Midterm Next Week

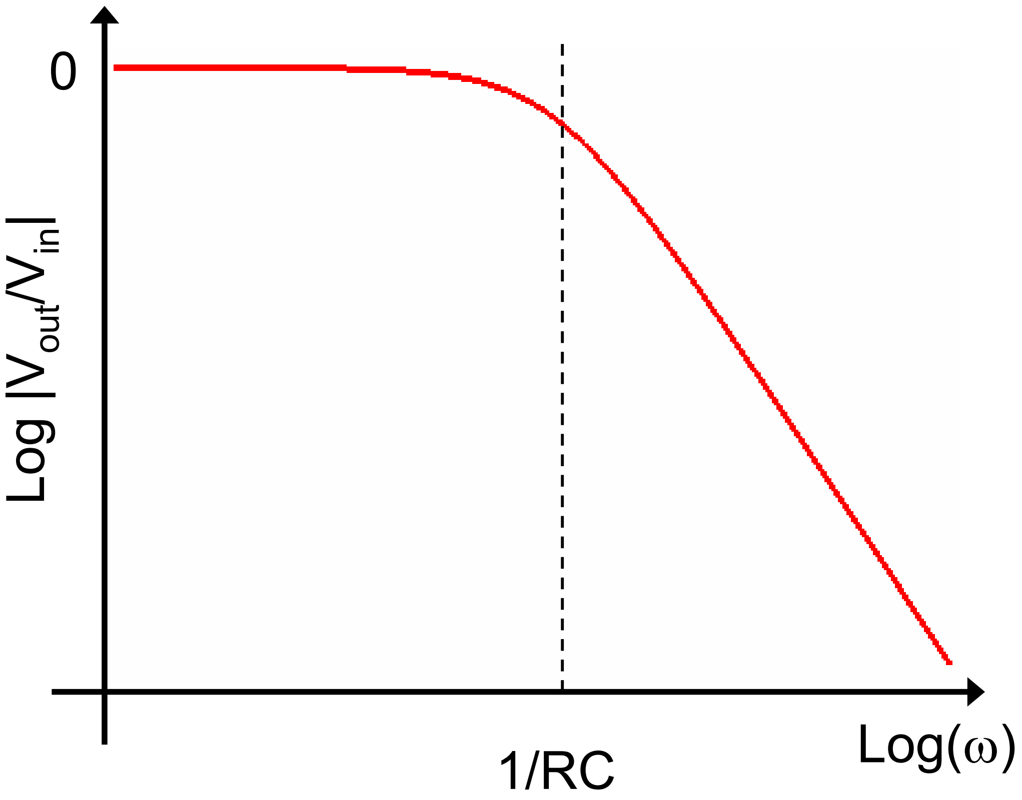
- Midterm next week in lab.
- Duration: 1 hour (2-3pm)
- Material on midterm:
  - Everything from first 4 weeks of class.
  - Thévenin's Theorem & Source Impedance.
  - Impedance of resistors, capacitors, and inductors.
  - Filters.
  - Basic oscilloscope use, resistor code, etc...

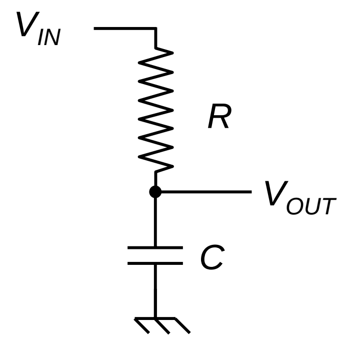
- The purpose of the midterm is to consolidate passive analog linear circuitry before we move onto non-linear devices.

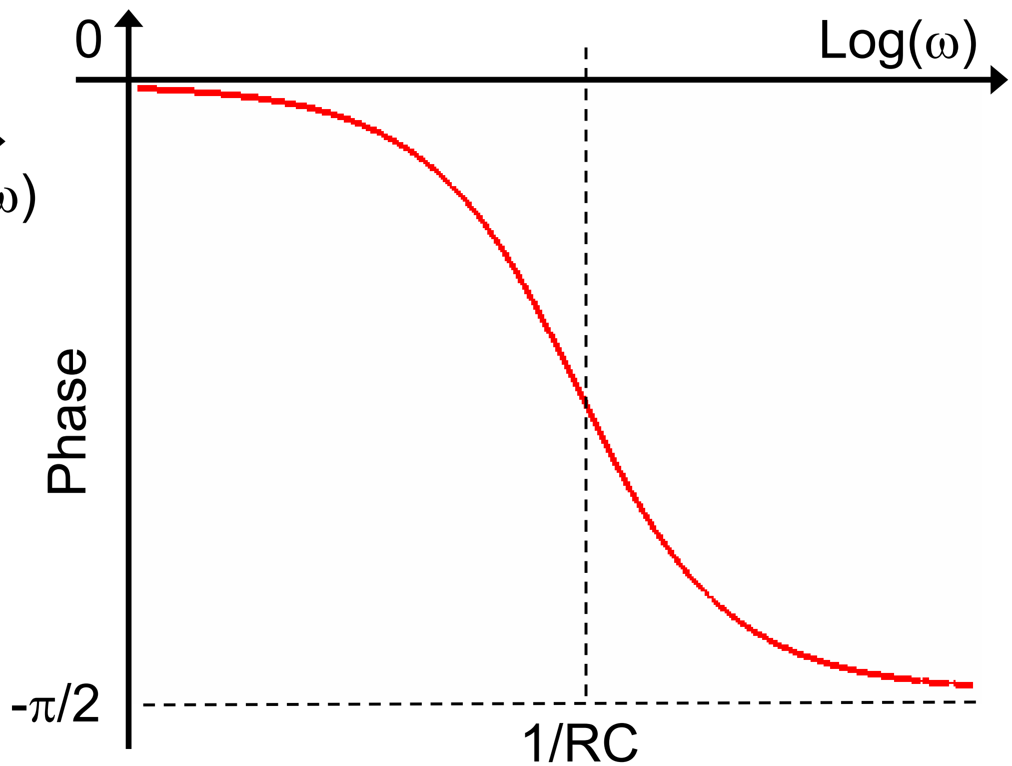
Comments on Lab Technique

- Lab books are improving.
- Please keep only one lab book (not the scribble book and the pristine, do-at-home “lab book”).
- Now that we have covered the basic concepts analog circuitry, we will be doing a lot more design.
- Techniques for improving lab speed and quality:
  - **Air out your lab book:** Leave plenty of blank space that you add to later … if you decide to add additional comments or analysis.
  - **Division of labor:** one person can be the circuit maker, while the other takes notes, does a quick analysis of data, eventually troubleshoots the circuit.
  - **Invest in a good set-up:** With a good set-up, data taking becomes quick and reliable.
  - Do **design exercises** before lab
  - **Plan experiments** before lab.

Low-Pass RC Filter

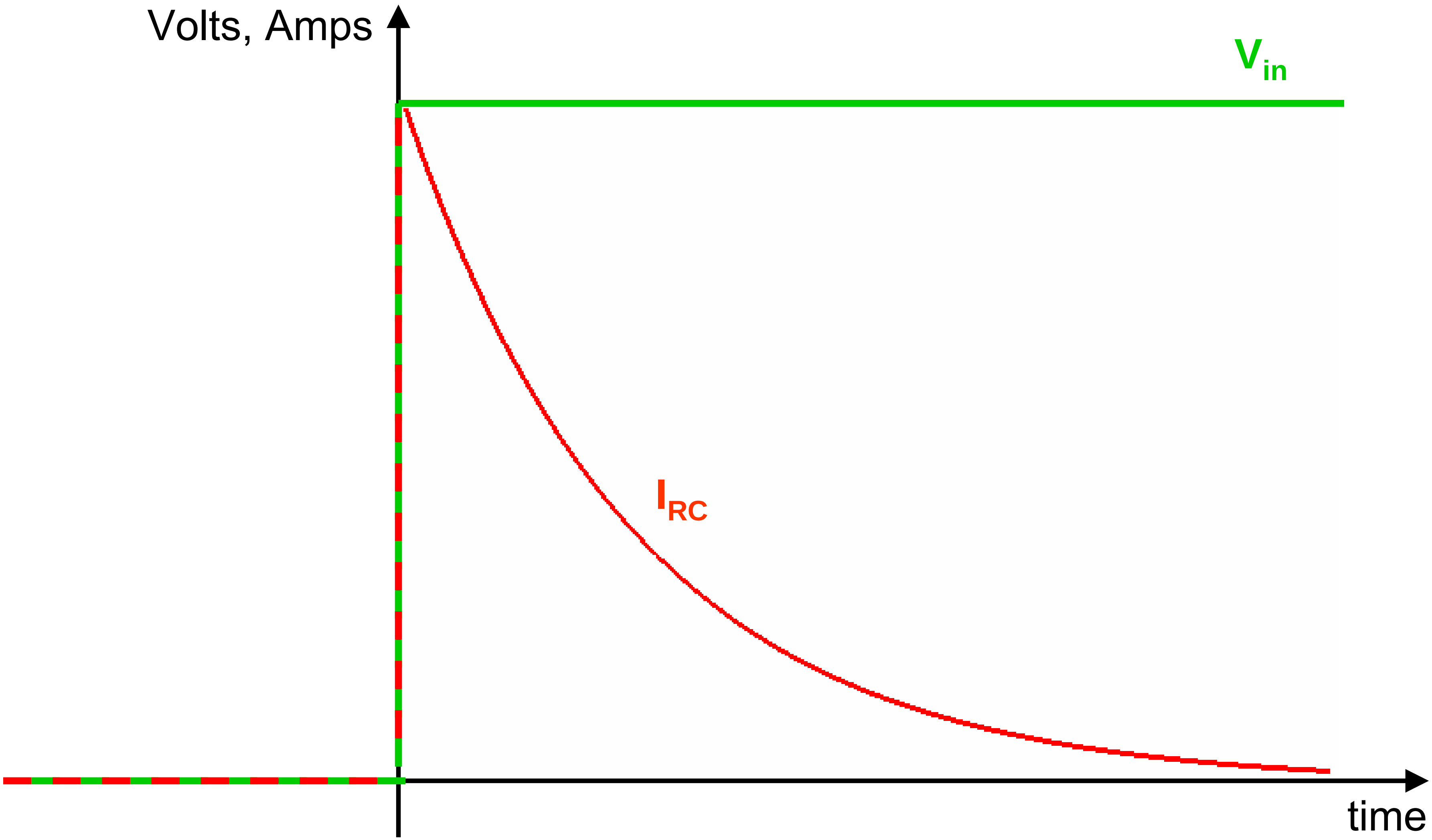






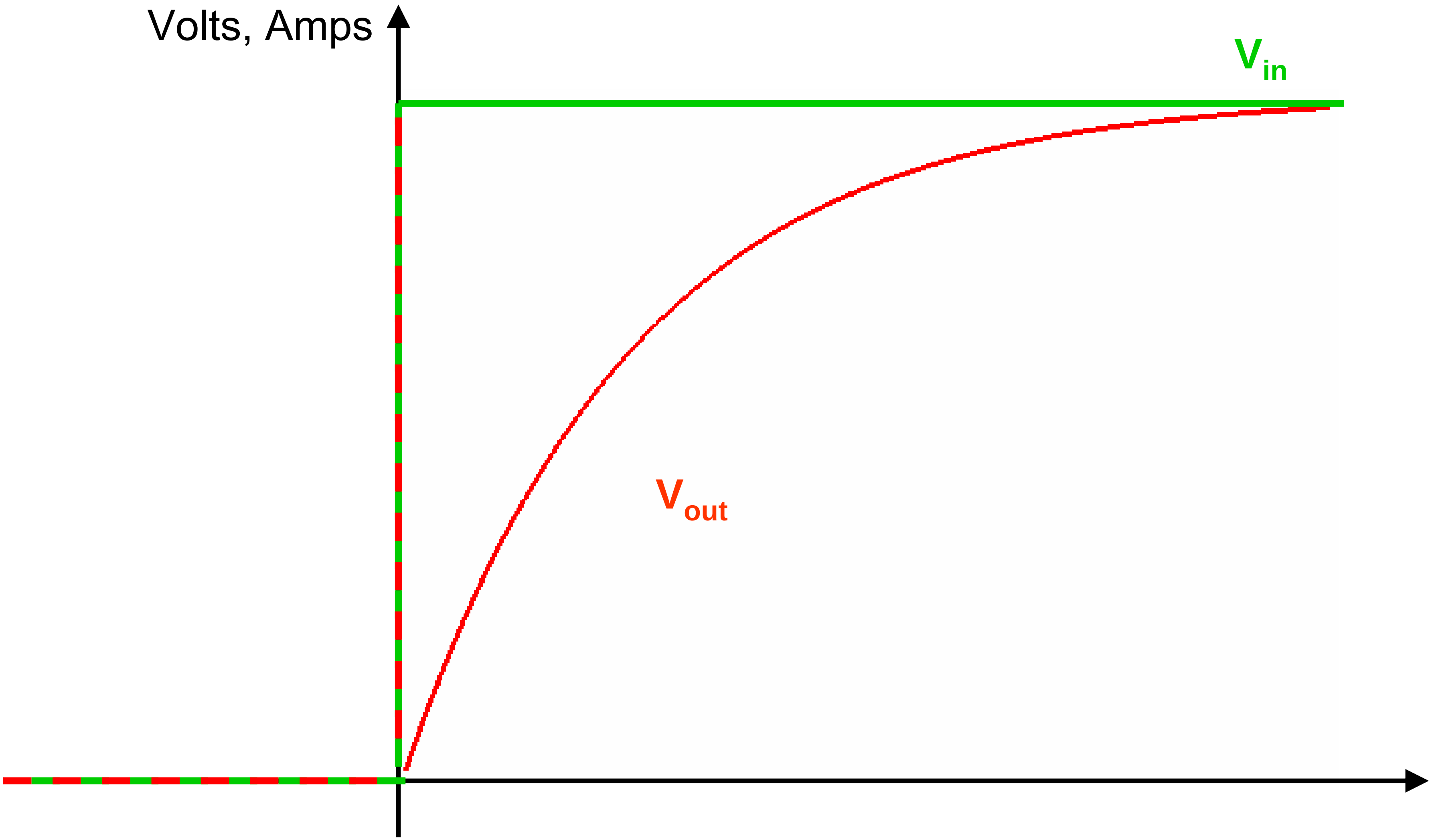
RC integrator

For frequencies above ω=1/RC, the RC low-pass filter integrates the current on the capacitor.

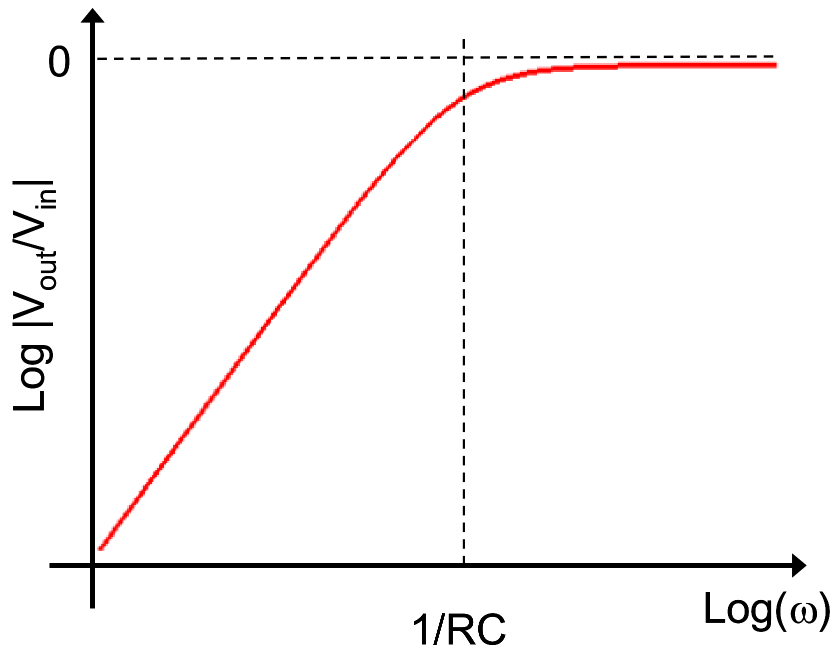


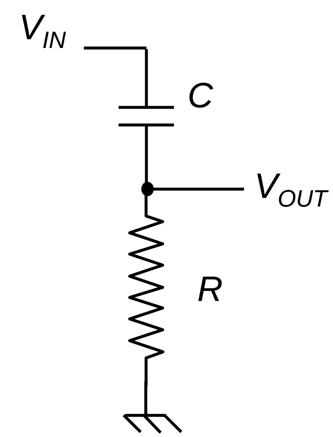
RC integrator

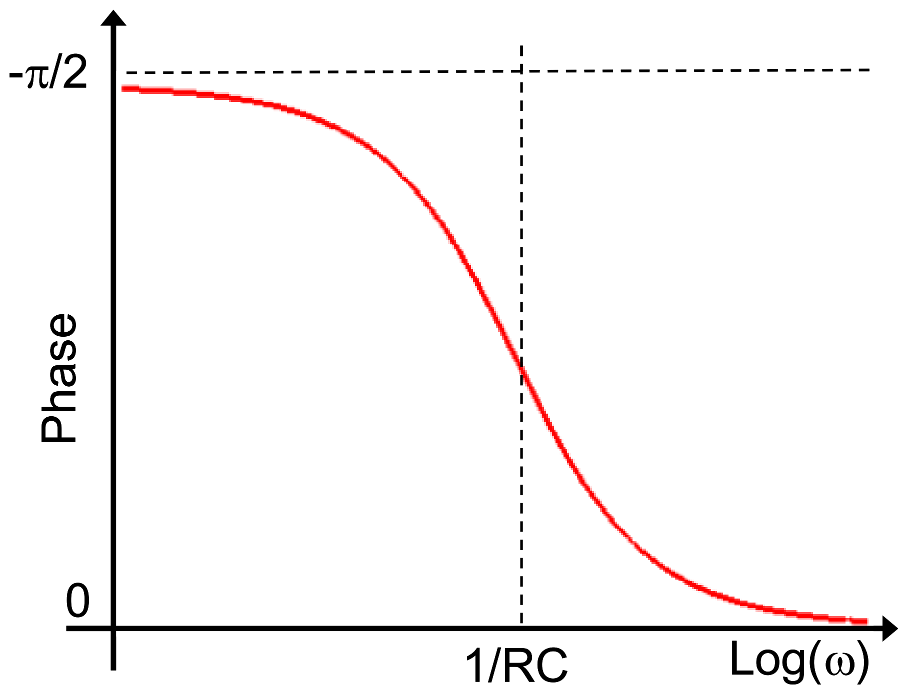
For frequencies above ω=1/RC, the RC low-pass filter integrates the current on the capacitor.



High-Pass RC Filter

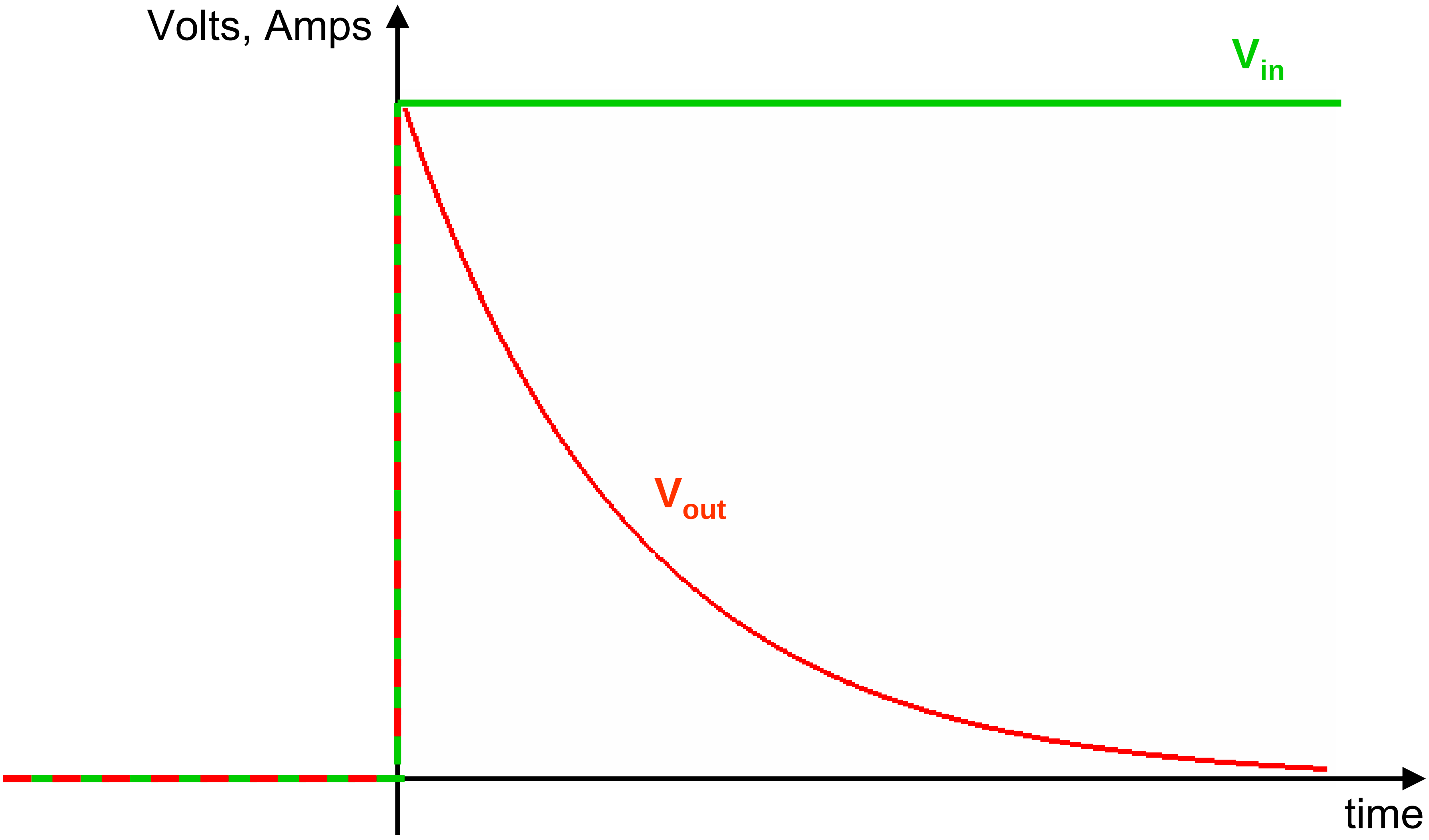






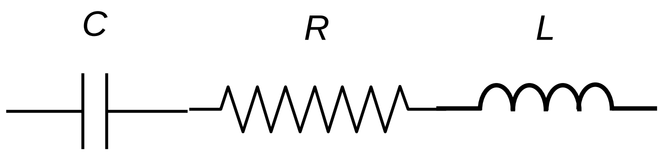
RC Differentiator

For frequencies below $\omega = 1/RC$, an RC high-pass filter differentiates the voltage on the resistor.



Capacitors …

- 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 → B)
  - → $Z_{inductor}=i\omega L$
- Circuit diagram for a real capacitor:

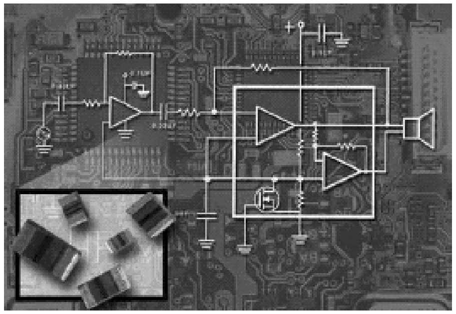


Capacitors Spec Sheet

Type FCA Acrylic Surface Mount Film Capacitors

Acrylic Stacked Metallized Film Capacitors for Filtering and Noise Attenuation

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



Highlights

- Smallest film chips
- 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 Vrms
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

Capacitors Spec Sheet

Type FCA Acrylic Surface Mount Film Capacitors

Specifications

Moisture Resistance:
After 500 hours with rated voltage applied at +40 °C and 90 to 95% RH, the capacitor will meet the following limits:
- ΔC = +20/–3% of the initial measured value
- DF ≤2.25% (at 1 kHz)
- IR > 100MΩ (C ≤0.33 µF)
- IR > 30MΩ•µF(C > 0.33 µF)

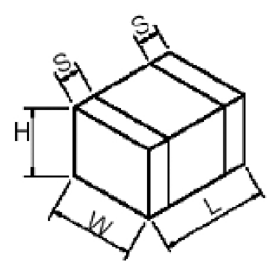
Dielectric Strength: Capacitor will withstand 130% of the rated voltage for 1 minute.

Life Test:
Apply 125% 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 = +7%/–20% of the initial measured value
- DF ≤1.65% (at 1 kHz)
- IR > 300MΩ (C ≤0.33 µF)
- IR > 100MΩ•µF(C > 0.33 µF)

Ratings

Capacitance (µF)	Voltage Rating (Vdc)	Catalog Part Number	dV/dt (V/µs)	Maximum Current (Arms)						
				10kHz	20kHz	50kHz	100kHz	200kHz	500kHz	1MHz
1.00	10	FCA1206A105M-H3	3	0.60	0.76	1.05	1.220	1.35	1.43	1.43
0.10	16	FCA0805C104M-J2	19	0.15	0.21	0.30	0.375	0.46	0.58	0.65
0.15	16	FCA1206C154M-H1	15	0.21	0.28	0.37	0.450	0.54	0.62	0.68
0.22	16	FCA1206C224M-H1	13	0.25	0.33	0.45	0.550	0.66	0.76	0.84
0.33	16	FCA1206C334M-H2	10	0.35	0.45	0.61	0.740	0.84	0.94	1.00
0.47	16	FCA1206C474M-H3	7	0.39	0.52	0.71	0.860	1.00	1.10	1.17
0.68	16	FCA1206C684M-H3	5	0.48	0.625	0.85	1.040	1.19	1.31	1.34
1.00	16	FCA1210C105M-G2	3	0.60	0.78	1.05	1.250	1.38	1.46	1.46

Outline Drawing



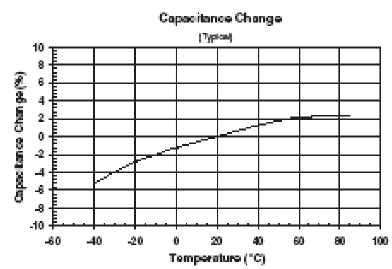
Outline Dimensions

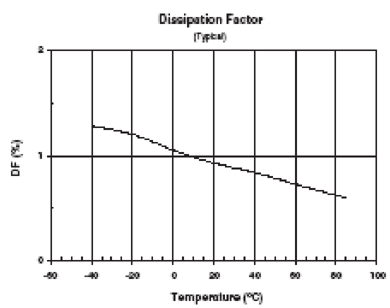
Part Number Suffix	Case Code	Inches				Millimeters			
		L (±.008in.)	W (±.008in.)	H (±.008in.)	S (±.012in.)	L (±0.2mm)	W (±0.2mm)	H (±0.2mm)	S (±0.3mm)
J2	0805	0.079	0.049	0.039	0.018	2.0	1.25	1.0	0.45
H1	1206	0.126	0.063	0.032	0.026	3.2	1.60	0.8	0.65
H2	1206	0.126	0.063	0.039	0.026	3.2	1.60	1.0	0.65
H3	1206	0.126	0.063	0.055	0.026	3.2	1.60	1.4	0.65
G2	1210	0.126	0.098	0.055	0.026	3.2	2.50	1.4	0.65

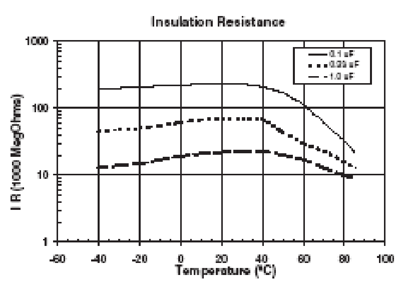
Capacitors Spec Sheet

Type FCA Acrylic Surface Mount Film Capacitors

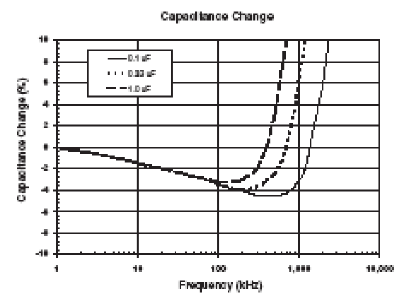
Temperature Characteristics

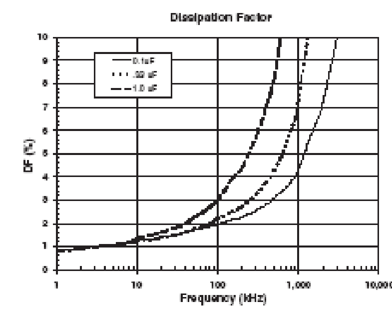


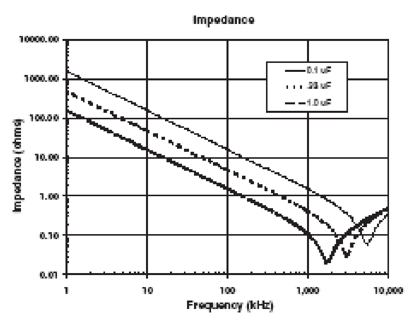




Frequency Characteristics







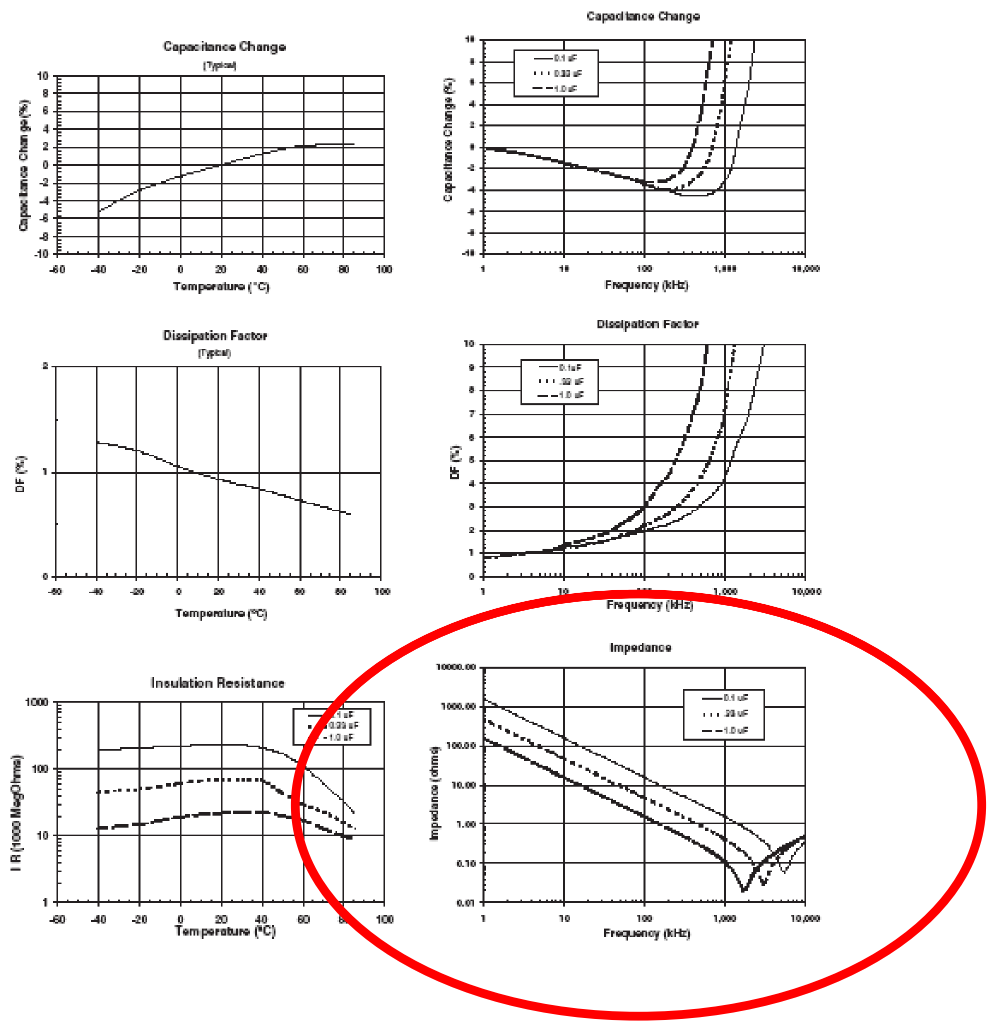
CDE Cornell Dubilier•1605 E. Rodney French Blvd.•New Bedford, MA 02744•Ph: (508)996-8561•Fax: (508)996-3830• www.cde.com

Capacitors Spec Sheet

Type FCA Acrylic Surface Mount Film Capacitors

Temperature Characteristics

Frequency Characteristics



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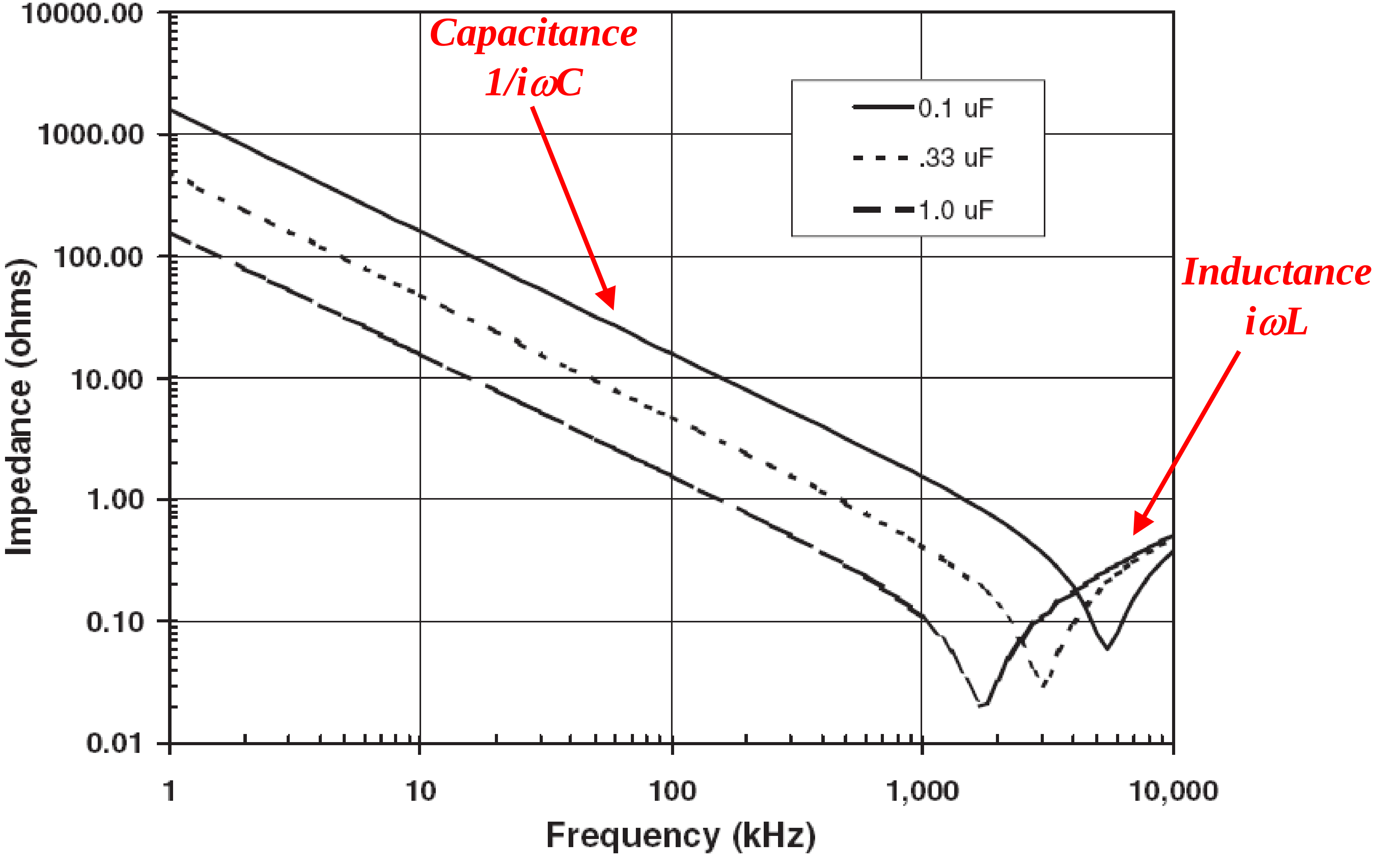
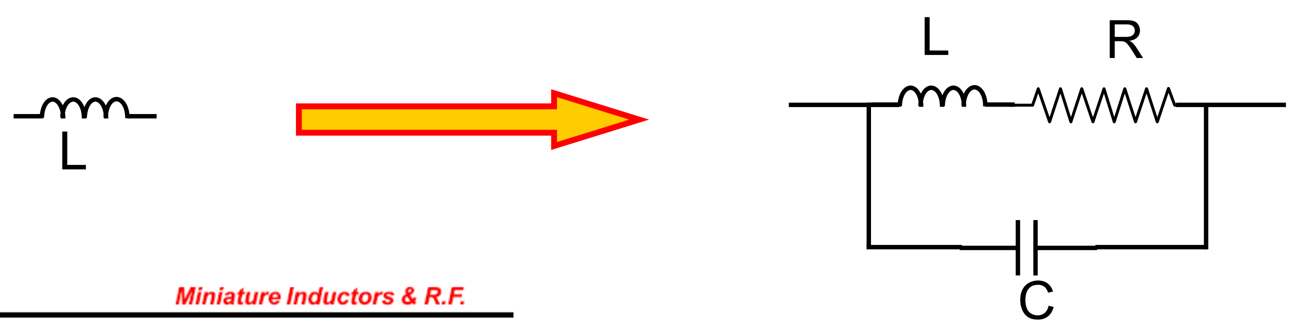
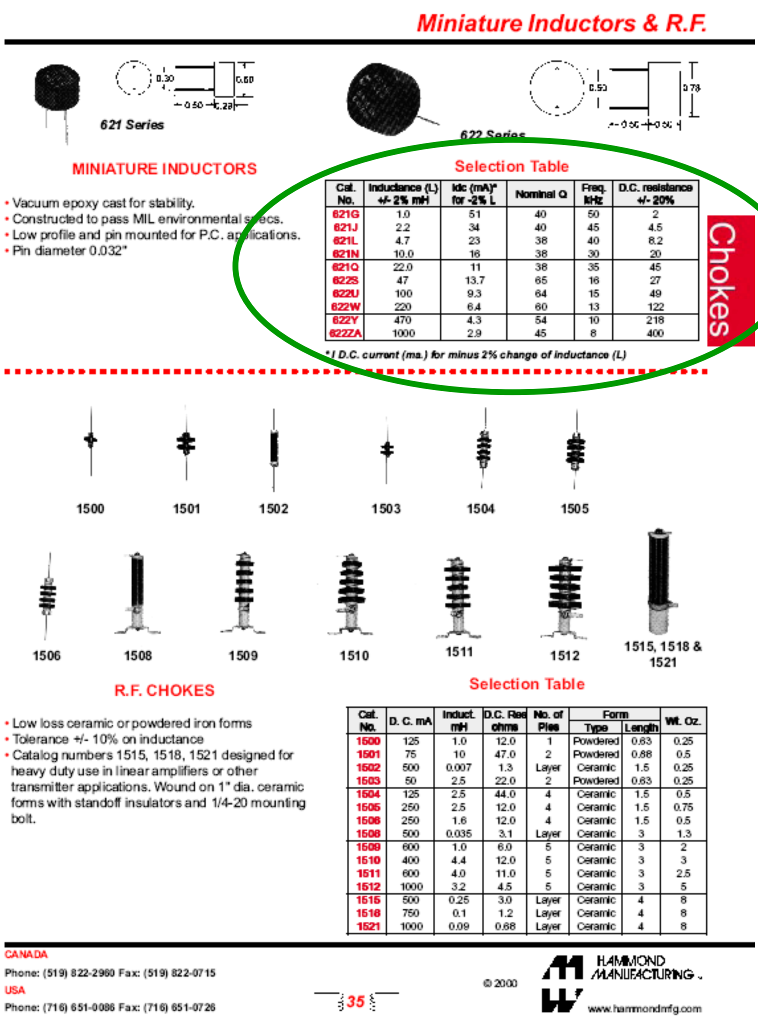
Capacitors Spec Sheet



Inductors: equivalent circuit model





Miniature Inductors & R.F.

621 Series

622 Series

MINIATURE INDUCTORS

- Vacuum epoxy cast for stability.
- Constructed to pass MIL environmental specs.
- Low profile and pin mounted for P.C. applications.
- Pin diameter 0.032"

Chokes

Selection Table

Cat. No.	Inductance (L) +/- 2% mH	Idc (mA)* for -2% L	Nominal Q	Freq. kHz	D.C. resistance +/- 20%
621G	1.0	51	40	50	2
621J	2.2	34	40	45	4.5
621L	4.7	23	38	40	8.2
621N	10.0	16	38	30	20
621Q	22.0	11	38	35	45
622S	47	13.7	65	16	27
622U	100	9.3	64	15	49
622W	220	6.4	60	13	122
622Y	470	4.3	54	10	218
622ZA	1000	2.9	45	8	400

*I D.C. current (ma.) for minus 2% change of inductance (L)

1500 1501 1502 1503 1504 1505

1506 1508 1509 1510 1511 1512 1515, 1518 & 1521

R.F. CHOKES

- Low loss ceramic or powdered iron forms
- Tolerance +/- 10% on inductance
- Catalog numbers 1515, 1518, 1521 designed for heavy duty use in linear amplifiers or other transmitter applications. Wound on 1" dia. ceramic forms with standoff insulators and 1/4-20 mounting bolt.

Selection Table

Cat. No.	D. C. mA	Induct. mH	D.C. Res ohms	No. of Pies	Form		Wt. Oz.
					Type	Length	
1500	125	1.0	12.0	1	Powdered	0.63	0.25
1501	75	10	47.0	2	Powdered	0.88	0.5
1502	500	0.007	1.3	Layer	Ceramic	1.5	0.25
1503	50	2.5	22.0	2	Powdered	0.63	0.25
1504	125	2.5	44.0	4	Ceramic	1.5	0.5
1505	250	2.5	12.0	4	Ceramic	1.5	0.75
1506	250	1.6	12.0	4	Ceramic	1.5	0.5
1508	500	0.035	3.1	Layer	Ceramic	3	1.3
1509	600	1.0	6.0	5	Ceramic	3	2
1510	400	4.4	12.0	5	Ceramic	3	3
1511	600	4.0	11.0	5	Ceramic	3	2.5
1512	1000	3.2	4.5	5	Ceramic	3	5
1515	500	0.25	3.0	Layer	Ceramic	4	8
1518	750	0.1	1.2	Layer	Ceramic	4	8
1521	1000	0.09	0.68	Layer	Ceramic	4	8

CANADA
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USA
Phone: (716) 651-0086 Fax: (716) 651-0726

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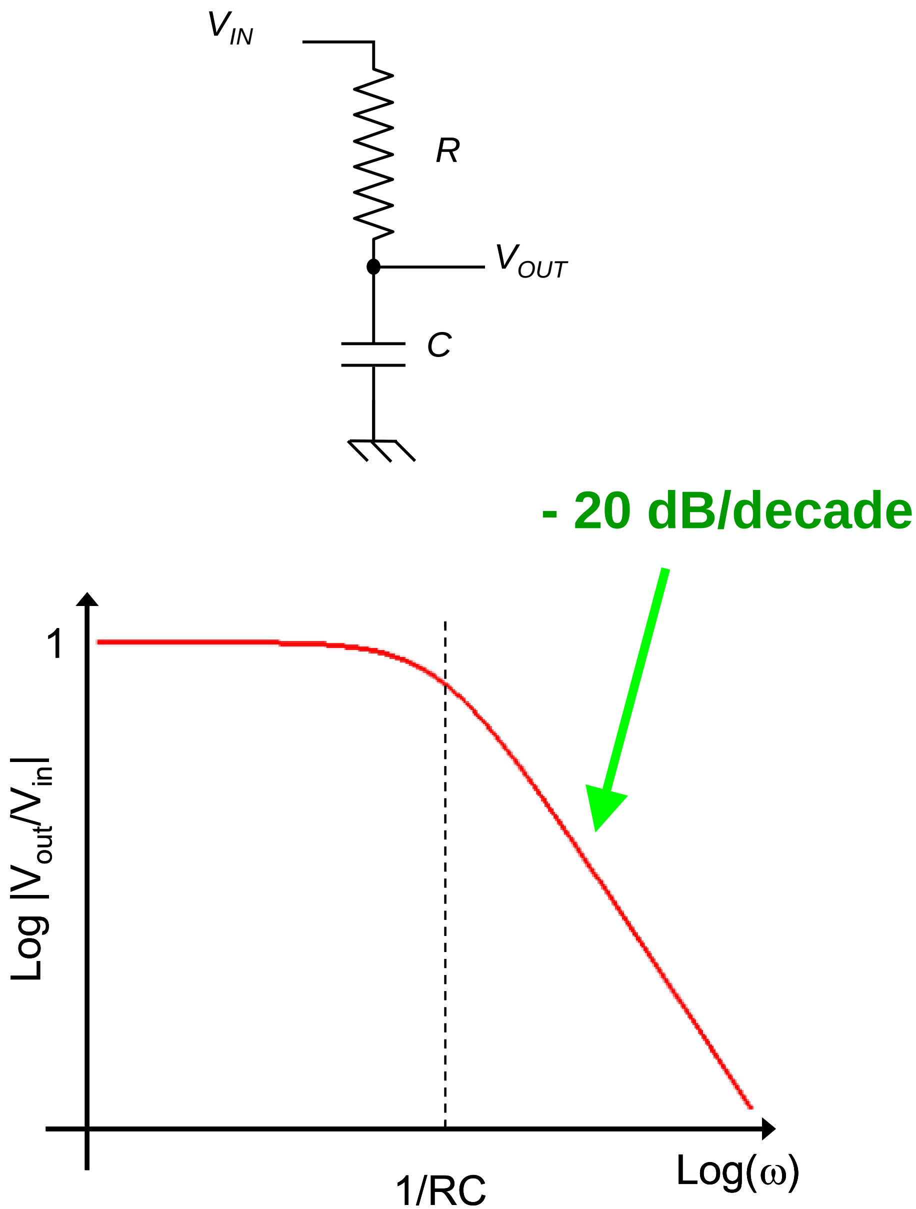
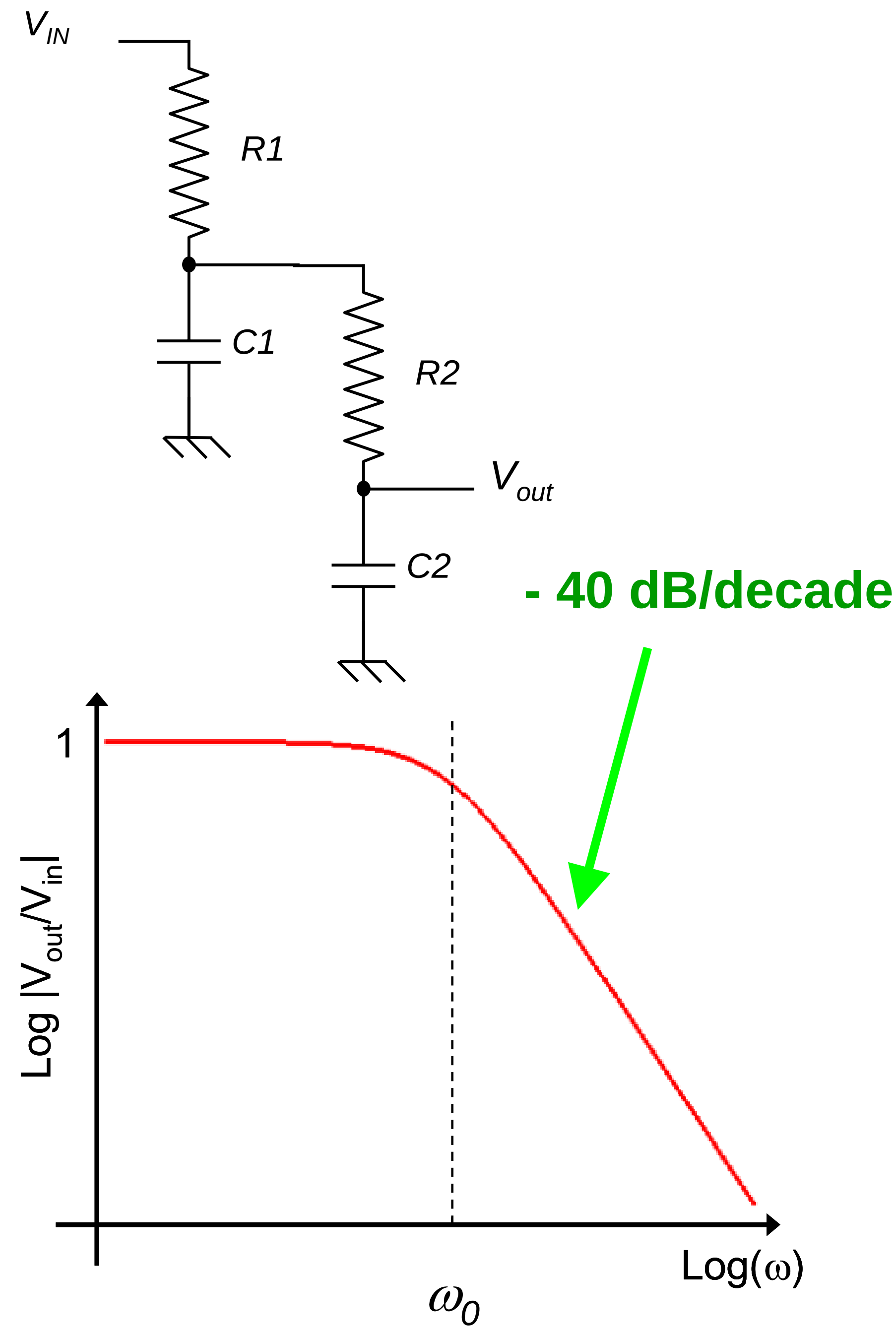
Cat. No.	Inductance (L) +/- 2% mH	Idc (mA)* for -2% L	Nominal Q	Freq. kHz	D.C. resistance +/- 20%
621G	1.0	51	40	50	2
621J	2.2	34	40	45	4.5
621L	4.7	23	38	40	8.2
621N	10.0	16	38	30	20
621Q	22.0	11	38	35	45
622S	47	13.7	65	16	27
622U	100	9.3	64	15	49
622W	220	6.4	60	13	122
622Y	470	4.3	54	10	218
622ZA	1000	2.9	45	8	400

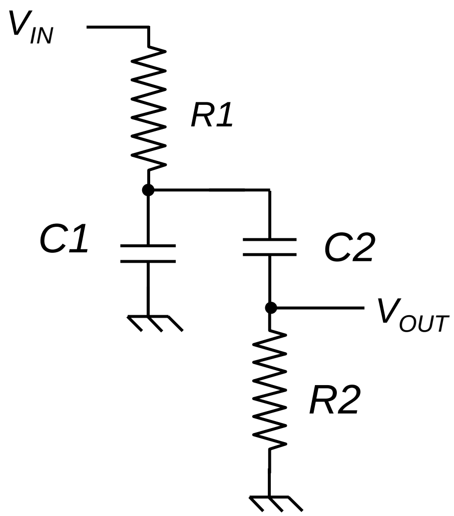
Inductors generally deviate further from ideal performance than capacitors.

RC Filter Combinations I

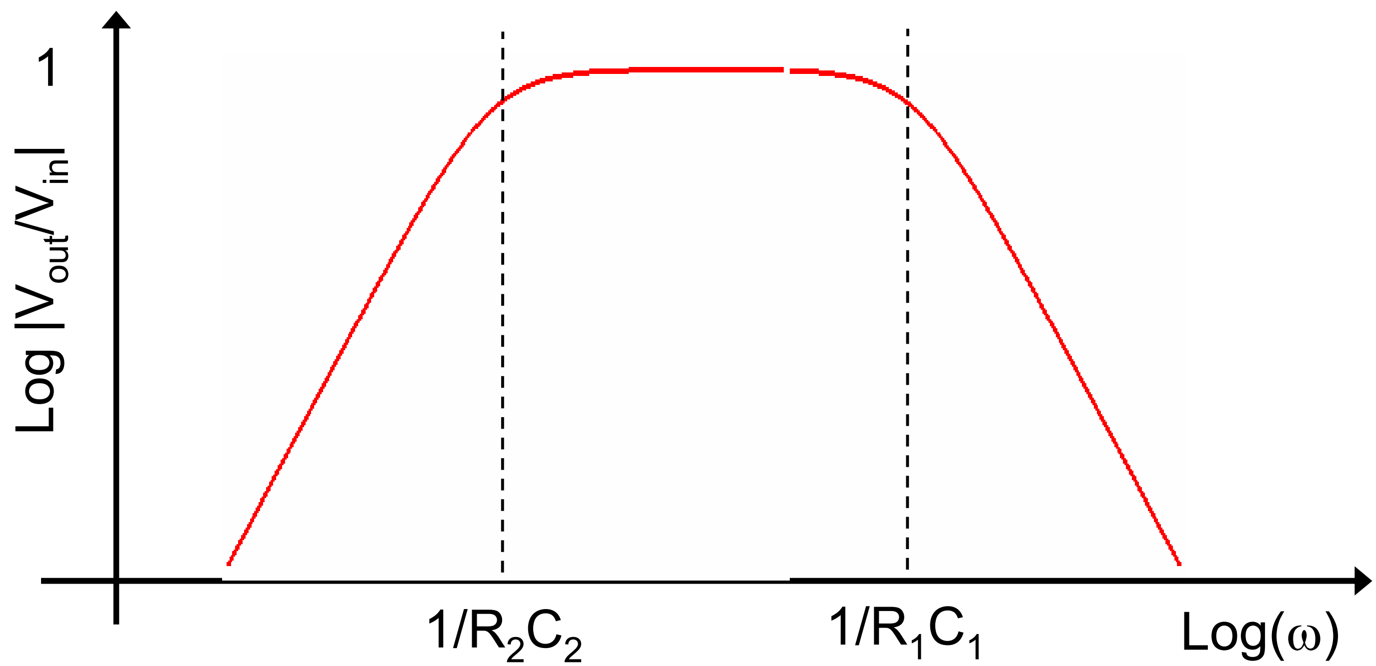




RC Filter Combinations II



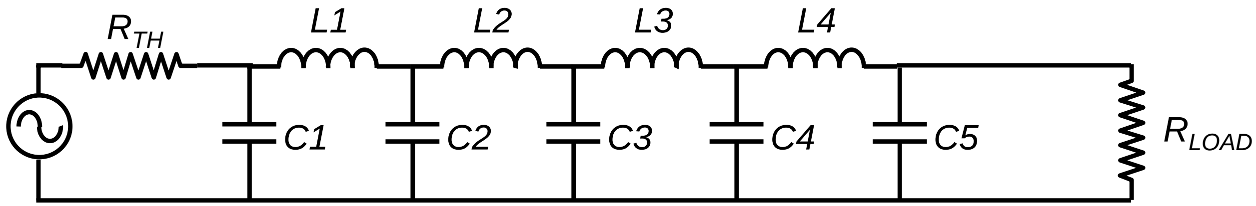
Pass-band filter

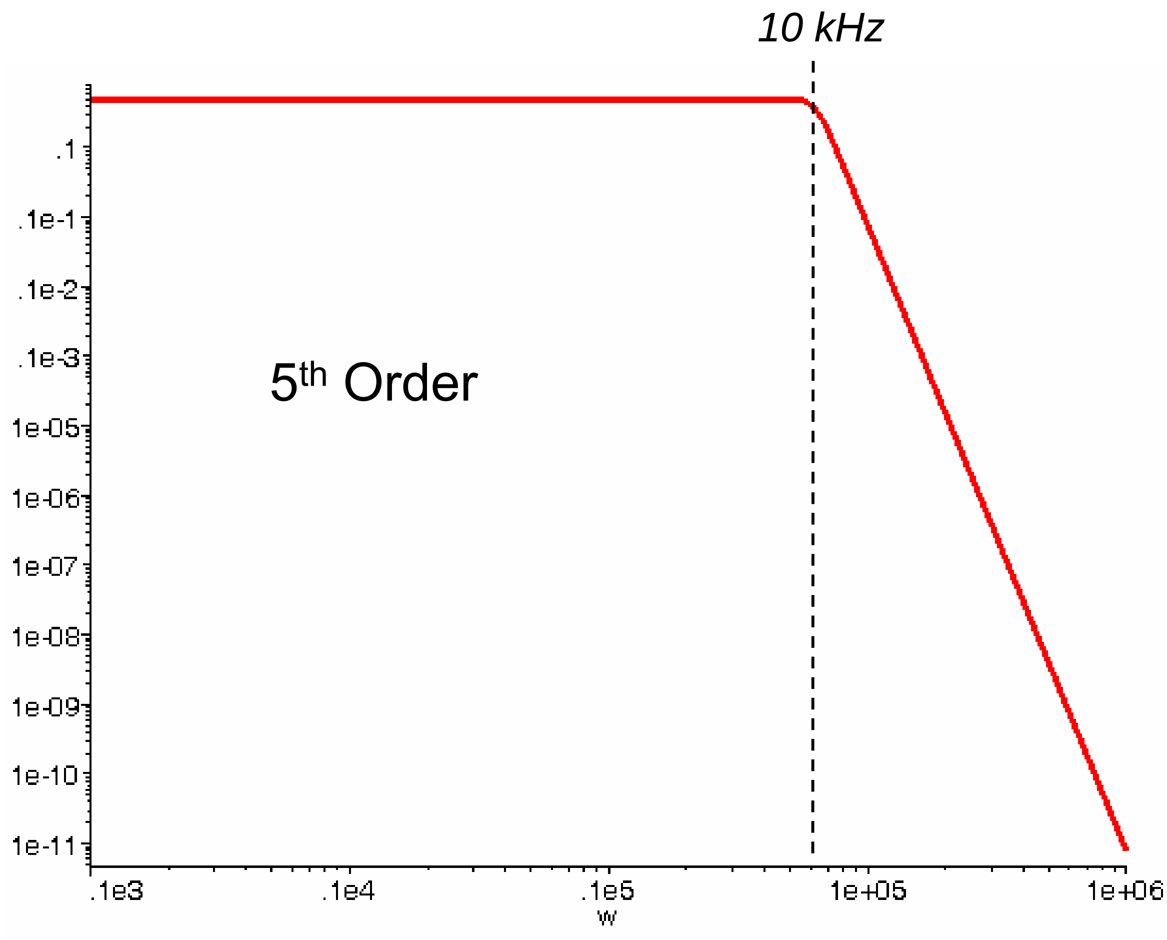


LC Filters

- 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 Filter





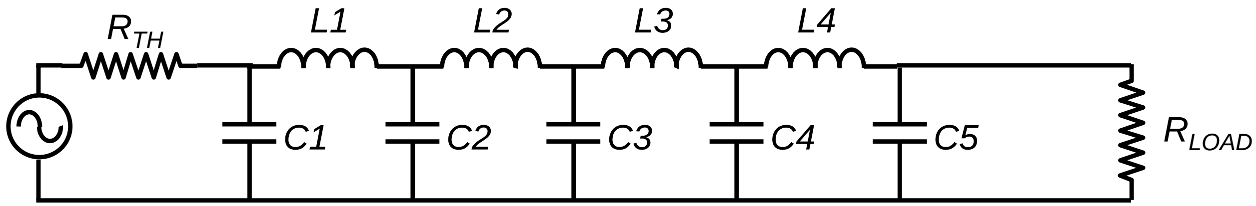
$C1 = C5 = 0.6946\ \mu F$
$C2 = C4 = 3.0642\ \mu F$
$C3 = 4\ \mu F$

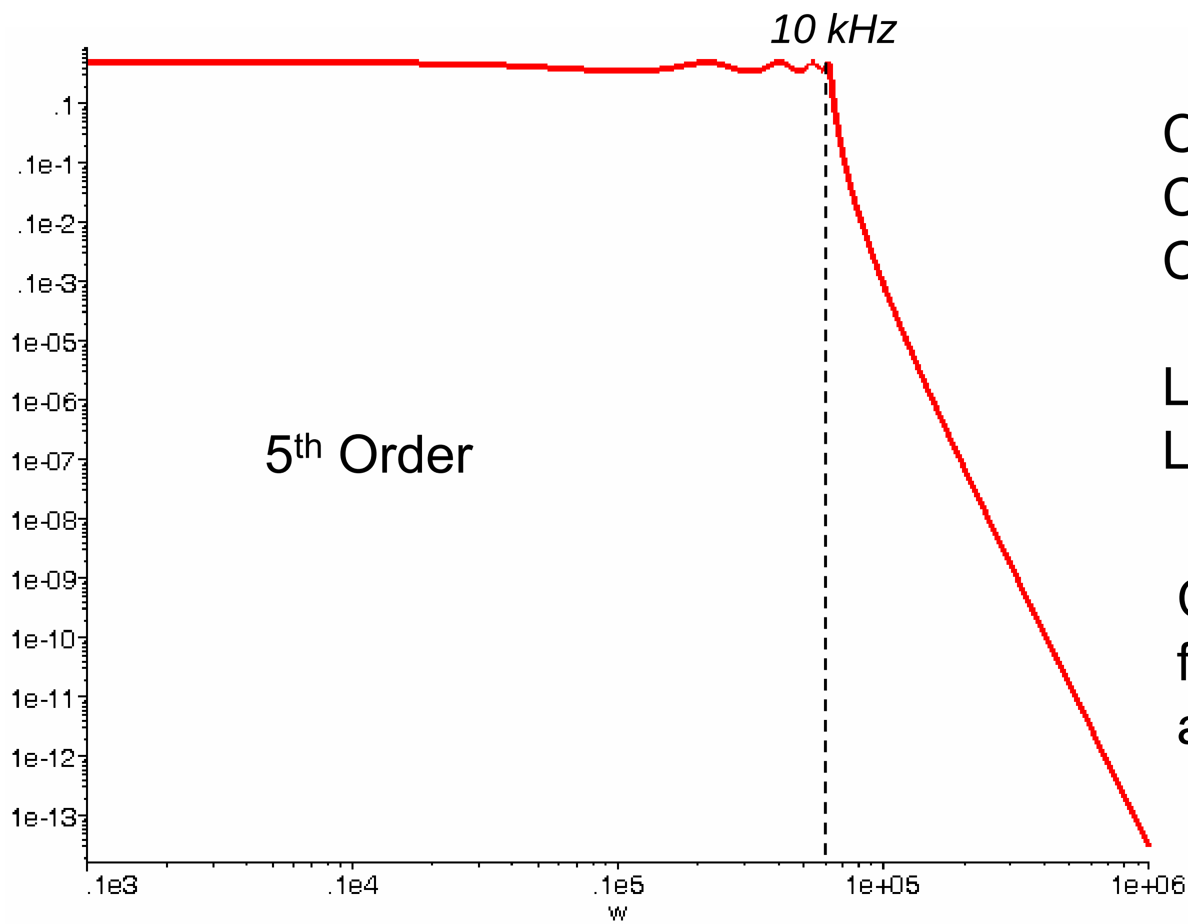
$L1 = L4 = 5\ mH$
$L2 = L3 = 9.397\ mH$

Butterworth filters have very flat pass-bands

Use Maple or another program to design

Chebyshev Filter





C1 = C5 = 1.125 μF
C2 = C4 = 1.486 μF
C3 = 1.505 μF

L1 = L4 = 0.617 mH
L2 = L3 = 0.646 mH

Chebyshev filters have very flat sharp cut-off knees, but are not very flat in pass-band.

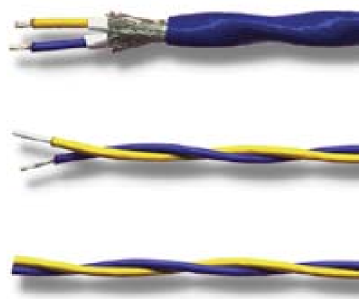
Use Maple or another program to design

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.



[image from www.gore.com]

- Twisted Pairs:
  - → Decent interference suppression.
  - → do not radiate much.
  - → Max analog ~ 250 kHz to 1 MHz.
  - → Max digital ~ 100 MHz - 1 GHz (with care).
  - → Easy to make.

- Coaxial Cables
  - → Excellent performance up to 1 GHz.
  - → No external interference.
  - → Do not radiate.
  - → typical impedance 50 Ω.