Capacitance vs Voltage

ClassII dielectric materials also change their capacitance value over time and with applied DC voltage, AC voltage. The effect over time is called aging and tends to lower the capacitance. The application of DC voltage tends to lower the capacitance, whereas the application of AC voltage (within a small signal range) tends to increase the capacitance.

Capacitance vs Temperature

027

Dielectrics vary in their response to the temperature and voltage. EIA created classifications of material called Class I and Class II and further nomenclature for the amount of variation in the Class II dielectrics. Due to the inherent ESR, the capacitor self heats during operation raising its temperature. The capacitance value chosen to be used in the application must include this potential change over the temperature.

- The variation in the Class I materials is specified in ppm (parts per million). It is typically less than 3000ppm (< 0.3%), so it will be ignored in this discussion. EIA standard EIA-198-D specifies a 3digit code to name classI and classII materials. See the netlink for the details of classI naming. One particular noteworthy classI type is C0G (C stands for 0, 0 often confused as letter O is multiplier of 0 and G stands for +/- 30ppm). This type is also called NPO (negative positive zero, meaning zero change for either positive or negative change in temperature). EIA standard The table below lists codes used for Class II materials, more commonly seen.

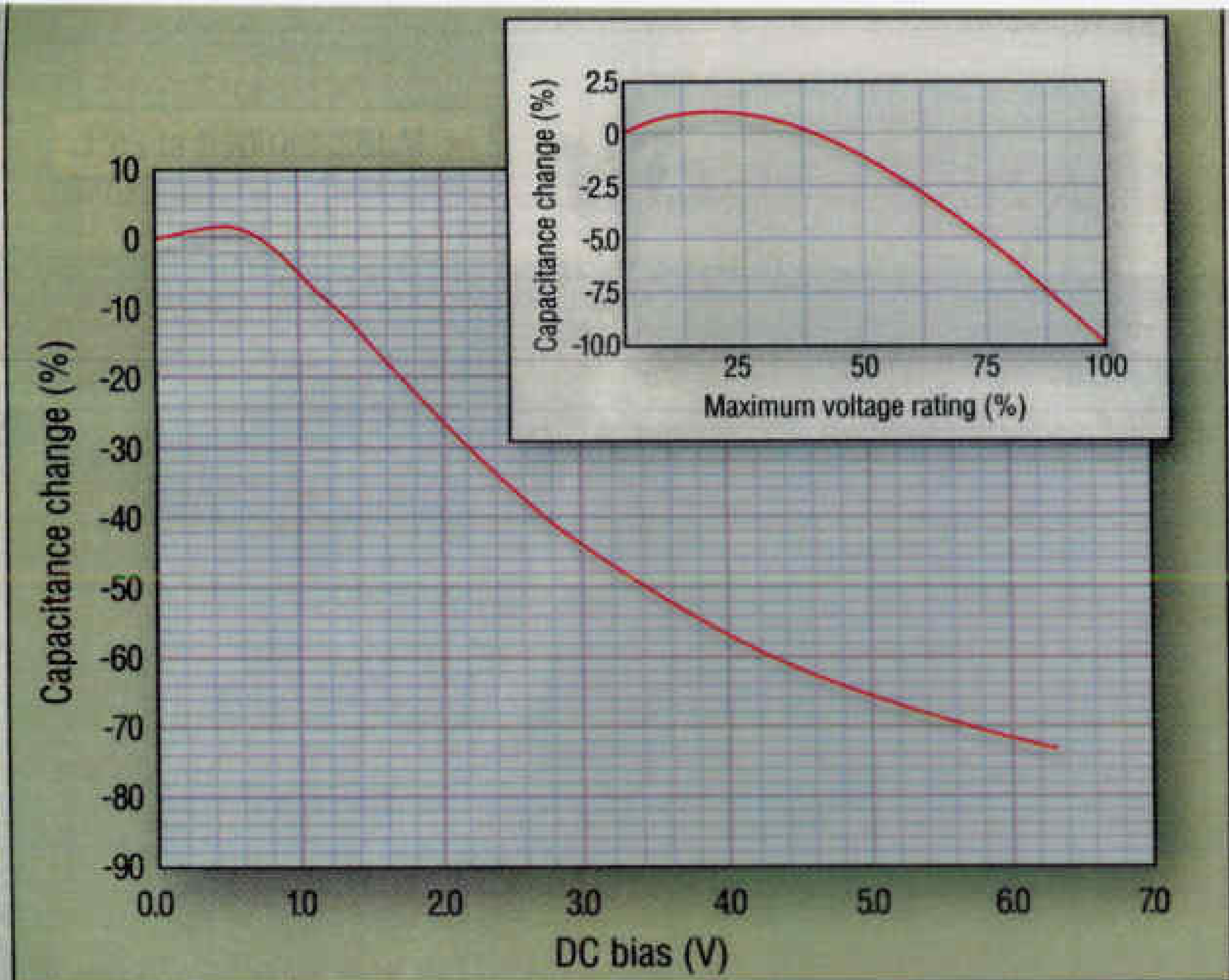


Fig. 2. *DC-bias effects for the X7R and X5R paint a dramatically different picture. At 28% of rated voltage, the capacitance is down almost 25% for the X5R.*

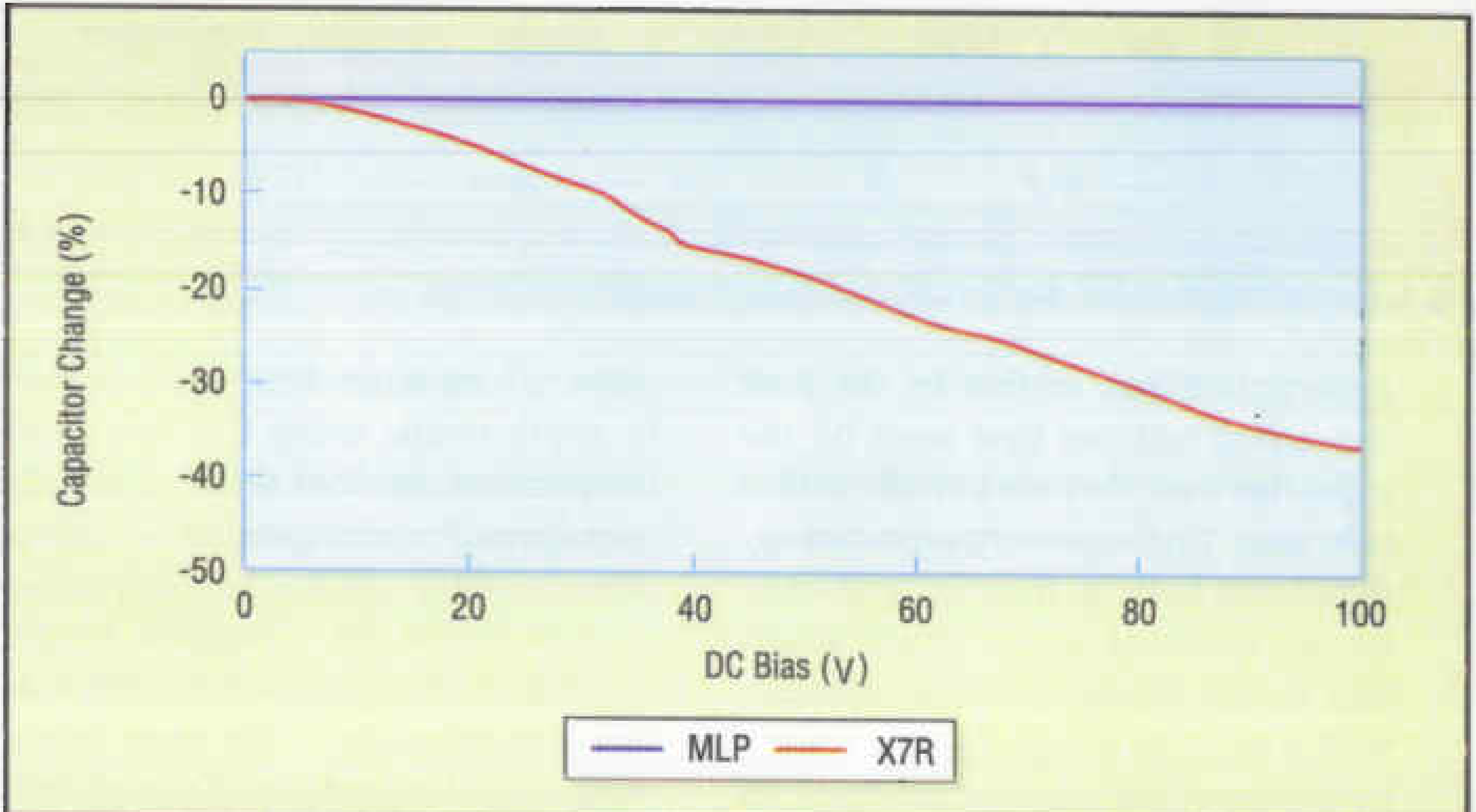
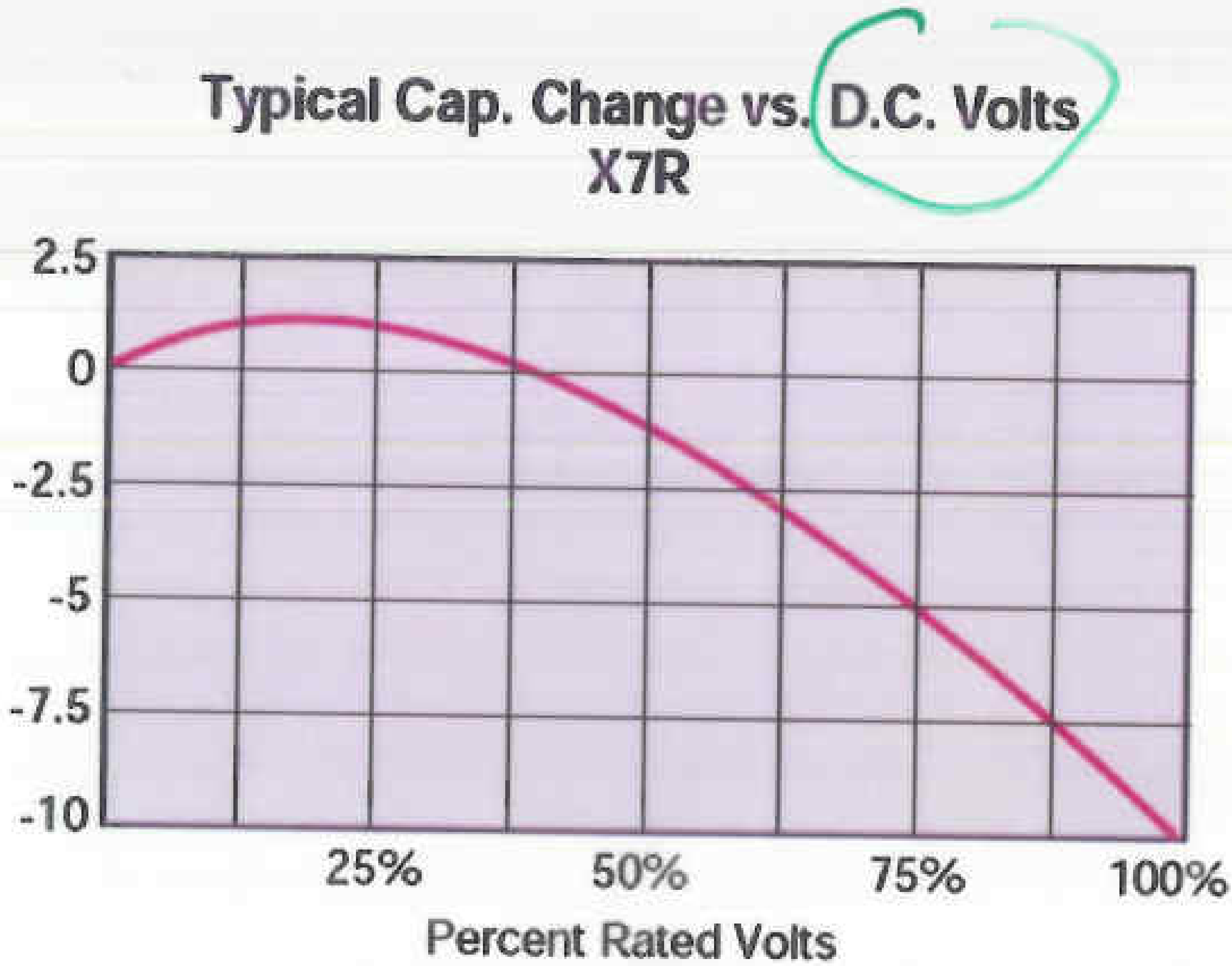
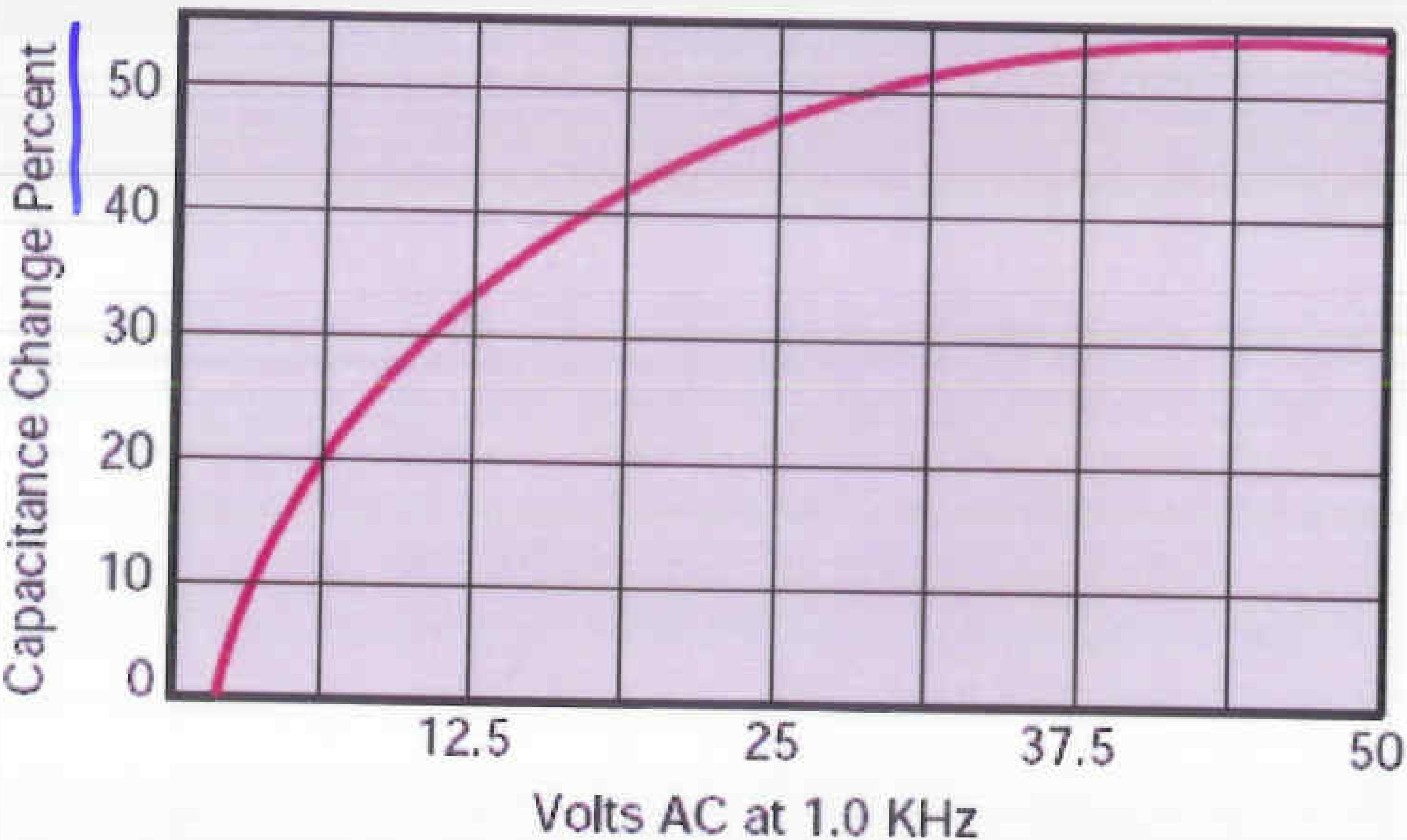


Fig. 7. *A multilayer ceramic capacitor loses capacitance as the dc bias voltage increases, while a multilayer polymer capacitor maintains a constant value.*


Typical Cap. Change vs. D.C. Volts
X7R
2.5
0
-2.5
-5
-7.5
-10
25%
50%
75%
100%
Percent Rated Volts

Cap. Change vs. A.C. Volts
X7R



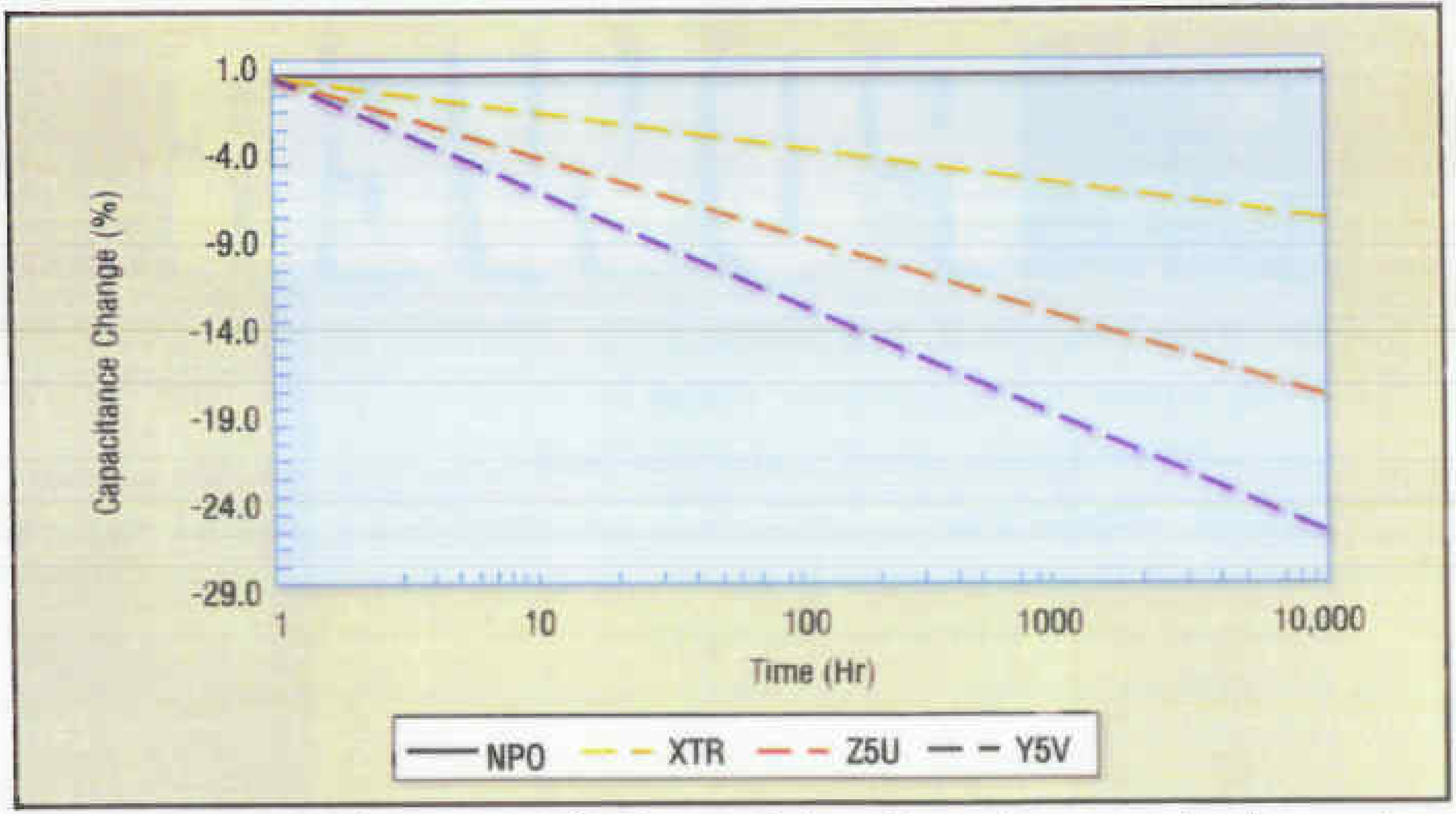


Fig. 6. *The choice of dielectric material influences the loss of capacitance over time in ceramic capacitors.*

Dielectric/ capacitor type	Typical dielectric constant	Typical aging rate (%)
Ceramic NPO	65	None
Ceramic X7R	2000	1.5 to 2.5
Ceramic BX	4000	3 to 4
Ceramic Z5U	8000	4 to 5
Ceramic Y5V	10,000	6 to 7
Ceramic (BP) capacitors	—	±21* (-2.5 to -4 per decade hour)
Ceramic (BP) capacitors	—	1.25 to 2.1
Tantalum (CSR) capacitors	—	±10

Table. *Aging rates of various dielectric types. *MIL-HDBK-1547A is considered overly pessimistic.*

$(1 - A \quad)$

EIA Class 2 TCC Designations

First Character: Defines the low temperature limit.

X = -55 °C Y = -30 °C Z = +10 °C

Second Character: Defines the high temperature limit.

5 = +85 °C 7 = +125 °C

Third Character: Defines the maximum capacitance change in percentage.

V = +22, -82%	R = ±15%
U = +22, -56%	P = ±10%
T = +22, -33%	F = ±7.5%
S = +22%	E = ±4.7%

Low ESR Chip Capacitors

The S-Series line of low ESR, high Q, high frequency multilayer ceramic capacitors is made with a proprietary combination of low loss dielectric and a highly conductive electrode system. This process lowers their equivalent series resistance. They are offered in 0201, 0402, 0603, and 0805 sizes, and in capacitance values from 0.2 pF to 220 pF.

Johanson Technology Inc., Camarillo, Calif.

Circle 315

Tantalum Chip Capacitor

The organic polymer KO-CAP (T520B) offers high capacitance in a smaller footprint. Used as a drop-in replacement for a 1210 high-capacitance ceramic, it can save board space as a replacement for C- and D-sized tantalum chips. With reduced ESR (70mΩ), there is enhanced capacitance retention in higher frequencies as compared to a standard MnO_2. It is offered in the "B" case size in 47μF rated at 6.3V, 68μF at 4V, and 100μF at 3V.

KEMET Electronics, Greenville, S.C.

Circle 317

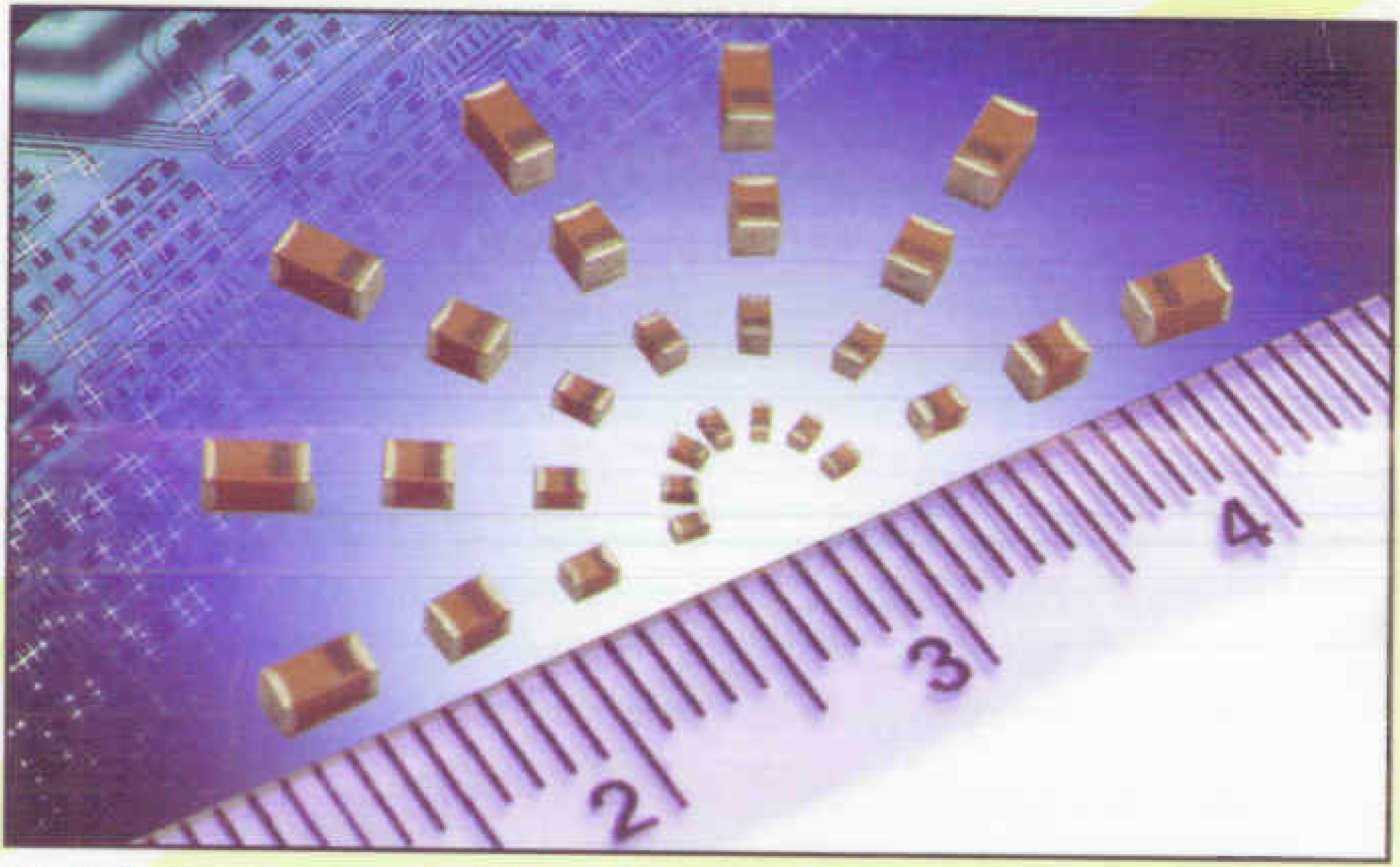
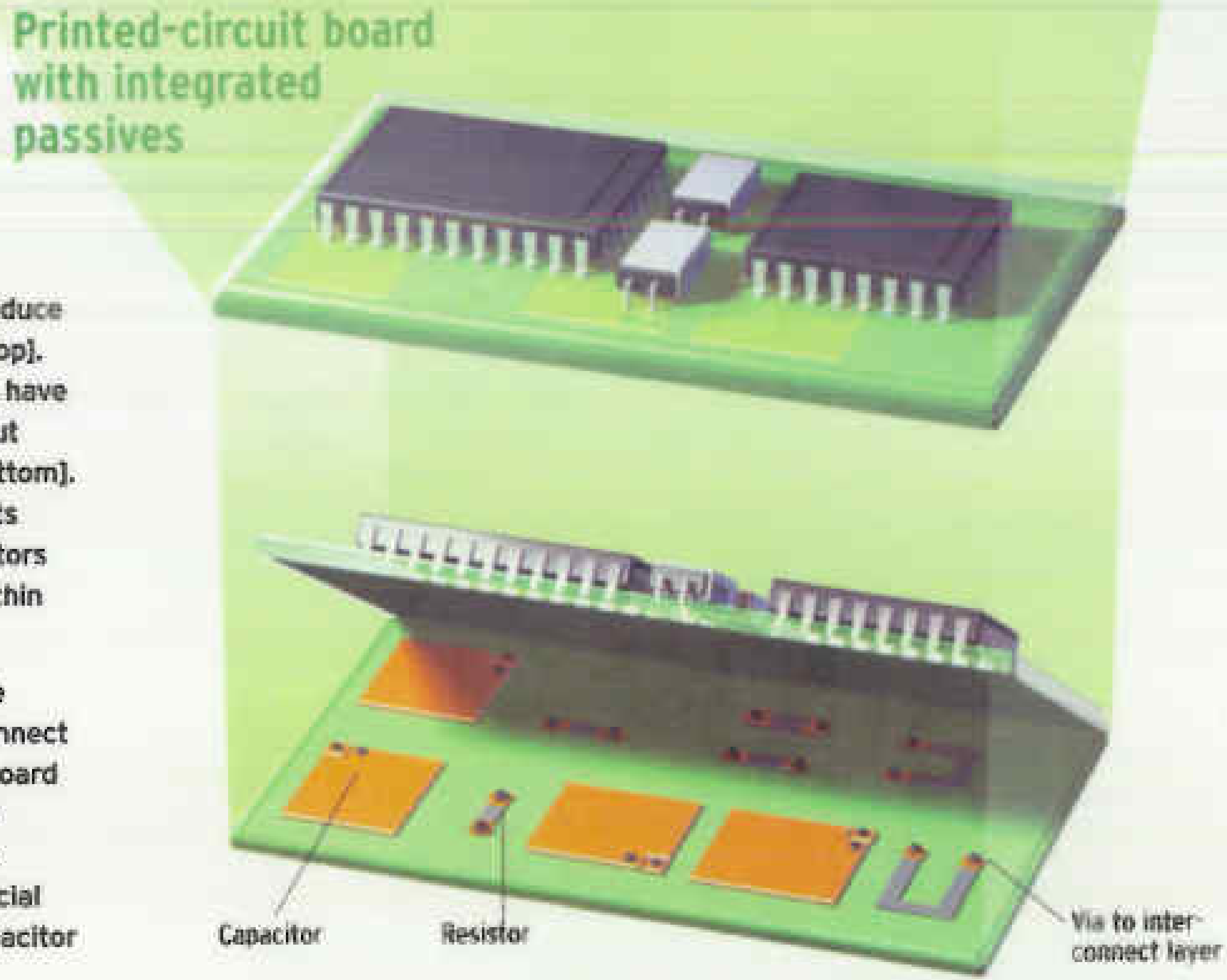


Fig. 3. *A growing trend with passive components is the migration to small case sizes. AVX's TACmicrochip series of tantalum chip capacitors deliver up to 10 µF in an 0402 case.*



Size Matters

Integrating passives can drastically reduce the size of an ordinary circuit board [top]. Here, four capacitors and six resistors have been removed from the surface and put into an extra layer of circuit board [bottom]. Resistors are copper connection points bridged by a resistive film, and capacitors are conductive plates separated by a thin film of dielectric material.

After the board is laminated, holes are drilled and plated to form vias that connect the integrated components to other board wiring. Not every value of passive can be replaced by an integrated one; two remain on the surface. Some commercial processes would require separate capacitor and resistor layers.

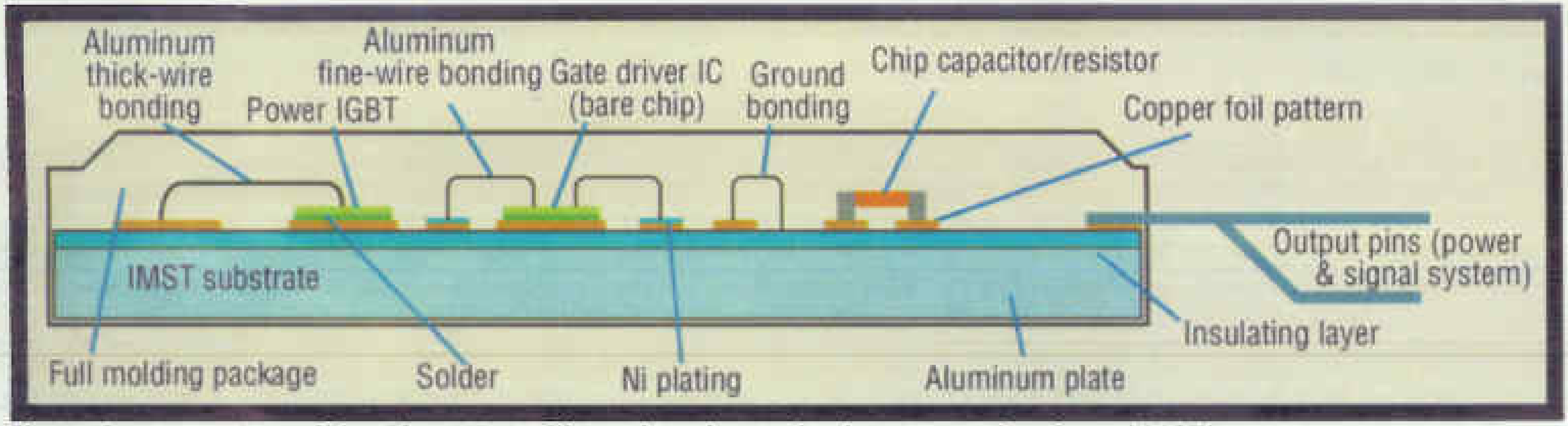
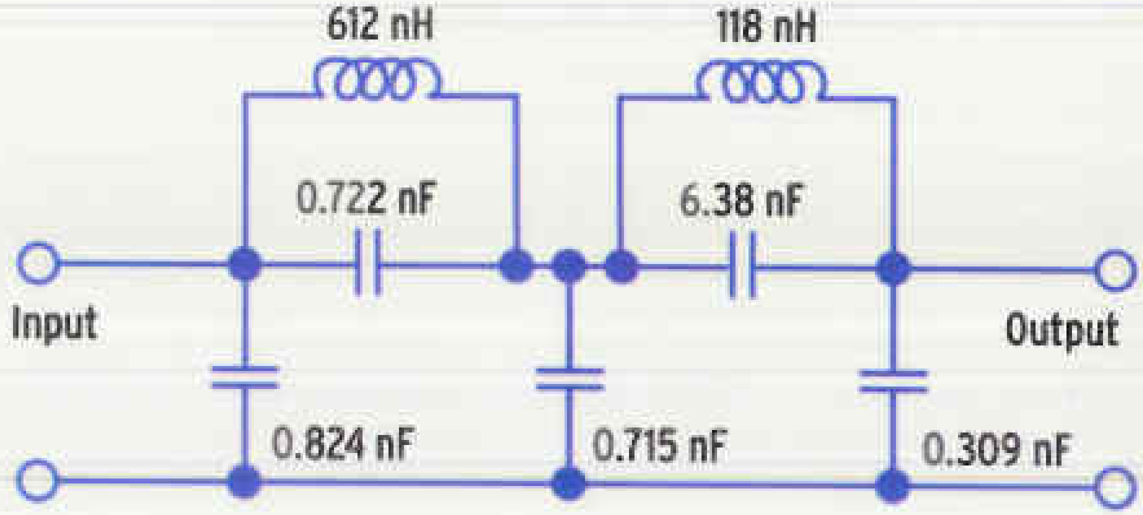
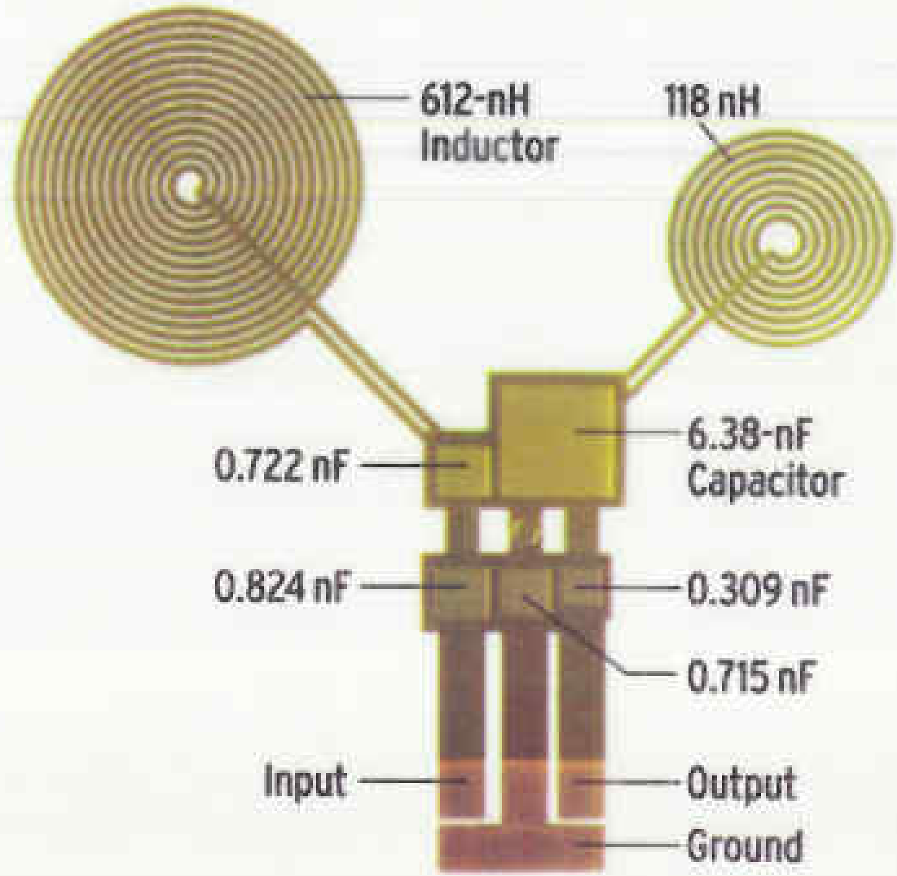


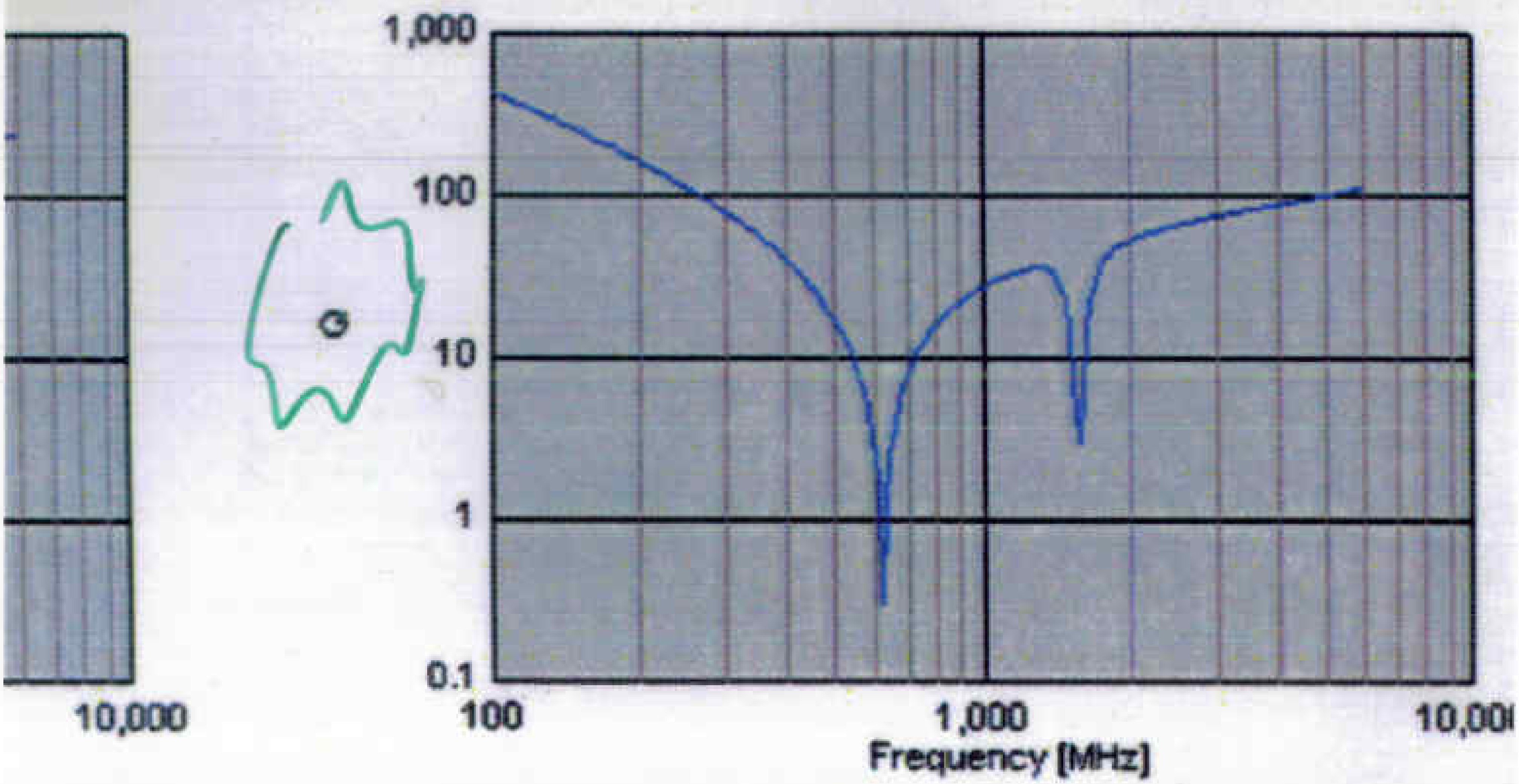
Fig. 5. *Cross-section of the PlugNDrive™ insulated metal substrate technology (IMST).*

A Very Flat Filter

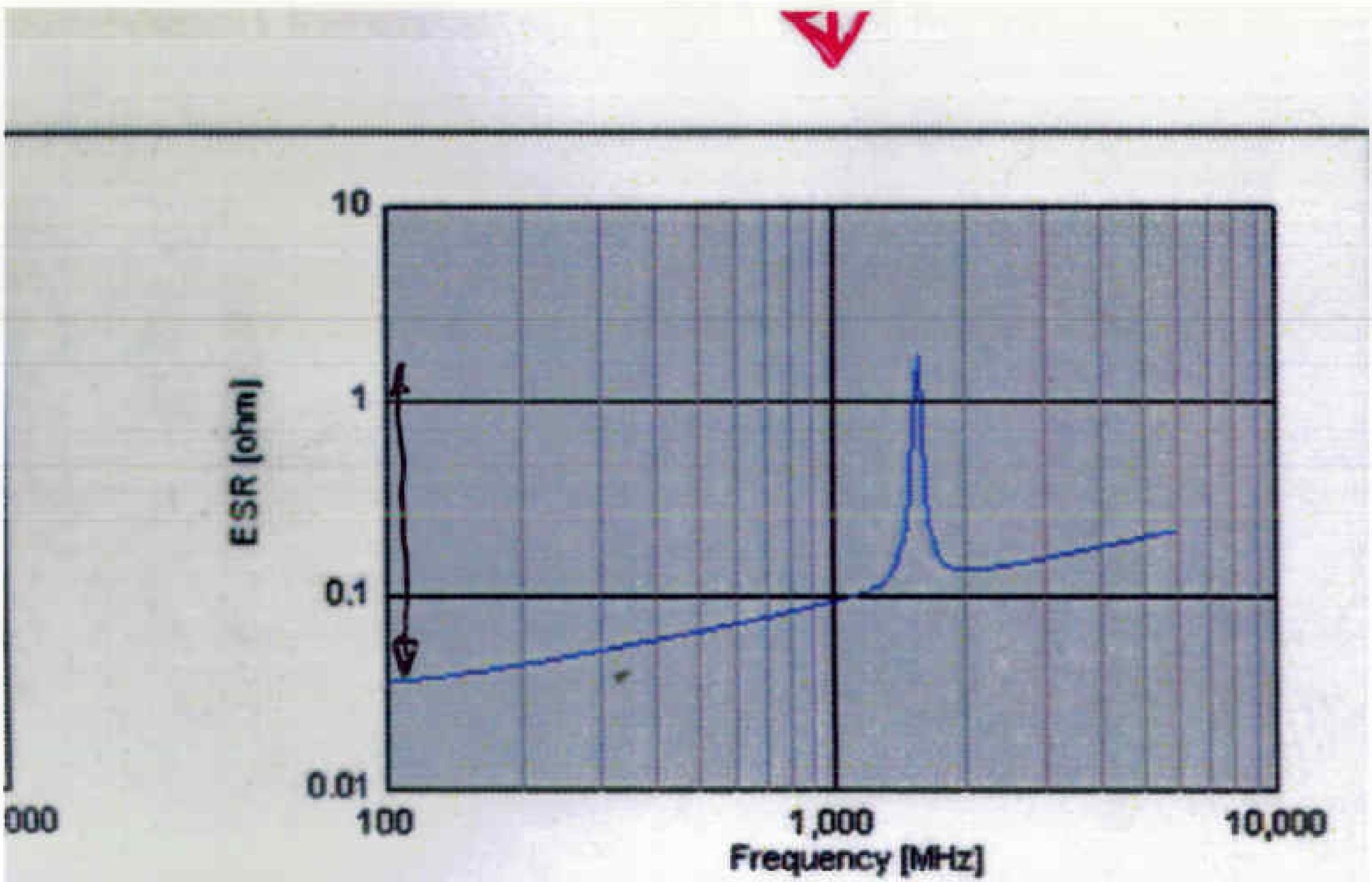
Inductors are angled away from each other to avoid crosstalk in this low-pass filter that fits between the layers of a circuit board. Designed by one of the authors, and built by Integral Wave Technologies (Fayetteville, Ark.) for NASA's Langley Research Center, the thickest part of this filter is less than 6 µm. Capacitors are made from a thin-film oxide, inductors from copper.







(b)



(c)