circuits, they yield distortion free sound and better high frequency filtering. The 1.0 µF 10 Vdc rating offers a film capacitor that is a direct replacement for tantalum “A” case capacitors. The nonpolar FCA capacitor has lower ESR and lower DCL than an equivalent tantalum capacitor, and in high frequency applications it takes a tantalum capacitor with ten times the capacitance to perform as well as the FCA capacitor.

The capacitor is constructed of noninductive stacked layers of metallized acrylic resin film with lead free solder (Sn/Ag/Cu) plated copper alloy terminals.

Specifications

- Capacitance Range: 0.10 µF to 1.0 µF
- Capacitance Tolerance: ±20% @ 1 kHz and +20 °C
- Rated Voltage: 16 Vdc [1.0 µF in 1206 case, 10 Vdc]
- AC Voltage Rating: 12 Virms
- Operating Temperature Range: -40 °C to +85 °C
- Dissipation Factor: 0.015 @ 1 kHz and +20 °C
- Dielectric Strength: 175% of rated voltage for 5 seconds
- Insulation Resistance (IR): After 1 minute @10 Vdc, +20 °C
  - IR >1000 MΩ (C ≥0.33 µF)
  - IR > 300 MΩ × µF (C ≥0.33 µF)
- Resistance to Soldering: The capacitor can withstand being heated in an oven at 235 °C for 200 seconds

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Capacitors Spec Sheet

**Specifications**

**Type FCA** Acrylic Surface Mount Film Capacitors

**Moisture Resistance:**
After 500 hours with rated voltage applied at +40 °C and 90 to 95% RH, the capacitor will meet the following limits:
- AC: -30% to -1% of the initial measured value
- IR: ≤2.5% (at 1 kHz)
- IR > 300mΩ to 15°C, 5% (C > 0.33 μF)

Dielectric Strength: Capacitor will withstand 150% of the rated voltage for 1 minute.

**Life Test:**
Apply 135% of the rated DC working voltage at 85 °C for 1000 hours, and then stabilize them to -20 °C. Capacitors will meet the following limits:
- C = ±15% of the initial measured value
- IR ≤1.65% (at 1 kHz)
- IR > 300mΩ (C ≤0.33 μF)
- IR > 1000mA (C > 0.33 μF)

**Ratings**

<table>
<thead>
<tr>
<th>Capacitance (μF)</th>
<th>Voltage Rating (Vdc)</th>
<th>Catalog Part Number</th>
<th>dV/dt (V/ps)</th>
<th>Maximum Current (Amps)</th>
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<tr>
<td></td>
<td>50kHz</td>
<td>15kHz</td>
<td>50kHz</td>
<td>15kHz</td>
</tr>
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**Outline Drawing**

![Outline Drawing](image)

**Outline Dimensions**

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<th>Suffix</th>
<th>Case Code</th>
<th>0.080in.</th>
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<th>0.080in.</th>
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<th>0.012in.</th>
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<td>0.033</td>
<td>0.048</td>
<td>0.028</td>
<td>0.041</td>
<td>0.028</td>
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<tr>
<td>H1</td>
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<td>0.126</td>
<td>0.063</td>
<td>0.032</td>
<td>0.063</td>
<td>0.023</td>
<td>0.062</td>
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Capacitors Spec Sheet

Type FCA  Acrylic Surface Mount Film Capacitors

Temperature Characteristics

Frequency Characteristics

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Capacitors Spec Sheet

Type FCA Acrylic Surface Mount Film Capacitors

Temperature Characteristics

Frequency Characteristics
RC Filter Combinations II

Pass-band filter

\[ \text{Log} \left( \frac{V_{\text{out}}}{V_{\text{in}}} \right) \]

\[ \frac{1}{R_2C_2} \]

\[ \frac{1}{R_1C_1} \]

Log(\( \omega \))

1

Log |\( \frac{V_{\text{out}}}{V_{\text{in}}} \)|
RC Filter Combinations I

- 20 dB/decade

- 40 dB/decade
LC Filters

- LC filters trade off smoothness and regularity (especially in the phase) for very sharp cut-offs.

- They don’t have to change the effective source impedance of a signal.

- They are used for high frequency applications.

- They are much harder to design.
Butterworth filters have very flat pass-bands. Use Maple or another program to design.
Chebyshev filters have very flat sharp cut-off knees, but are not very flat in pass-band.

Use Maple or another program to design

\[ C_1 = C_5 = 1.125 \, \mu F \]
\[ C_2 = C_4 = 1.486 \, \mu F \]
\[ C_3 = 1.505 \, \mu F \]
\[ L_1 = L_4 = 0.617 \, mH \]
\[ L_2 = L_3 = 0.646 \, mH \]
Transmission Lines

They’re the wires you use to connect different components (resistors on a breadboard … function generator to oscilloscope).

3 Types:  ➢ Wires:

➢ Simple and Cheap.
➢ Almost no interference suppression.
➢ Radiate and receive like an antenna.
➢ To be avoided.

➢ Twisted Pairs:
➢ Decent interference suppression.
➢ Do not radiate much.
➢ Max analog ~ 250 kHz to 1 MHz.
➢ Max digital ~ 100 MHz.
➢ Easy to make.

➢ Coaxial Cables
➢ Excellent performance up to 1 GHz.
➢ No external interference.
➢ Do not radiate.
➢ Typical impedance 50 Ω.

[image from www.gore.com]