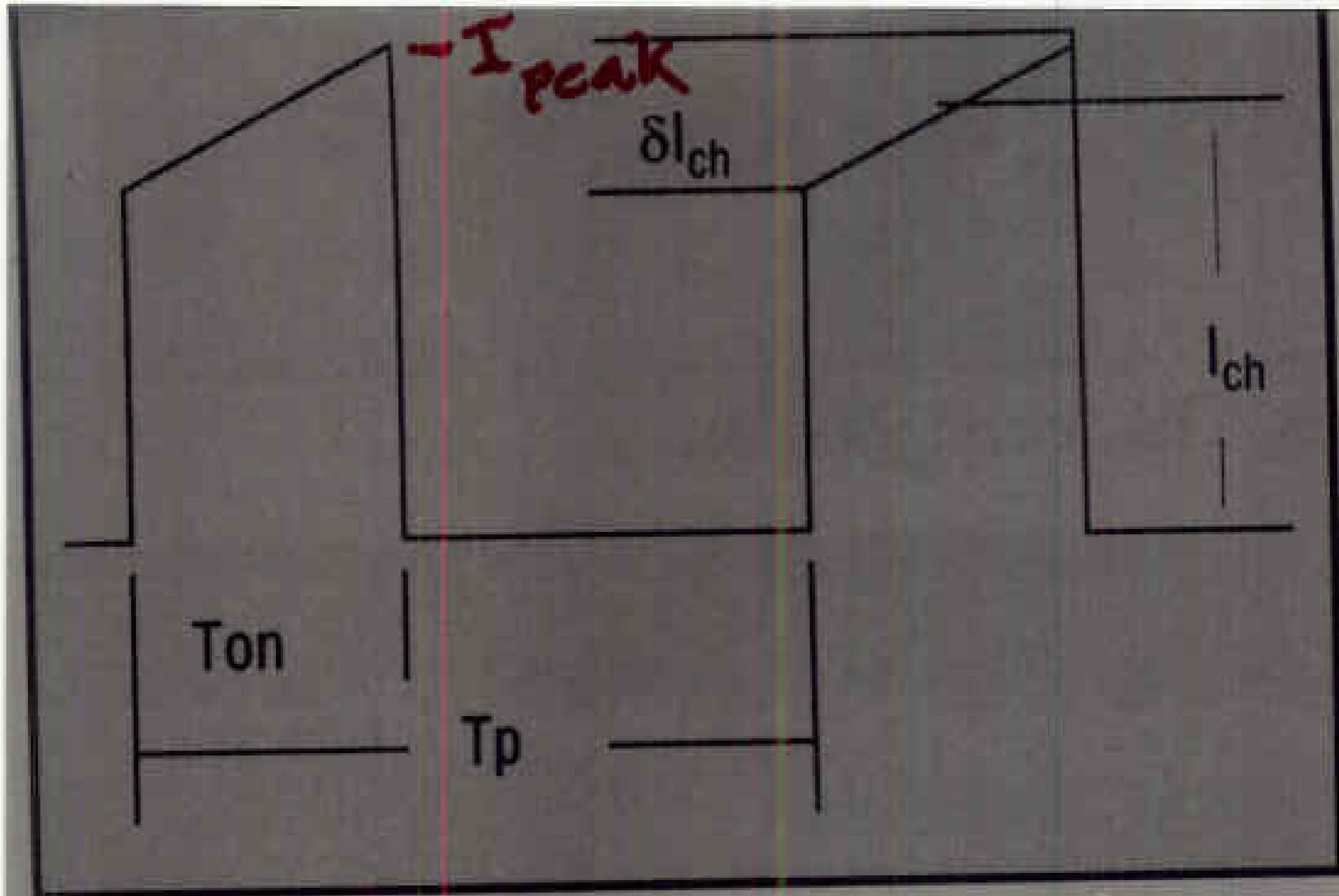


Fig. 2. *Input pulse current.*

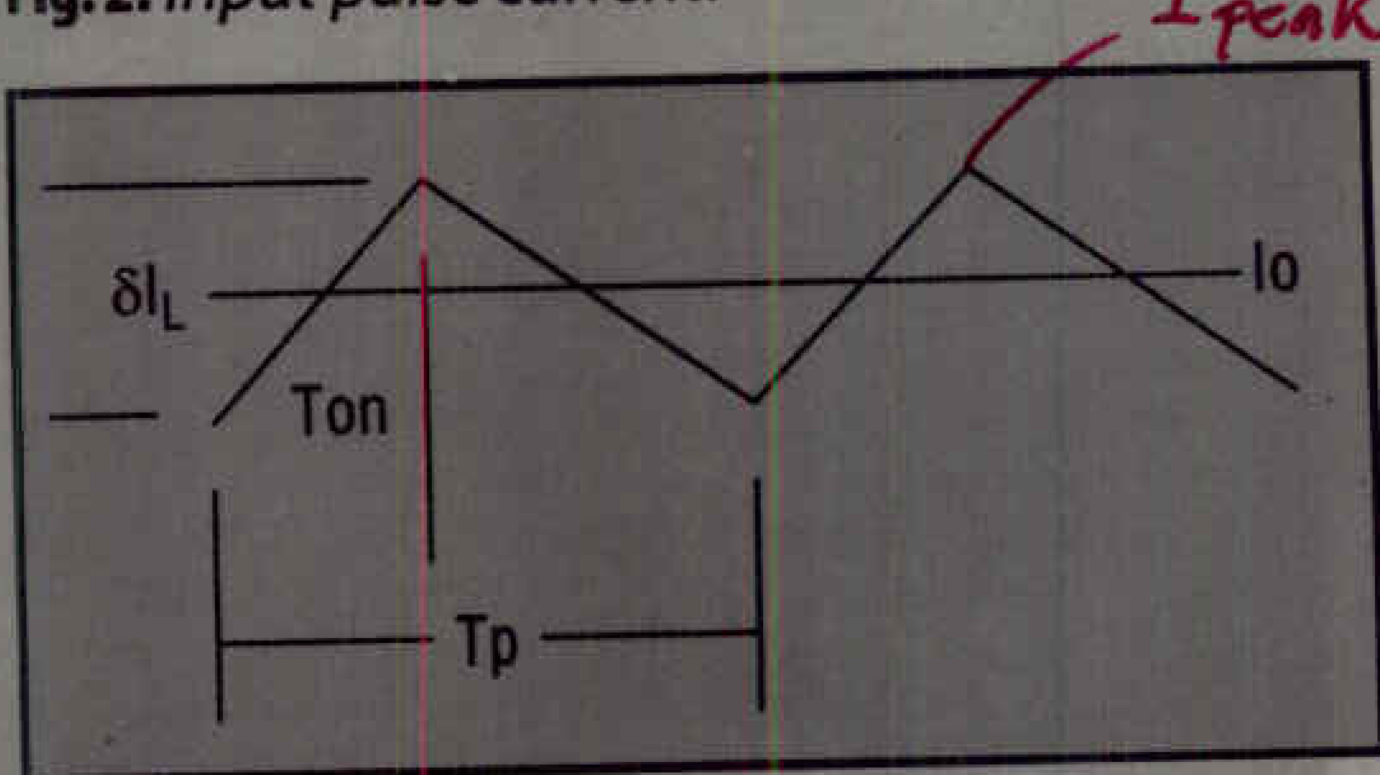


Fig. 3. *Output inductor ripple current.*

ower distribution system, this current

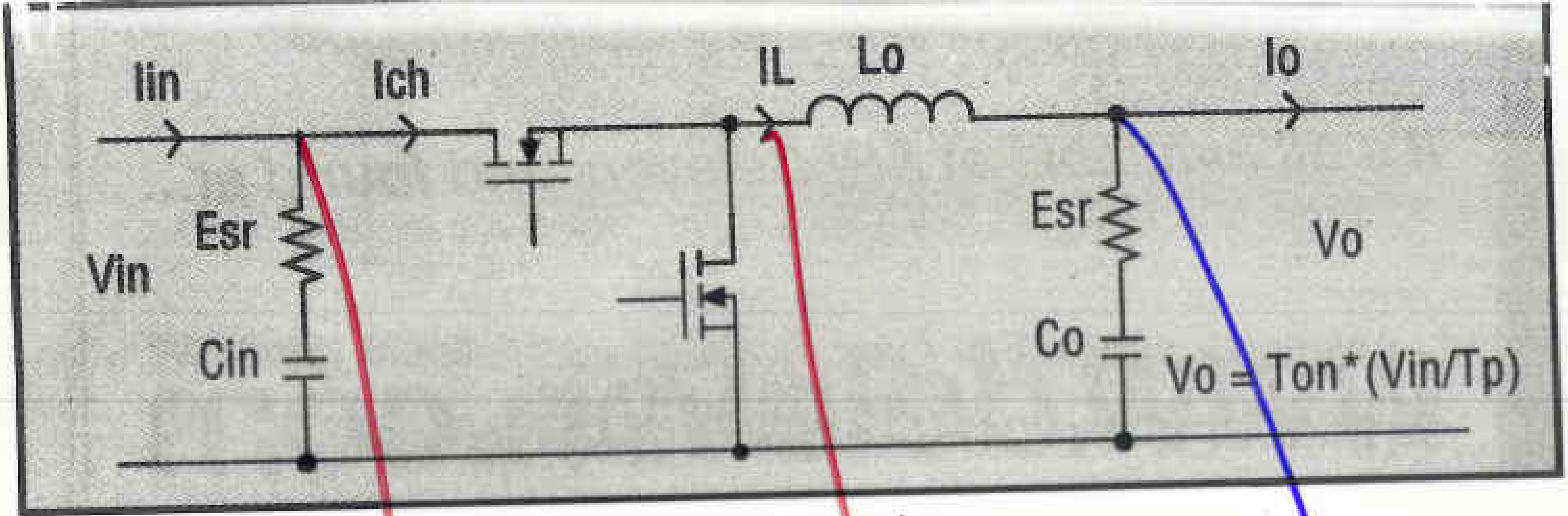


Fig. 1. *Conventional buck converter topology.*

The shunt transistor remains on during the time pe-

V_{peak} I_{peak} V_{peak}

IGBT, FET Choice
Thyristor
C_{IN} Choice

C_{out} Choice

We thus conclude

:

- A buck converter draws spikes of input current (i.e. with sharp edges). That produces a high dI/dt --- and therefore lots of noise originating at the input.
- Same for the buck-boost.
- The only exception is the boost, in which the input is in series with the inductor, and therefore the input current waveform is a slowly rising and falling ramp (no "sharp edges"). This makes *the boost topology reasonably insensitive to input decoupling (no significant dI/dt on input side).*

Therefore, **providing effective input decoupling (for the power stage) is a very important goal of good PCB layout --- *especially for the Buck and the Buck-Boost*** .

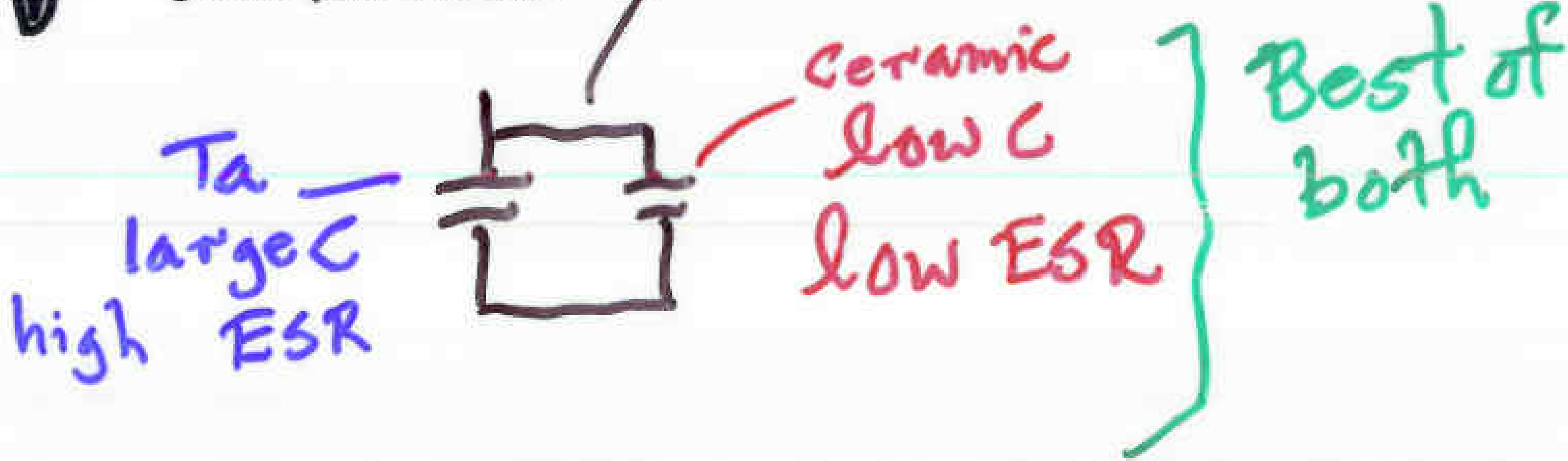
OK

Decoupling is a DUAL requirement!

In general, the decoupling requirements at the input of a power converter should be visualized as <u>dual</u> requirements:

- Decoupling for the **power stage** (buck and buck-boost in particular).

- *Irrespective of the topology*, the **IC control sections** (and switch drivers --- which also draw spikes of current to drive the Mosfet switch), need good input decoupling t prevent noise from infiltrating the IC and causing malfunction. This is usually provide by ceramic capacitors placed very close to the IC --- **right next to the supply and ground pins of the IC.**



Decoupling and the SIMPLE SWITCHER family

For example:

- In a buck converter driving a Mosfet, we need a large "bulk capacitor" (e.g. a low-grade Aluminum Electrolytic) in parallel to a low-ESR ceramic.

- In a buck converter driving a BJT, we can usually get away with a single low-grad bulk cap close to the IC (no ceramic).

- The third generation SIMPLE SWITCHER (buck) family (LM267x) uses a (high-speed) MOSFET as the switch. Therefore, because of the high crossover spee (typically 30ns), the noise is relatively worse (more *"customer complaints"* too!). ***We therefore always need a 0.1uF to 0.47uF capacitor right next to the pin of the IC.*** This component is in fact the most important component in the entire PCB layout (the second being the diode, which has to be very close too, to reduce the trace length from SW pin to switching node). In fact, customers have reported anomalous behavior even if the ceramic decoupling capacitor was ver close, but on the <u>other</u> side of the PCB --- i.e. the intervening vias apparently ha enough stray inductance to cause the IC to malfunction, especially under abnormal situations like overloads and output shorts.

- The second generation SIMPLE SWITCHER (buck) ICs (LM259x) use a BJT switch , so we can usually combine the input decoupling requirements of the power stage and IC into one single low-grade (e.g. aluminum electrolytic) bulk capacitor. It seems that not only this particular series of ICs has a higher level o

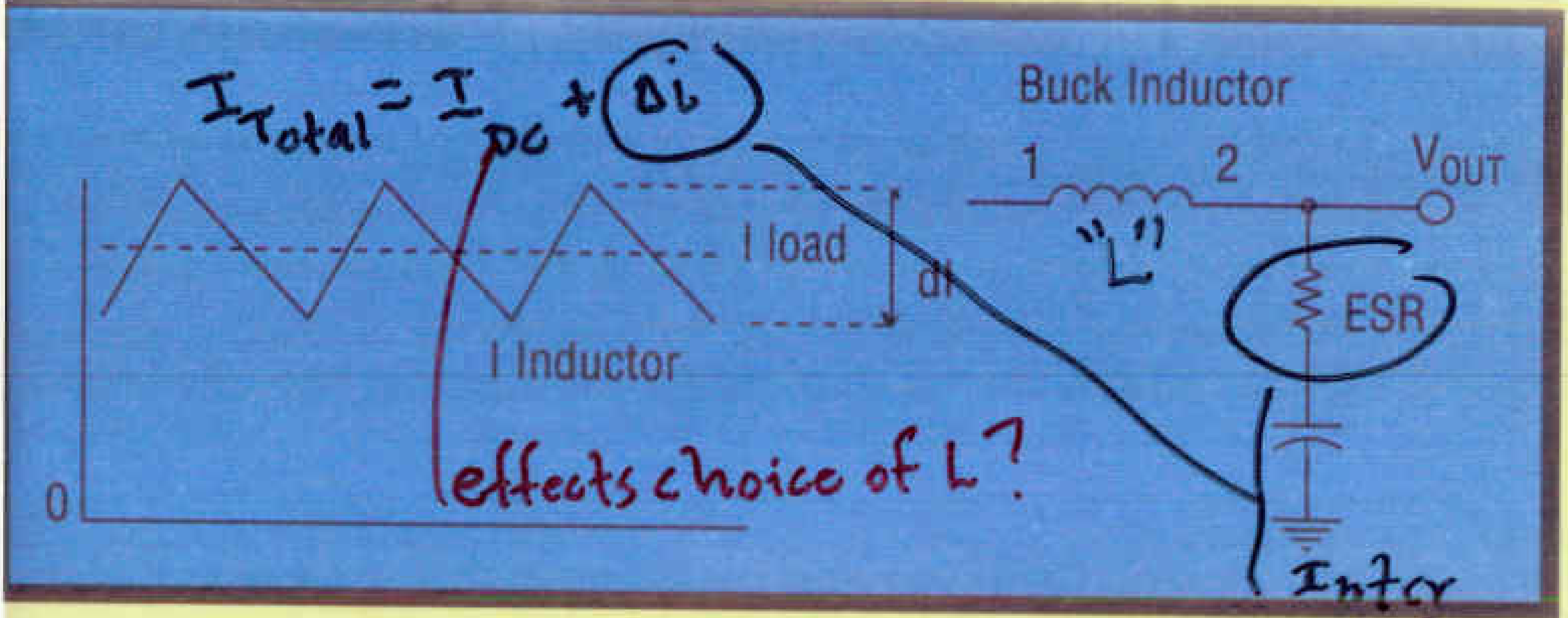


Fig. 1. *Inductor ripple current and Buck output circuit.* Related

① "L" is doing energy storage $E = \frac{1}{2} L i^2$

② "L" sets Δi (ripple) into C_{out} : Chapter 3

$\Delta V_{out} \approx \Delta i \, R(ESR)$ } want 1 – 50mV

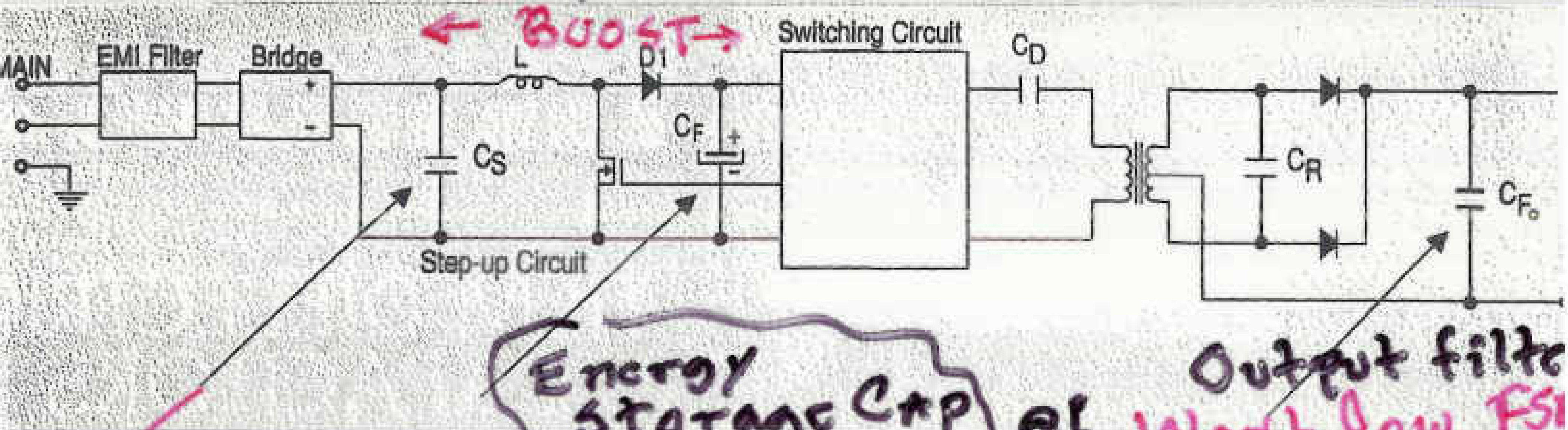
$$L \text{ (chosen) by} \geq \frac{V_L(max)\, dt \ (\approx 1/f_{sw})}{\Delta i \text{ (ripple)}}$$ ← customer spec

"Lytics" for f < 100 KHz

Why? Are

Al_2O_3 ↕ $d = 1000$ Å $\Rightarrow C = \frac{\epsilon A}{d}$

← BOOST →



Capacitors in switchmode power supply.

Energy Storage Cap

Output filter @ f_{sw} Want low ESR to avoid $\Delta I_c R_{ESR}$ Not to low or oscillation occurs

largest C ("lytic")
- filter mains to acceptable DC
- Handle V_{ac} sag surge
- I_{sw} shunt

} Very low ESR ESL ← i stress high

The application is specific. So is the capacitor.

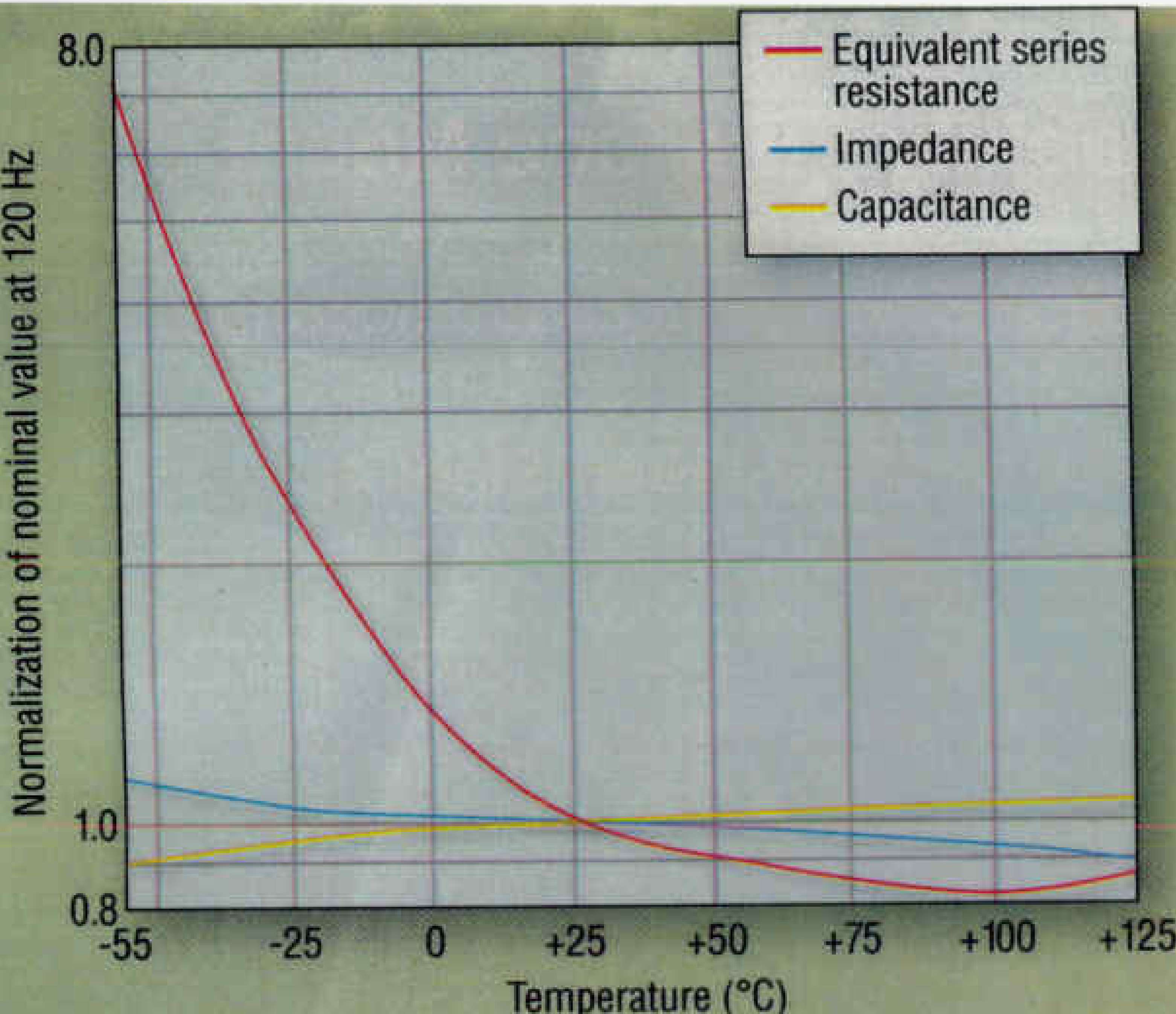
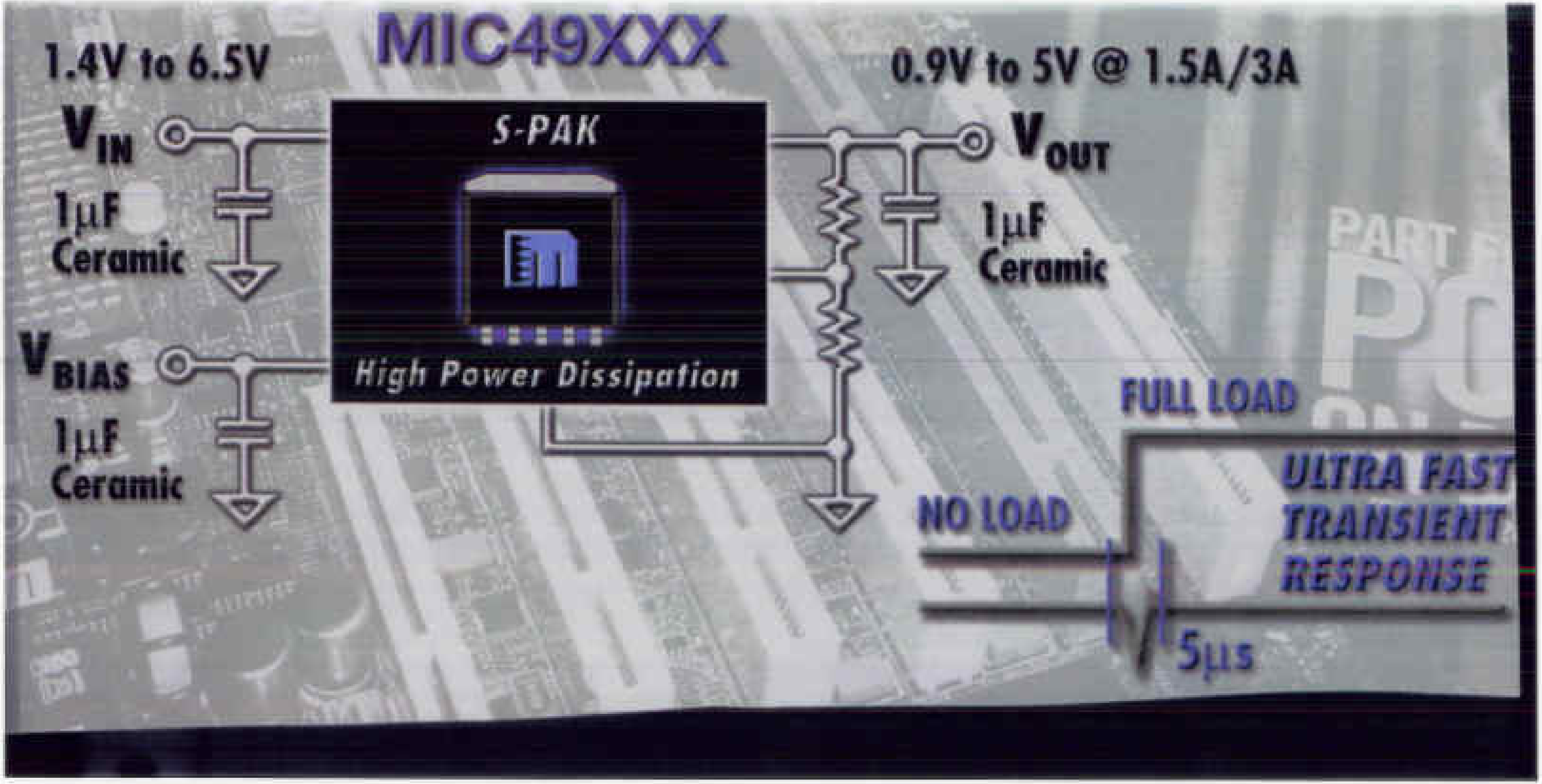


Fig. 6. *The wet-tantalum curves show a dramatic rise in ESR at low temperature. (Data courtesy of NASA.)*


MIC49XXX
1.4V to 6.5V
0.9V to 5V @ 1.5A/3A
V IN
1µF
Ceramic
V BIAS
1µF
Ceramic
S-PAK
High Power Dissipation
V OUT
1µF
Ceramic
FULL LOAD
NO LOAD
ULTRA FAST
TRANSIENT
RESPONSE
5µs

Film vs. Electrolytic Caps

Same ripple current

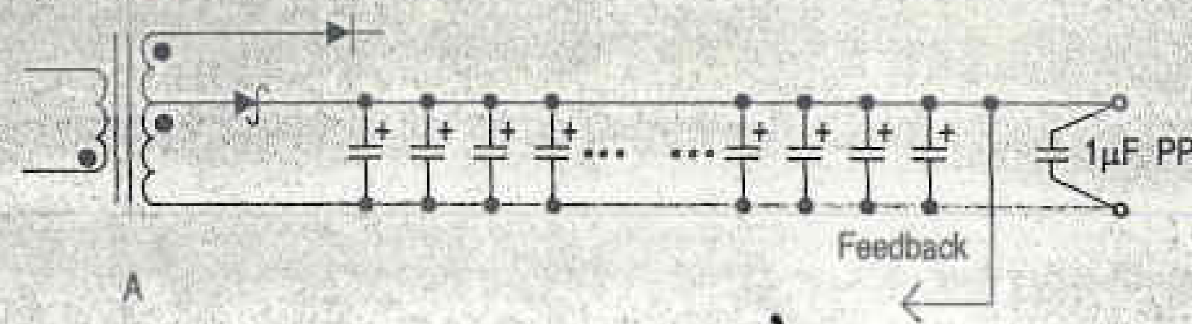
Converter Components

Parallel Group
std value

C = 42 x 330μF
C_T = 13,860μF

Cost: Highest
Response: Fastest

many electrolytics
$R_{ESR}/42$

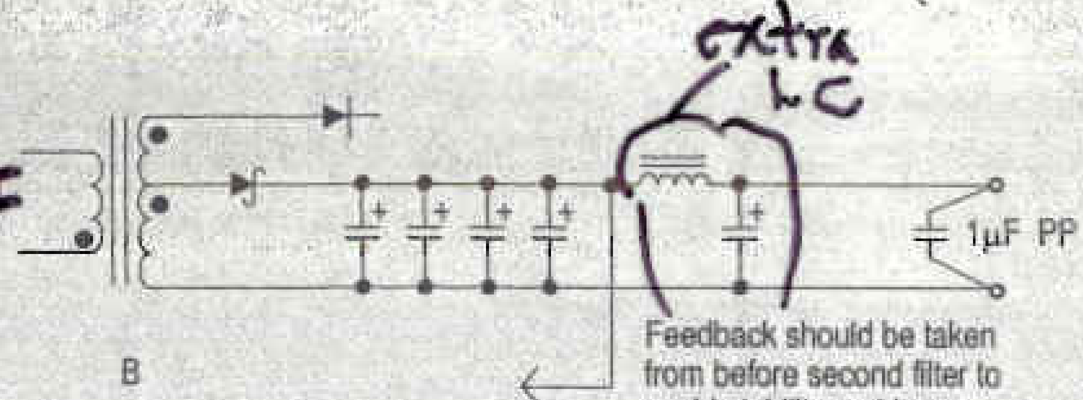


A

C = 4 x 330μF
C_T = 23,320μF

Four "Lytics total 23mF

Cost: Intermediate
Response: Intermediate (Reduced Load Regulation)

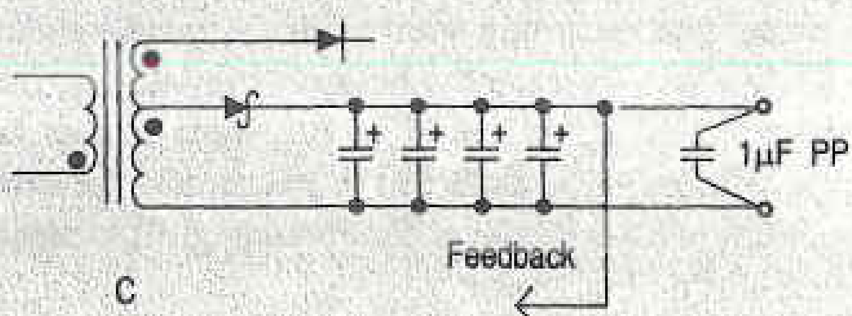


B

C = 4 x 15,000μF
C_T = 60,000μF

60mF

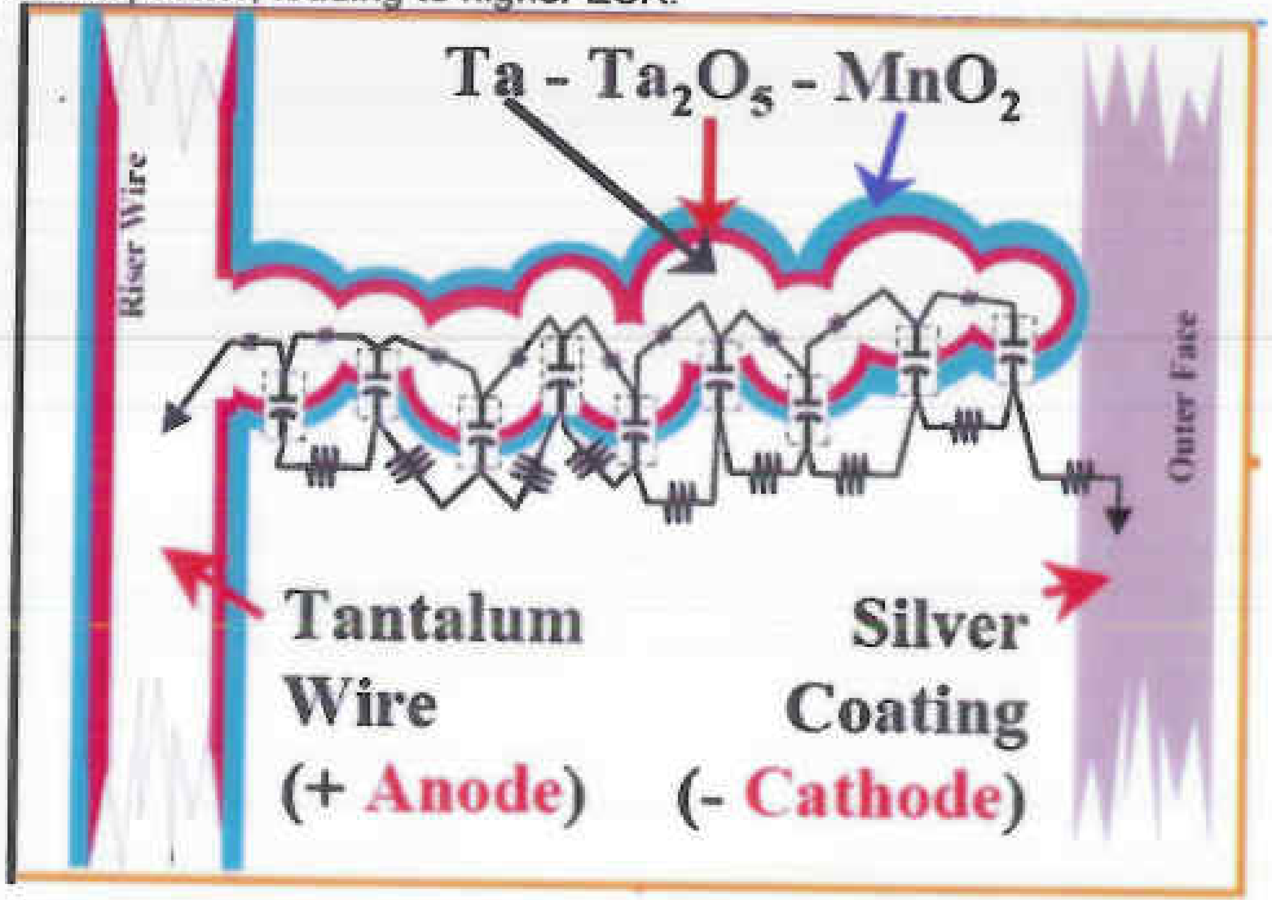
Cost: Least
Response: Slowest



C

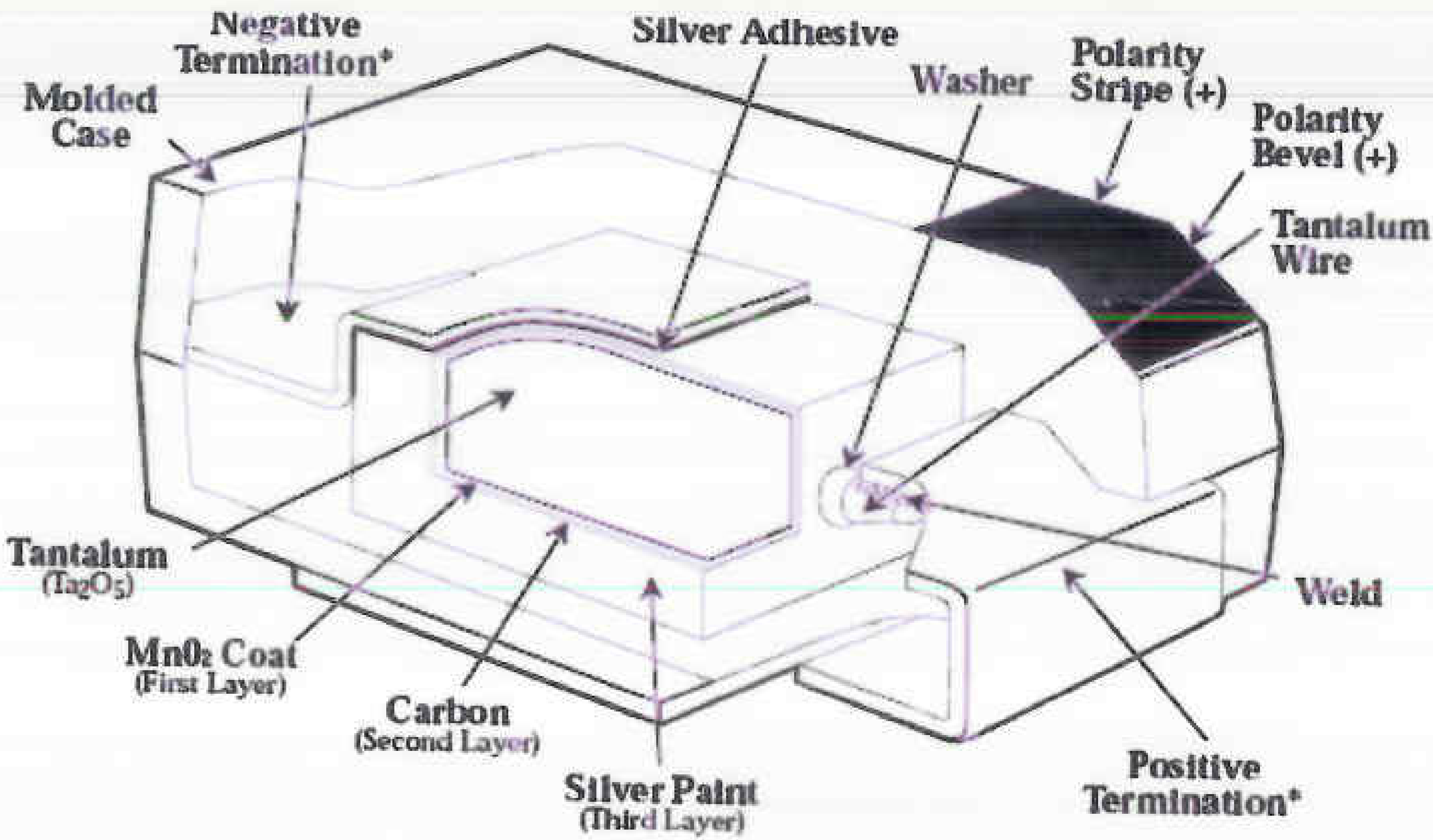
Output filters for equivalent ripple.

- Following picture illustrates the distributed resistance in the construction of a Tantalum capacitor, leading to higher ESR.



- Although the ESL is negligible in most capacitors, some of the same factors that affect ESR, also affect ESL:

- Tantalum
  - Small size vs C
  - High capacitance
  - Low ESR (30-150mohm)
  - Use caution on input
  - Being replaced by niobium



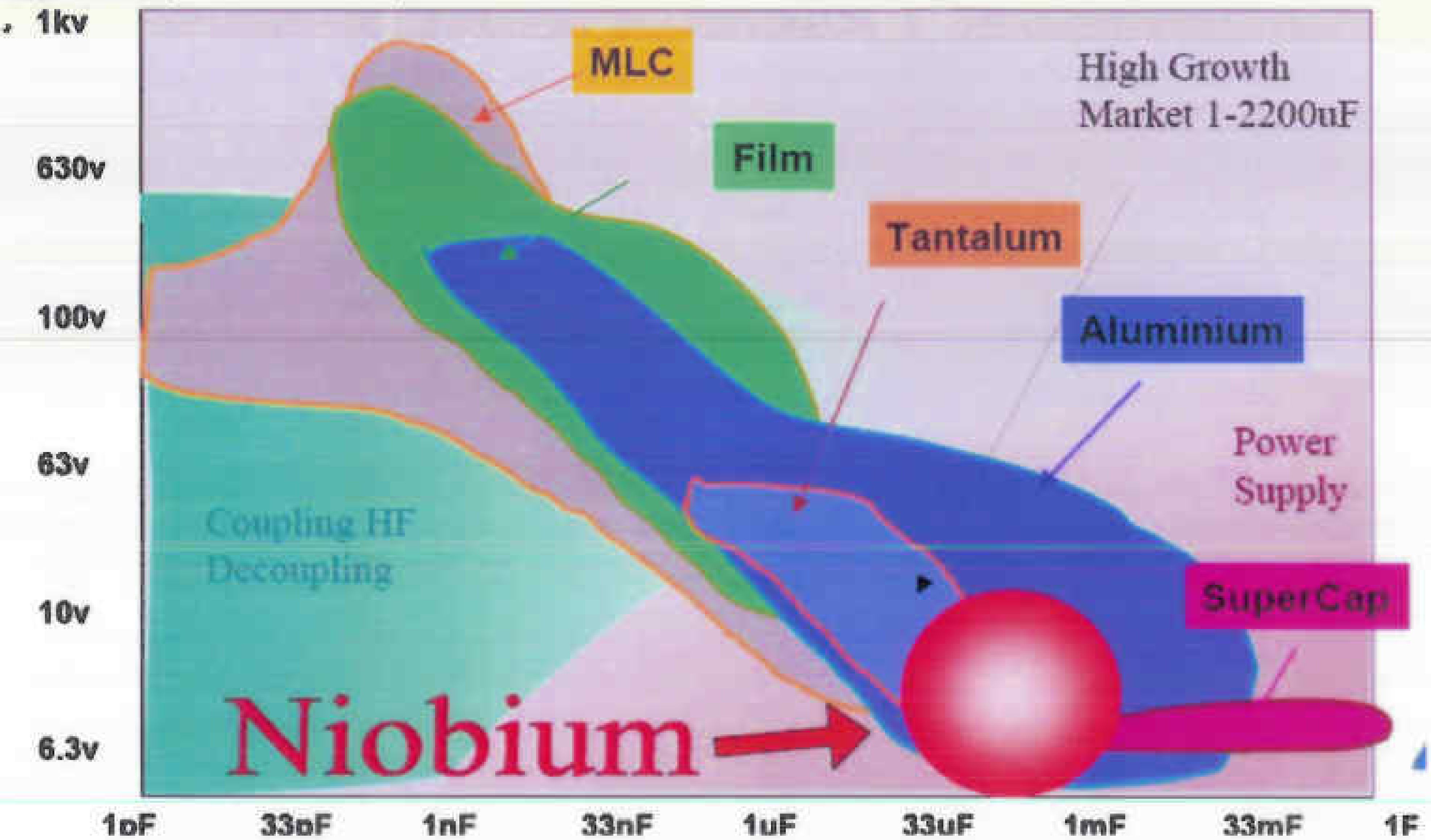
*Termination Solder Coating 90 Sn/10Pb

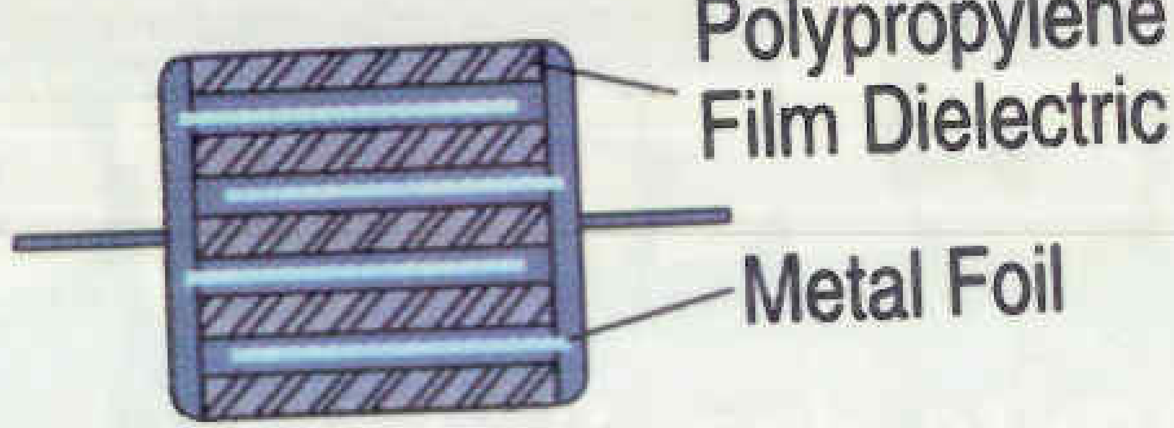
0ft

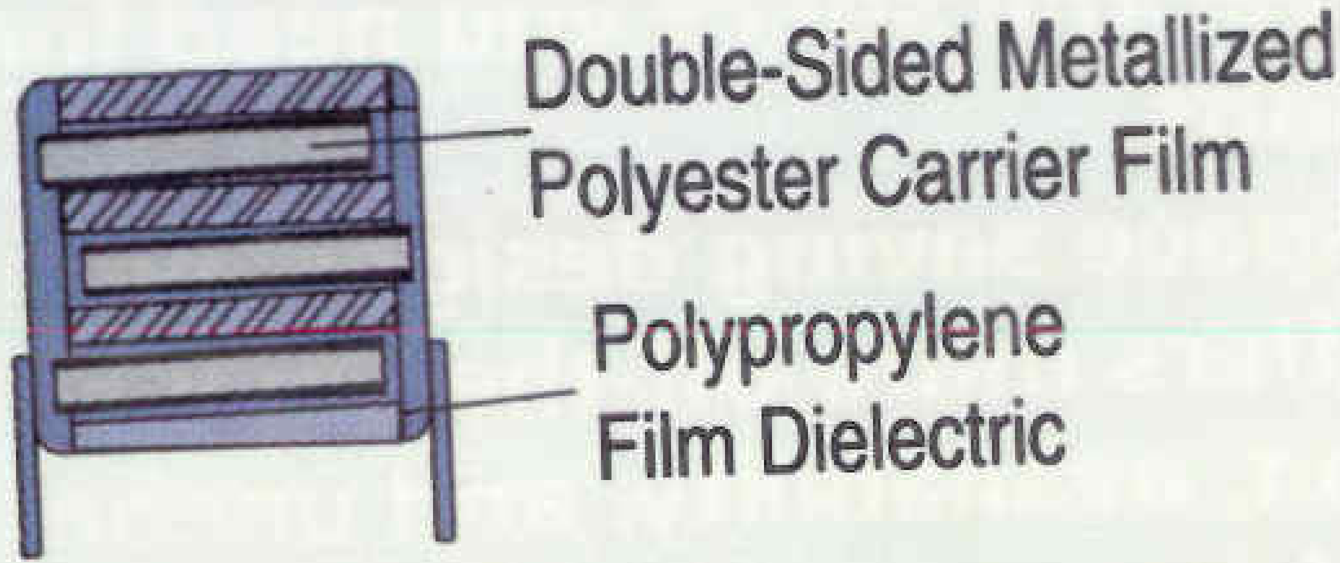
Decoupling and the Pitfalls of Tantalum Capacitors

Tantalum capacitors have a capacitance per unit volume almost 3 times better than Aluminum Electrolytics. However:

- Their max rating is typically less than 50V.
- Even that rating is "nebulous", since 50% derating of the max voltage rating ma) need to be applied.
- Voltage derating is specifically recommended when the capacitor may see a lar(inrush current --- like the input cap of all topologies, and also the output cap of tl boost topology. So for example, a 35V Tantalum cap may then be usable only u to about 18V. (That is roughly a "derating" of 50%).


1kv
630v
100v
63v
10v
6.3v
1pF
33pF
1nF
33nF
1uF
33uF
1mF
33mF
1F
MLC
Film
Tantalum
Aluminium
High Growth
Market 1-2200uF
Power
Supply
SuperCap
Coupling HF
Decoupling
Niobium


Polypropylene
Film Dielectric
Metal Foil


Double-Sided Metallized
Polyester Carrier Film
Polypropylene
Film Dielectric

Compare old "Lytics" to Metal Film Capacitors

Superior

Technology	ESR at 100kHz (mΩ)	Ripple Current (A_{rms})	Δ C/C 1 to 100 kHz (%)	Δ C/C at -55°C (%)	Leakage Current (μA)
Metallized Polypropylene	<10	>6	<1	<1	<1
Aluminum Electrolytic	>100	<0.6	>-25	>-30	>50

Technology	ESR(mΩ)			
	-40°C	-20°C	+25°C	+85°C
Metallized Polypropylene	12.5	11	10	9
Aluminum Electrolytic	—	25,000	3,000	250

Performance of metallized polypropylene capacitors vs. aluminum electrolytics. Capacitance is 10μF, 450VDC.)

Lytics "dry up" over t - T

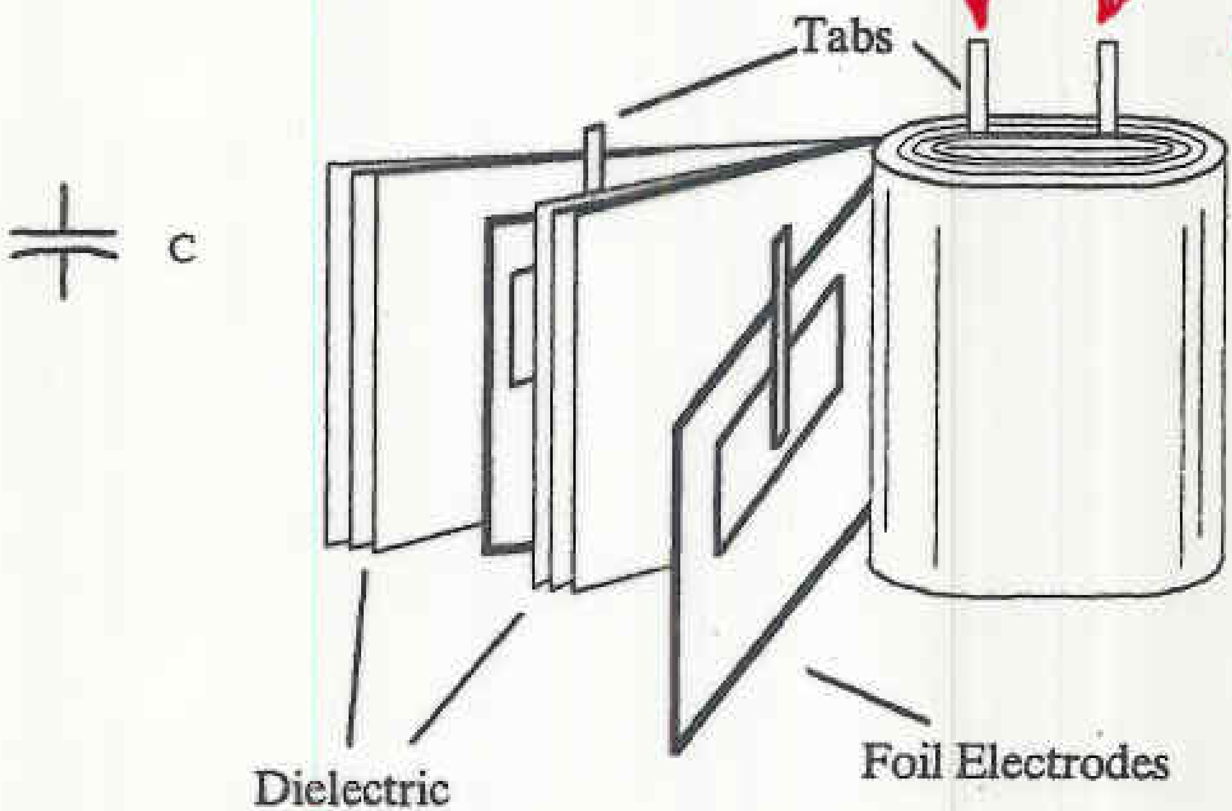
Lytics are Not bipolar or stand reverse voltage

Metal/Film are self-healing on many failures

More tabs
Lower ESR
Lower L (parasitic)

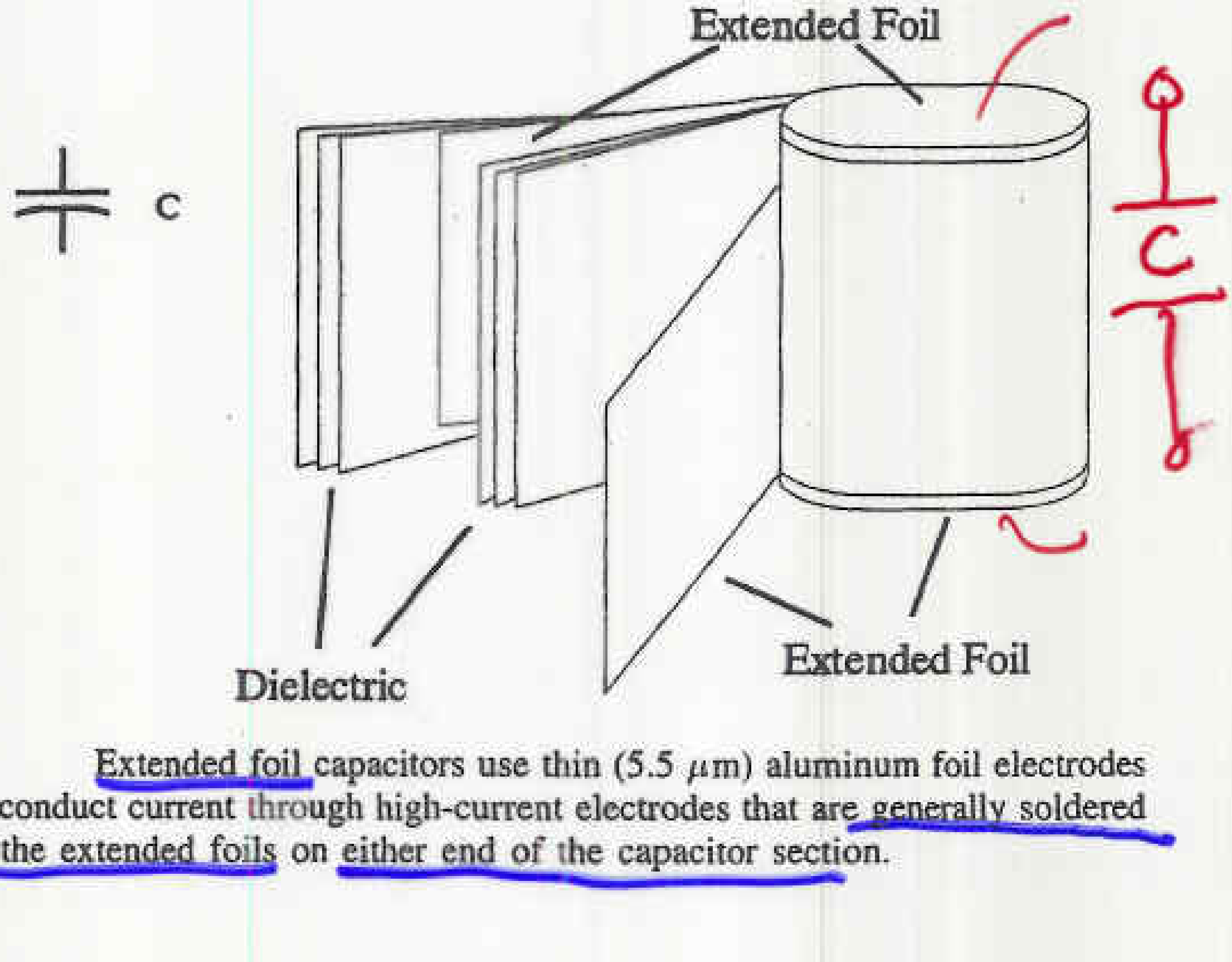
Short & fat desired

CAPACITOR WITH TABS



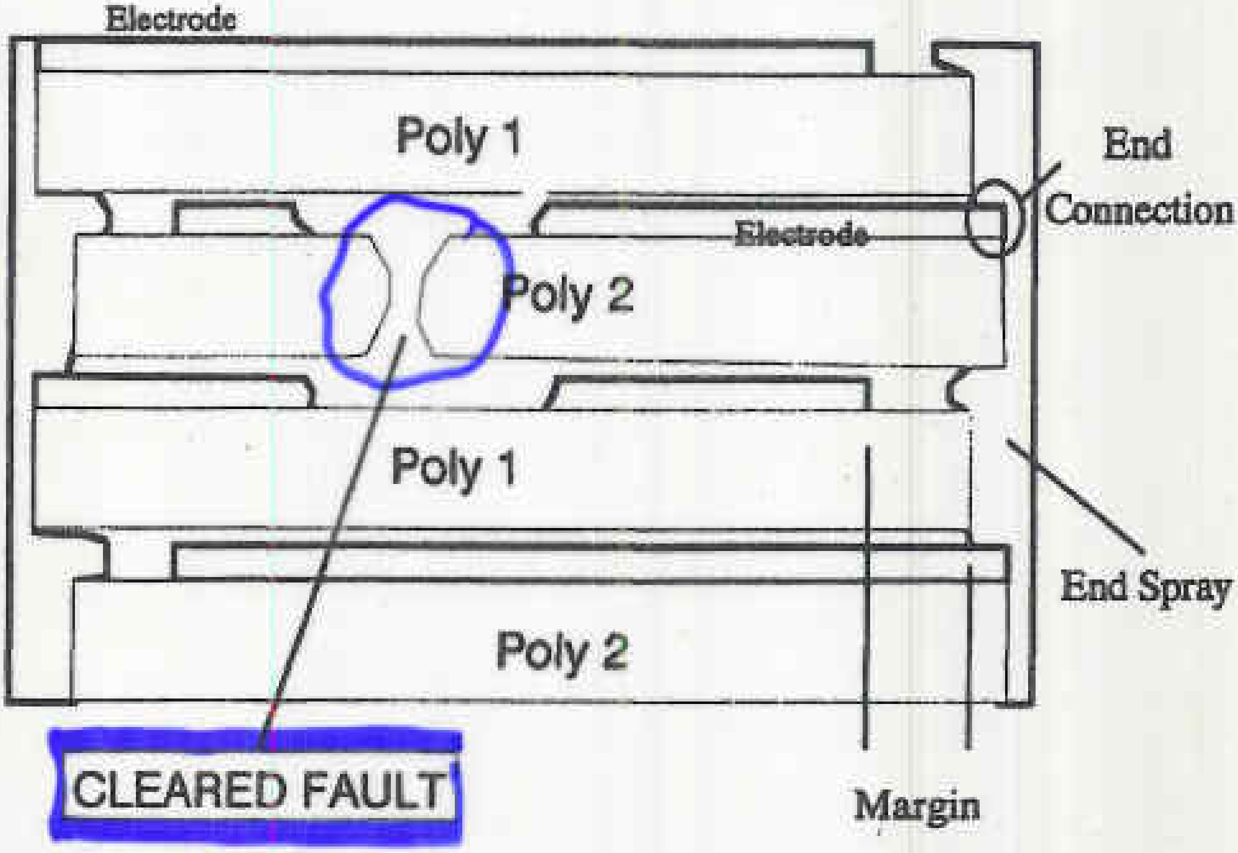
Inserted tab capacitors use thin (5.5 μm) aluminum foil electrodes conduct current through the capacitors and out through tabs to the load.

CAPACITOR
WITH EXTENDED FOIL ELECTRODES



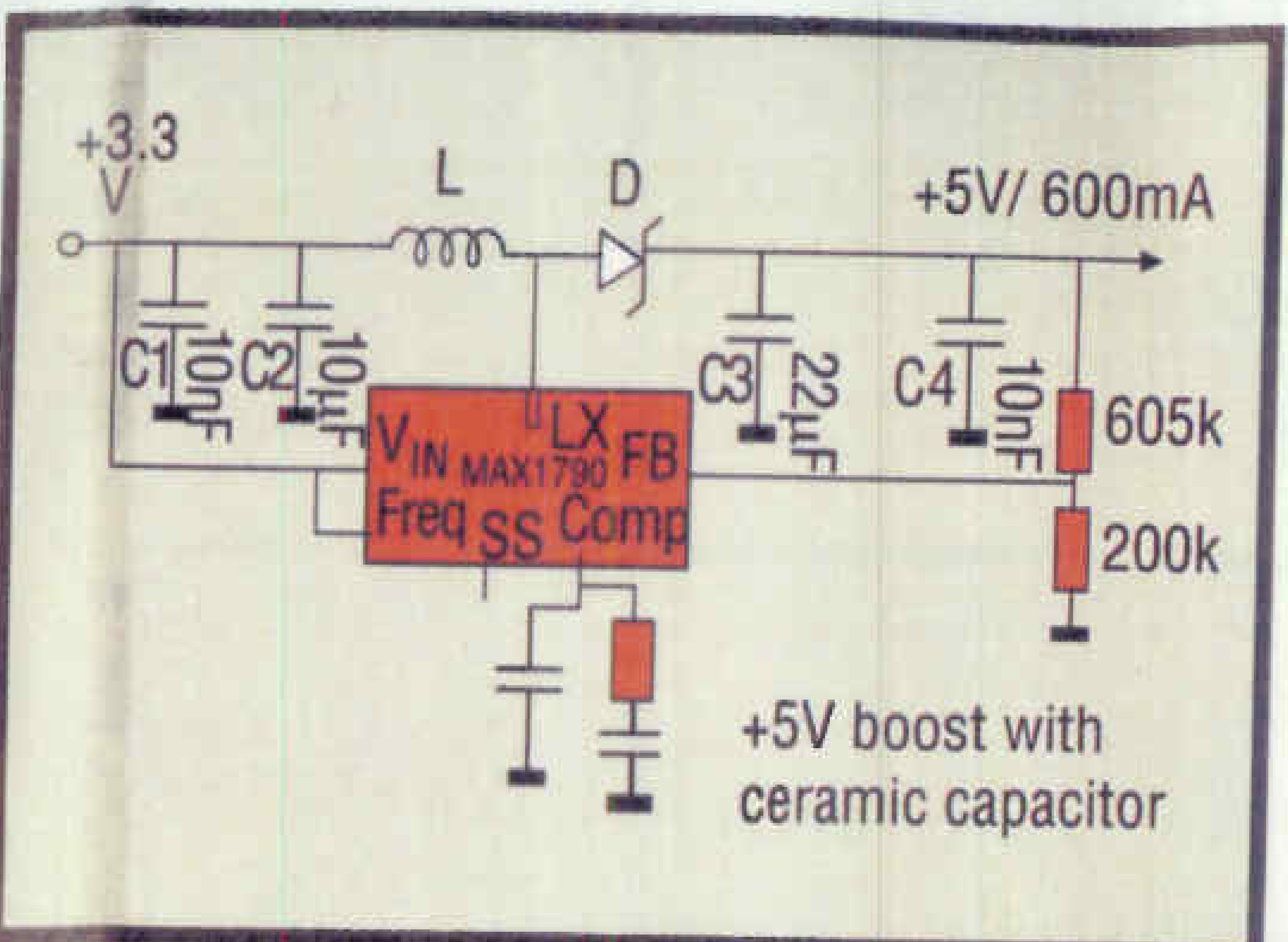
Extended foil capacitors use thin (5.5 μm) aluminum foil electrodes to conduct current through high-current electrodes that are generally soldered to the extended foils on either end of the capacitor section.

Metallized Polymer Capacitor Construction

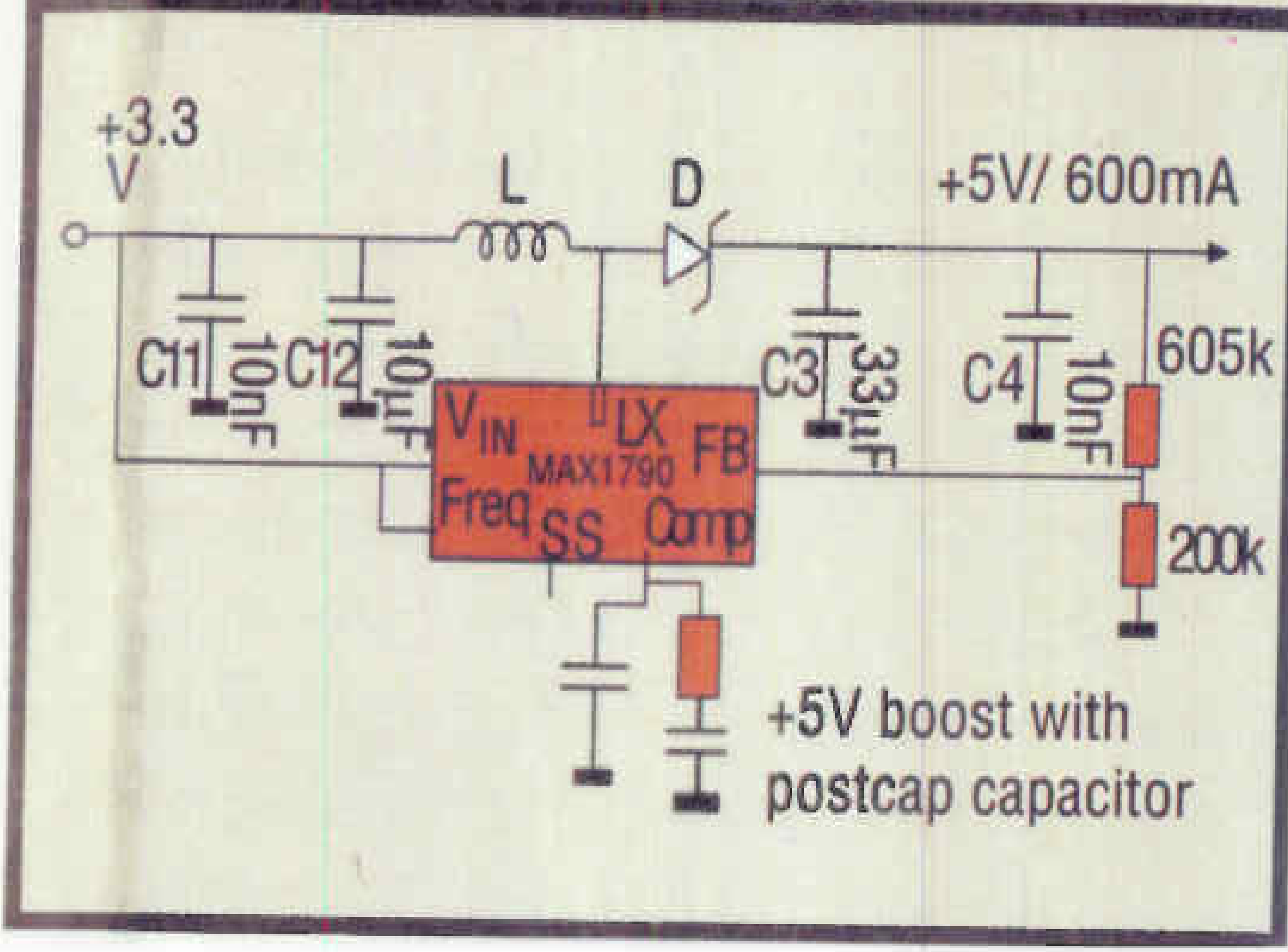


Once the fault illustrated in Fig. 9 has been cleared, the capacitor will continue to function with the only measurable damage being a small loss of capacitance.

- Specialty Polymer Aluminum
  - Very Low ESR (10-50mohm)
  - High capacitance
  - Small size
  - Limited suppliers



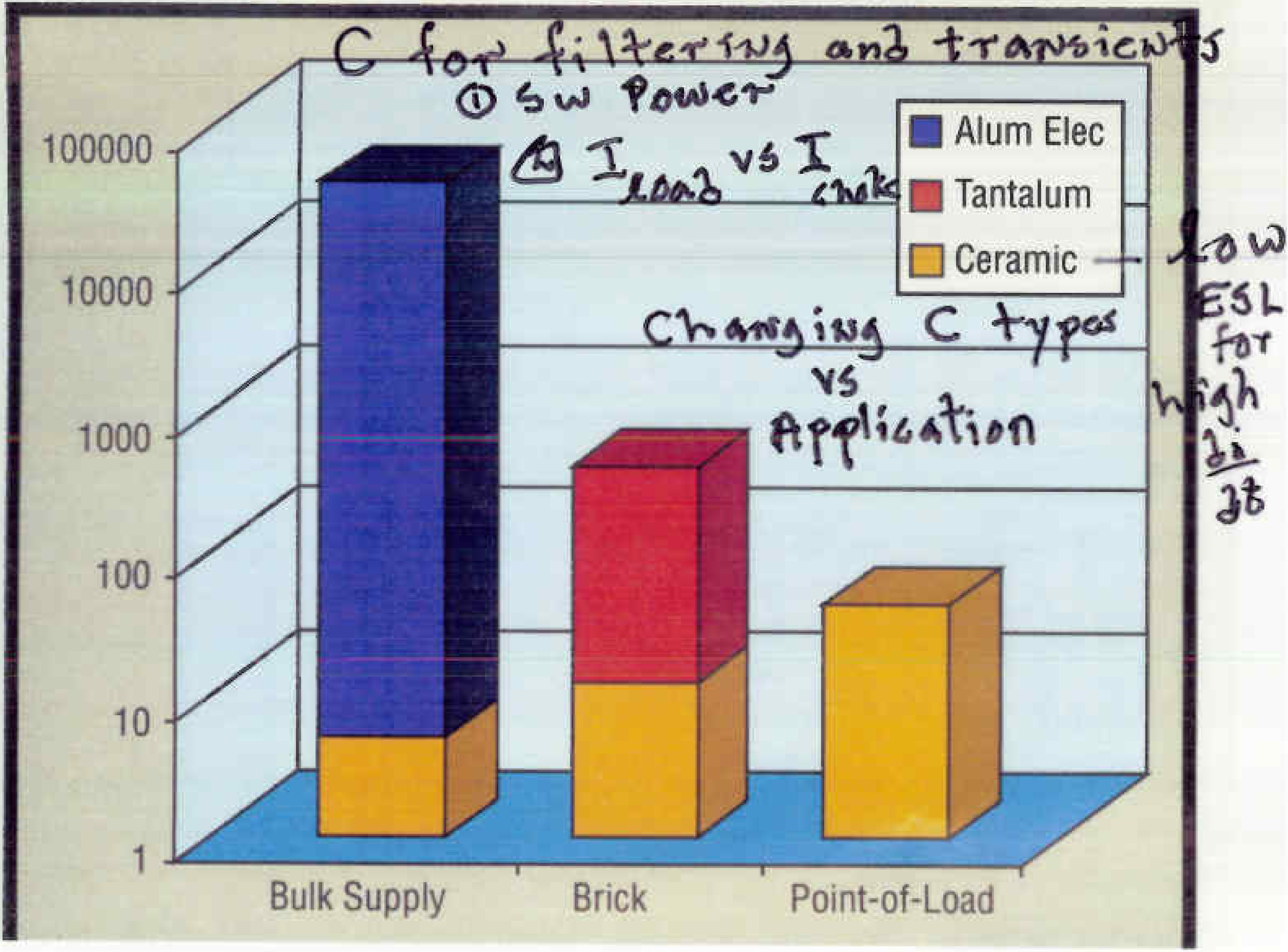
+5V boost with ceramic capacitor



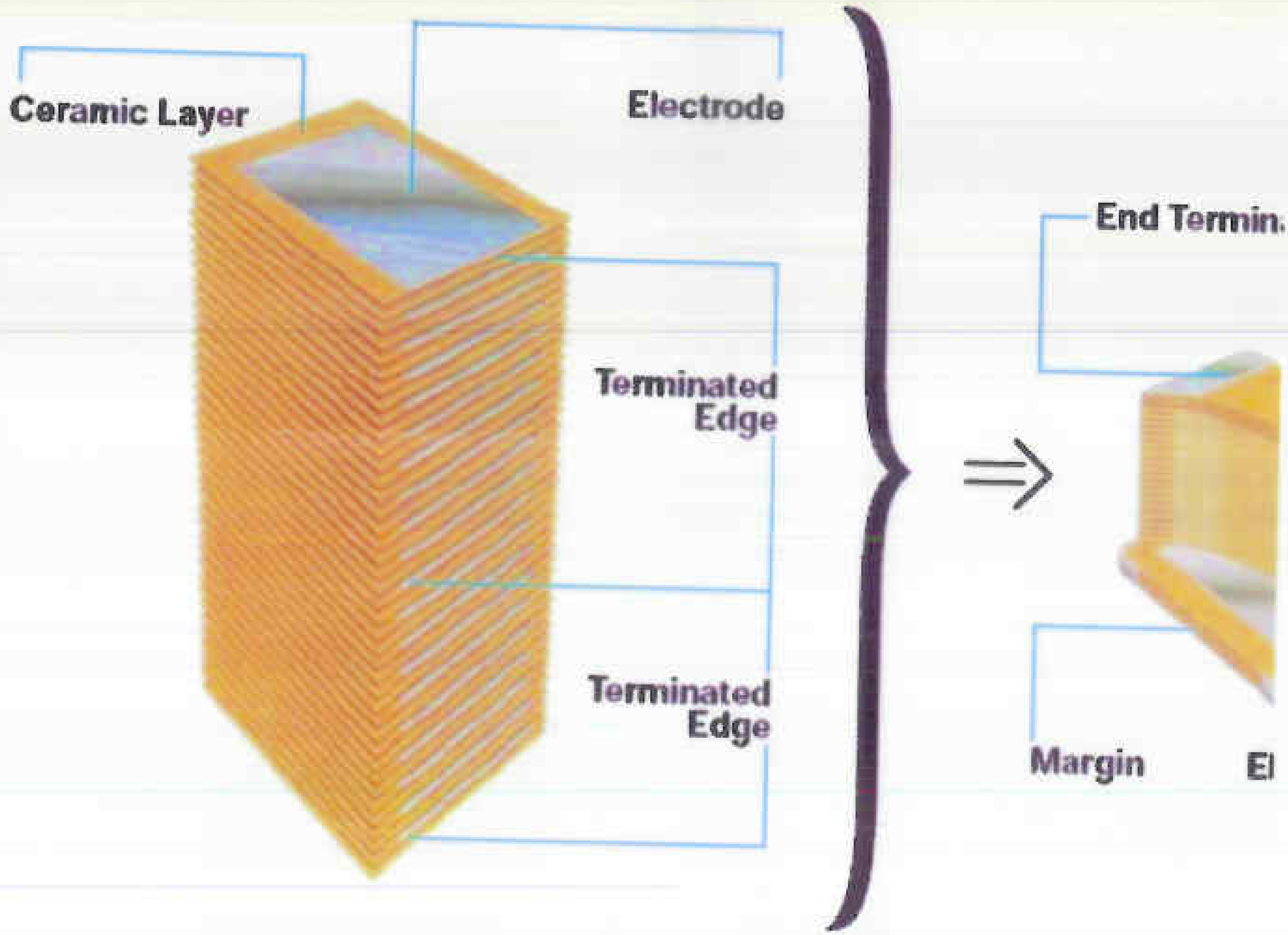
+5V boost with postcap capacitor

Parameter	Electrolytic	Metallised Polypropylene
Capacitance value (original)	32.4mF ↘ 6x –	
Capacitance value (final)		5.4mF
Configuration	48 caps, 24 in // x 2 in series	3 units in parallel
Nominal dc voltage	480V x 2 (800V)	1000V
r.m.s. current	1000A at 2kHz	900A at 2kHz
Max. thermal rating		456A (x3) at 50°C
Max. operating temperature	50°C	50°C
Overall volume	86.4 litres	28.5 litres *3 smaller
Inductance		~20nH for 3 units in parallel
ESR (total)	2.1mΩ	0.1mΩ *20 smaller
Surge voltage	1.1 x Un	2 x Un
Price comparison (caps only)		95% of electrolytic solution

More V rails | lower |V|, Faster f



- Ceramic
  - X5R or X7R best temperature coefficient
  - Lowest ESR (1-10mohm)
  - Can generate audible noise in some applications
  - DC Bias reduces capacitance
  - Small size, Low cost



Multilayer Ceramic Capacitor

Figure 1

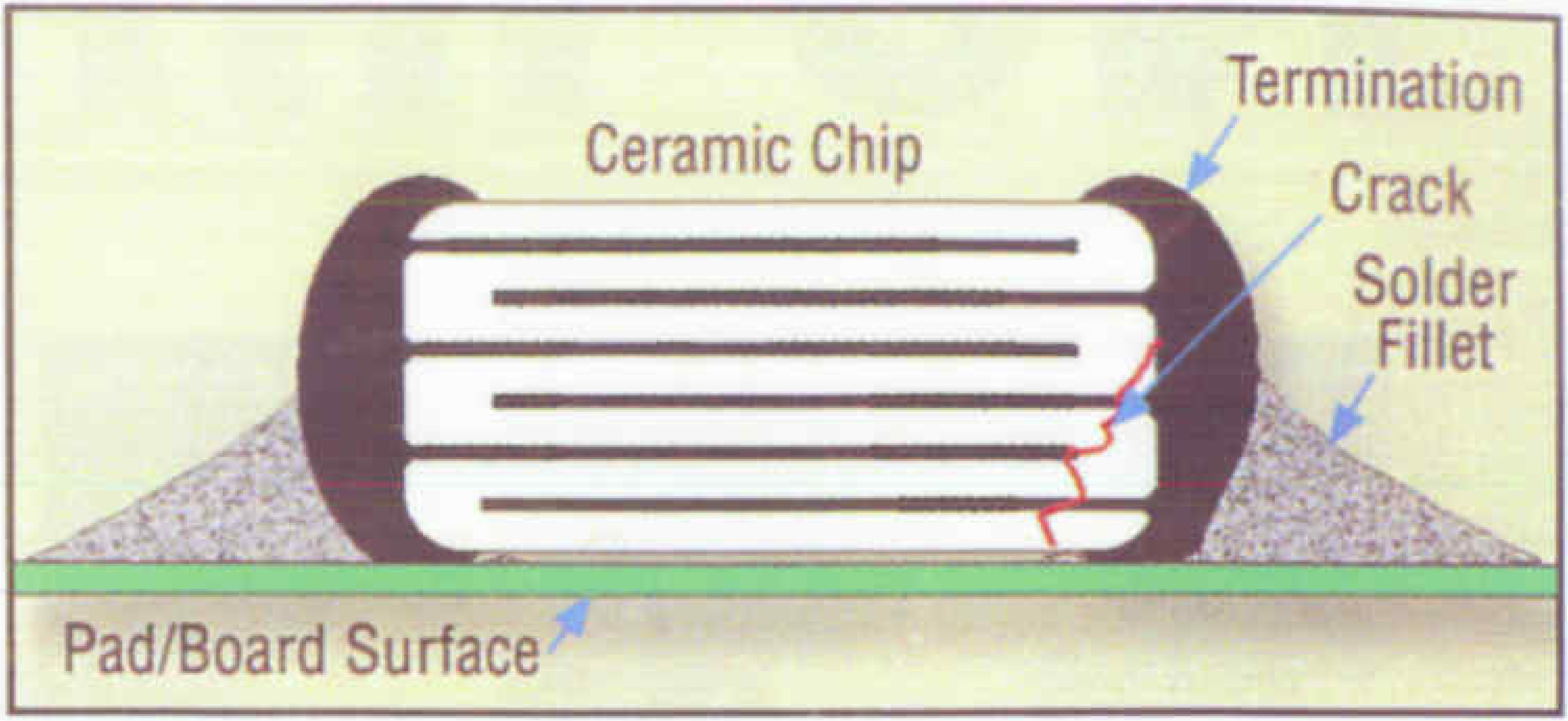


Fig. 1. *A multilayer ceramic capacitor exhibits cracking.*

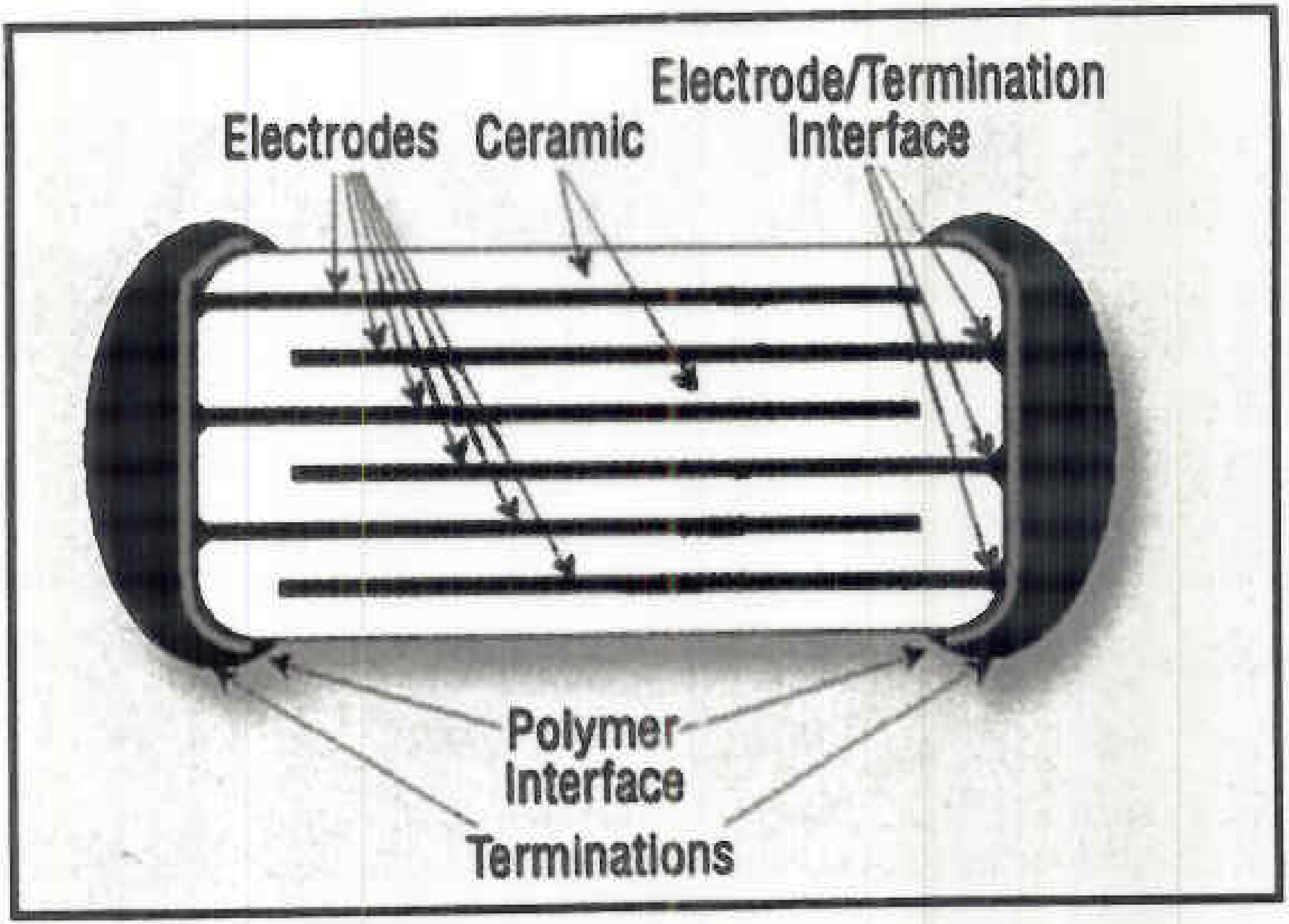


Fig. 3. *The addition of a conductive polymer termination layer improves the mechanical flexibility of a ceramic capacitor.*

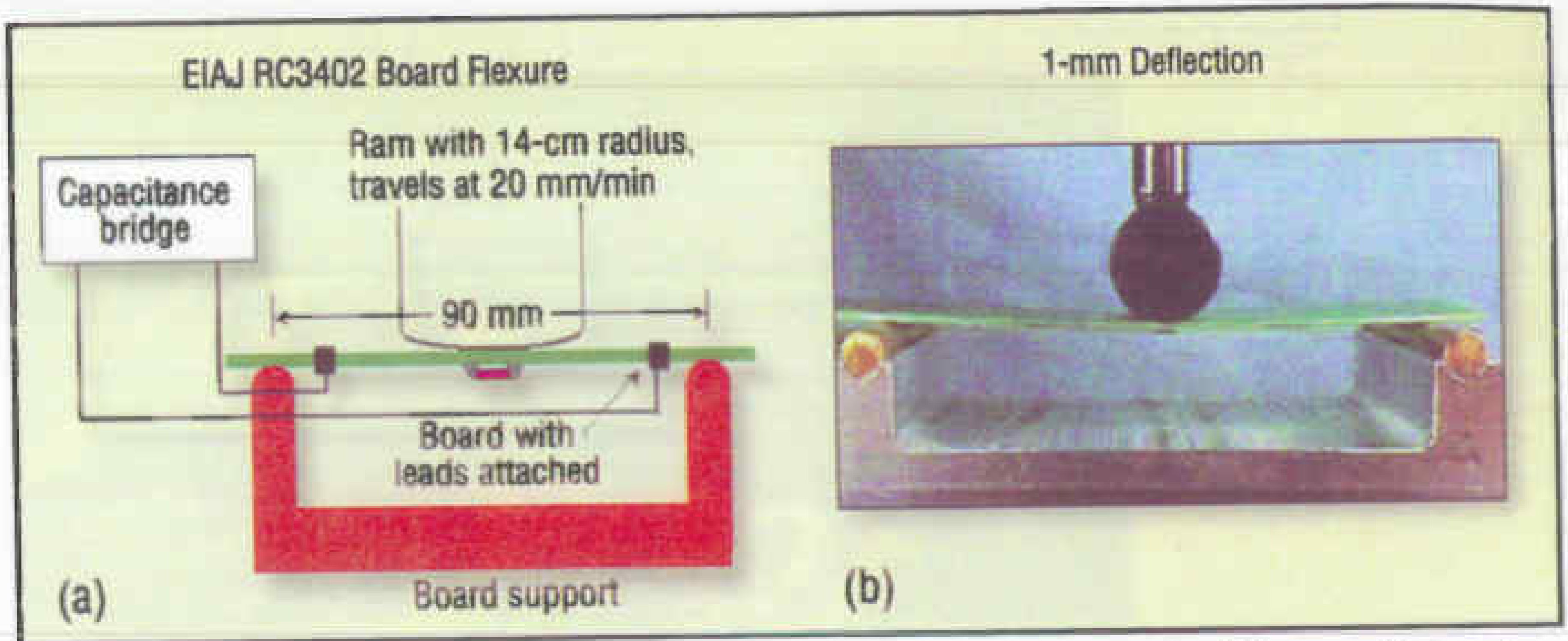


Fig. 4. *EIAJ RC3402 specifies the above setup (a) to measure a capacitor's ability to withstand flexing. If deflection produces a capacitance shift, the capacitor fails. A 1-mm deflection is used as an acceptance level for no failures (b).*

$R_{ESR} < \frac{R_{Tantalum}}{100}$