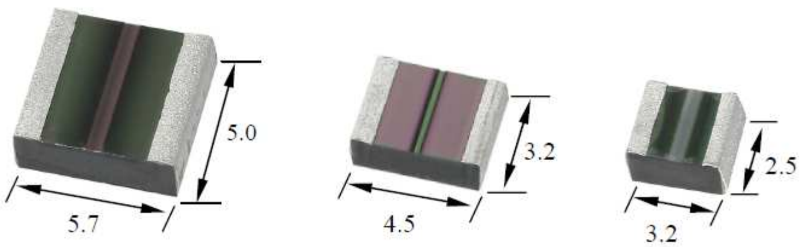
FEATURES AND APPLICATIONS OF
POLYMER THIN FILM MULTI-LAYER CAPACITOR "PML CAP"

PML CAP

Polymer Multi-Layer Capacitor (PML CAP) is a surface mounting capacitor with multiple metal-deposited polymer layers that are continuously laminated together with metal deposition on a polymer film.
This PML CAP has been developed by Rubycon's original vacuum deposition technology, and realizes drastic downsizing against conventional film capacitor.

FEATURES

- Construction and Equivalent Circuit
  The appearance and construction of PML CAP are shown in Photo 1 and Fig. 1 respectively. The equivalent circuit of the capacitor is also shown in Fig. 2, in which both of "Rd" and "Cd", which are arising from dielectric absorption, can be negligible in usual applications.



(a) 5750 Size (b) 4532 Size (c) 3225 Size

Photo 1 Appearance of PML CAP (Unit: mm)

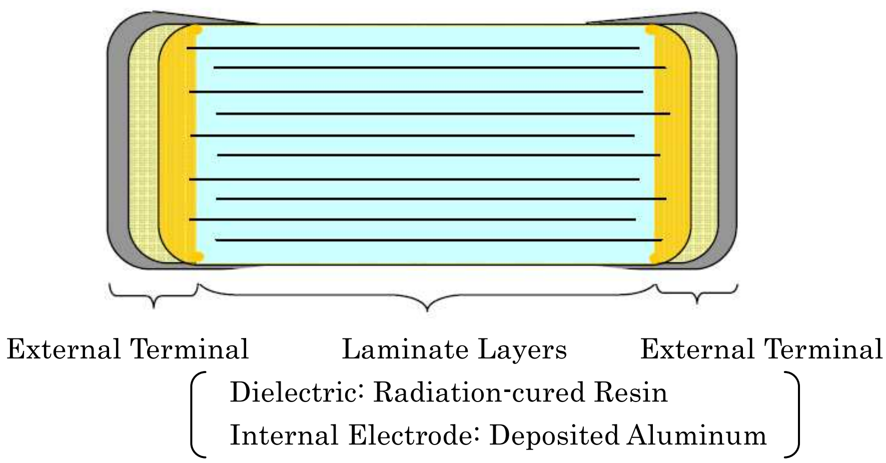


Fig. 1 Construction of PML CAP

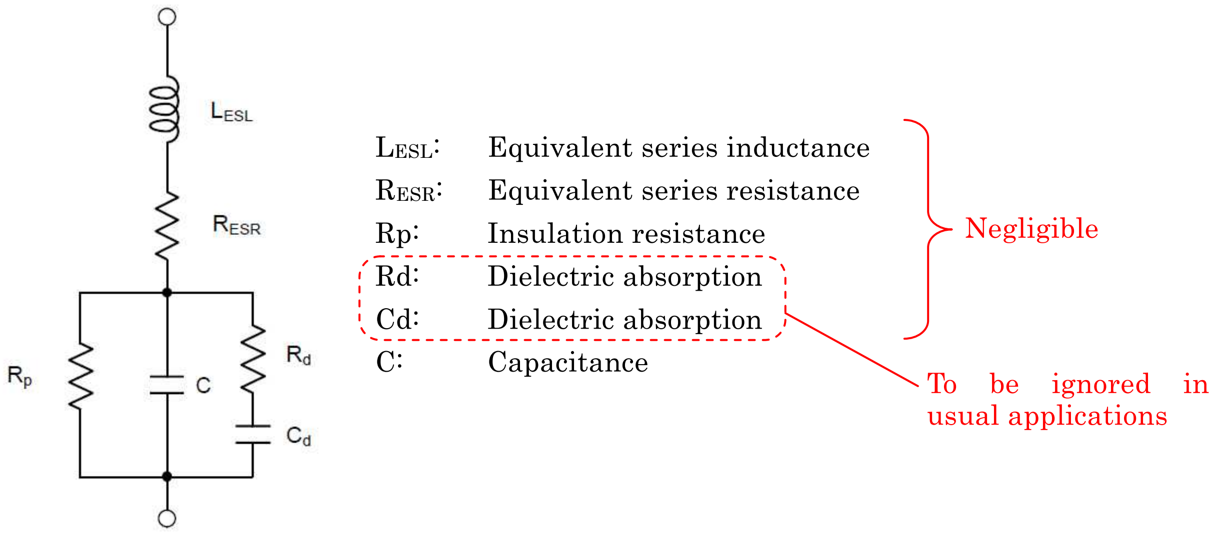


Fig. 2 Equivalent Circuit

PML CAP has quite thin dielectric films produced with vacuum deposition, so that size is about a tenth of a conventional film capacitor.

- Electric Characteristics

Specifications of PML CAP are shown in Table 1, and the comparison with other SMT capacitors is shown in Table 2.
Electric characteristics are equivalent to those of polyester film capacitor.
PML CAP has many advantages against Multi-Layer Ceramic Capacitor (MLCC) such as less howling, less dielectric absorption and no capacitance loss at application of DC voltage, since it has no piezoelectric effect.

Table 1 Specifications of PML CAP

Item	Specification
Capacitance Tolerance	±20% (M)
Dissipation Factor (tan δ)	≤1.5%
Withstand Voltage	To be free of abnormality when the voltage as high as 150% of the rated one is applied for 1 minute or when the voltage as high as 175% of the rated one is applied for 1 to 5 seconds.
Insulation Resistance	300MΩ･μF

Table 2 Comparison of PML CAP with other SMT Capacitors
(other than electrolytic capacitor)

Capacitor	PML CAP	Film Multi-Layer Cap.	MLCC
Dielectric	Radiation-cured Resin (Acryl)	Resin Film (PEN, PPS)	High-permittivity Ceramic ($BaTiO_3$)
Thickness of Dielectric	<1μm/layer	≥3 μm/layer	<1μm/layer
Dielectric Constant	Approx. 3	Approx. 3	2,000 – 5,000
Internal Electrode	Deposited Al	Deposited Al	Nickel Paste
Rated Voltage	16 – 63VDC	10 – 250VDC	2.5 – 3,150VDC
Capacitance	0.1 – 22μF	0.001 – 1 μF	68p – 100 μF
Temperature Range	-55 – +125°C	-55 – +125°C	-55 – +150°C (X8R)
Size	Middle	Large	Small
Features	Less noise and excellent DC bias characteristic because of no piezoelectric effect	Less noise and excellent DC bias characteristic because of no piezoelectric effect	Poor DC bias characteristic because of piezoelectric effect. Temperature compensation type has good DC bias characteristic with less compact size

- Heat Resistance

  PML CAP uses a thermosetting resin as dielectric material with the thermal weight loss starting point over 300°C, so as to ensure high heat resistance.

ELECTRIC CHARACTERISTICS

Electric characteristics of PML CAP are compared with those of high-permittivity ceramic capacitor.

- Impedance-Frequency Characteristic

  Performances of impedance and equivalent series resistance (ESR) against frequency, which are important in use for passing capacitor, are shown in Fig. 3.

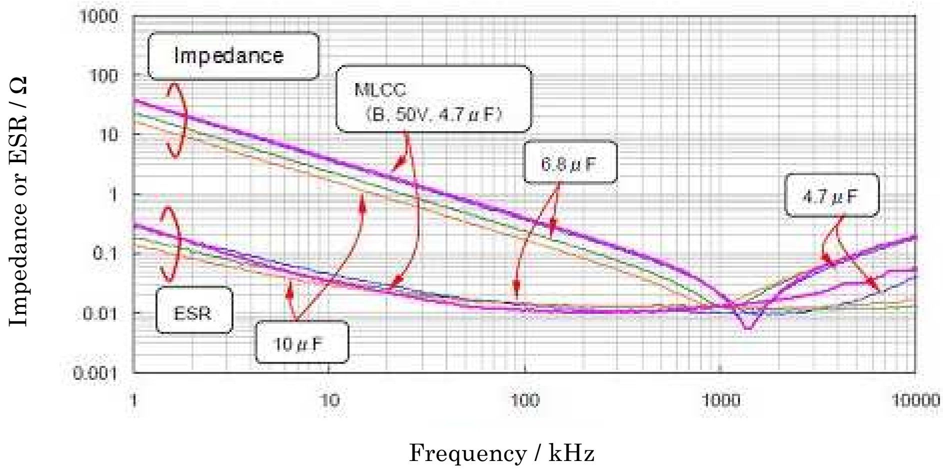


Fig. 3 Impedance/ESR vs. Frequency

PML CAP has small values of ESR and ESL (equivalent series inductance), which are close to those for MLCC.

- DC Bias Characteristic

  DC bias characteristic important for the use as passing or coupling capacitor is shown bin Fig. 4. PML CAP has no capacitance fluctuation when DC voltage is applied, since it has no piezoelectric effect. It is the major advantage against MLCC. For example, MLCC with the rated voltage of 50V is much smaller in size than PML CAP of the same capacitance. However another MLCC capacitor with much higher capacitance is required to use at 25VDC in order to work in the same capacitance as PML CAP, so that actual size of MLCC at 25VDC will be close to PML CAP.

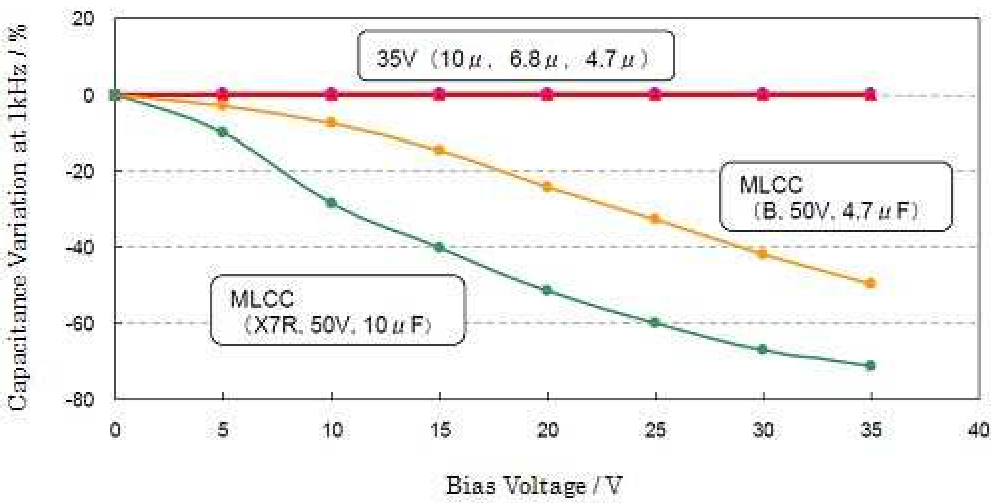


Fig. 4 Capacitance vs. DC Bias Voltage

- Temperature Characteristic

  Temperature characteristic, important to input coupling or filter capacitor, is shown in Fig. 5. Capacitance variation factor between -55°C and +125°C is about +520ppm/degree.

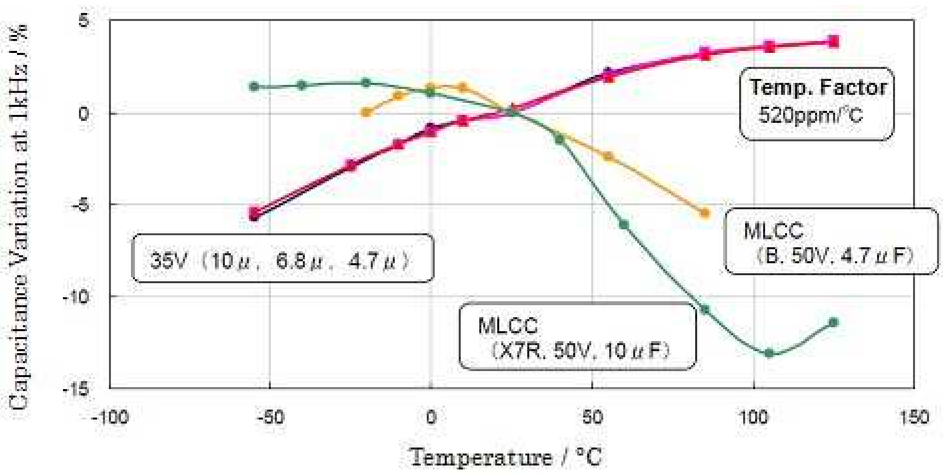


Fig. 5　Capacitance vs. Temperature

➢ Howling Characteristic

Howling characteristic, important for the use to silent instruments, is shown in Fig. 6. Fig. 6 (a) shows sound pressure level at 1.4kHz with the pulse of $3V_{peak}$. The difference in the level between PML CAP and MLCC is -20dB, that is the level of PML CAP is a tenth of the level for MLCC.

Fig. 6 (b) shows a result of howling-frequency characteristic when capacitor is mounted to a LCD backlight circuit. Noise of MLCC increases in the middle frequency range over 1kHz due to piezoelectric effect. Noise of PML CAP is high in the low frequency range under 1kHz due to Coulomb force. Thus PML CAP is superior to MLCC, because noise in the range between 1kHz and 10kHz is audible to humans so that capacitors with less noise in this range are preferable.

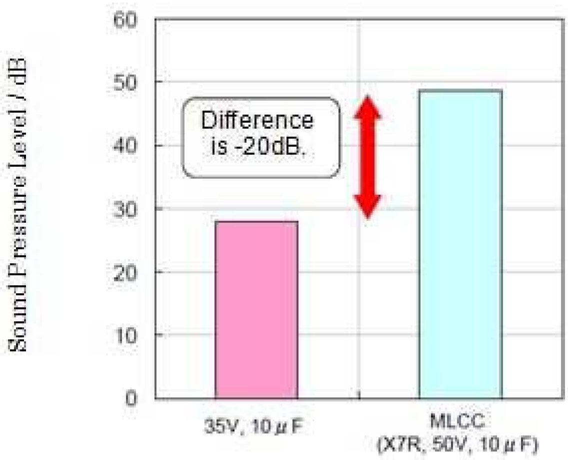


Fig. 6 (a)　Howling at 1.4kHz with 3Vpeak

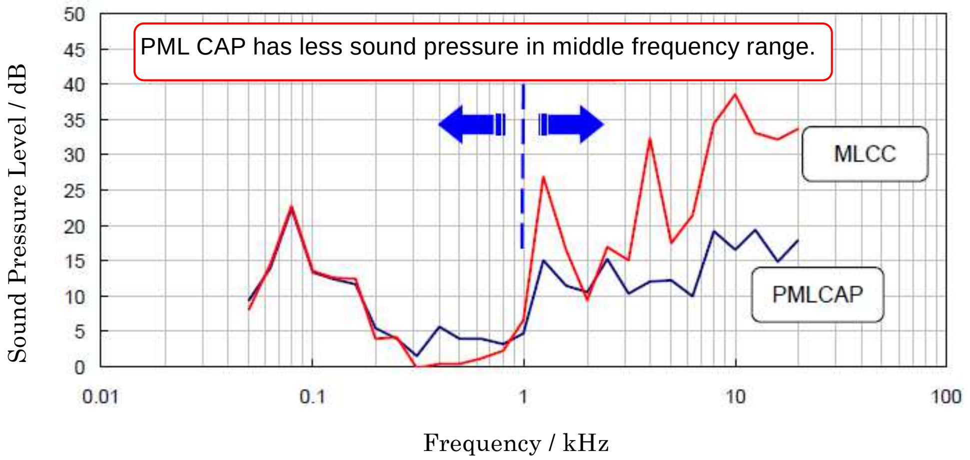


Fig. 6 (b) Howling-frequency Characteristic on LCD Backlight Circuit

- Dielectric Absorption

Dielectric absorption happens due to delayed polarization of dielectric. Fig. 7 shows dielectric absorption data for PML CAP and MLCC. The values in this figure are the highest ones regardless of time, while JIS specifies recurrence voltage to be measured at 5 minutes.

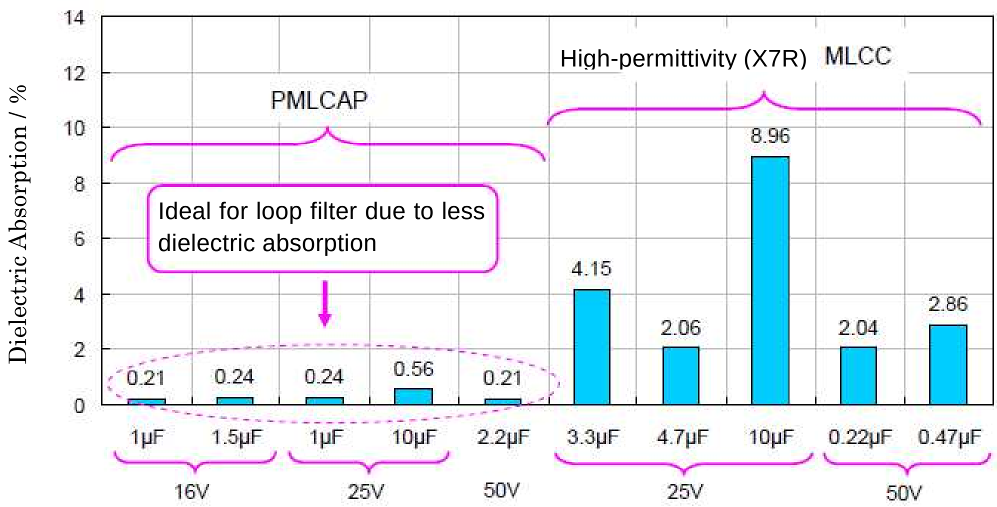


Fig. 7 Dielectric Absorption

Dielectric absorption of PML CAP is equivalent to that for polyester film capacitor, both of which are much superior to MLCC.

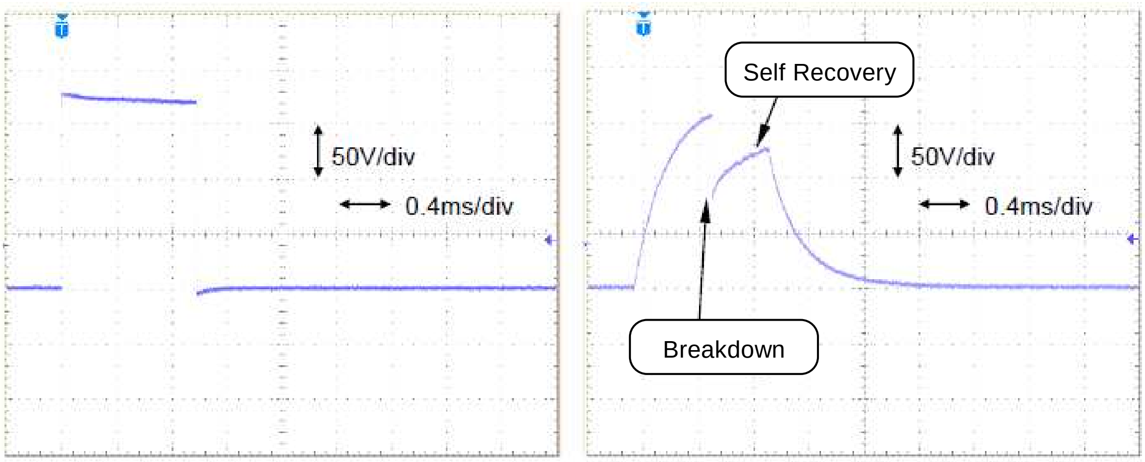
Without restriction in size, polypropylene film capacitor with large lead wires is more excellent in dielectric absorption. However PML CAP is the best capacitor having both of good dielectric absorption characteristic and small size.

- Self Recovery

If an excessive voltage pulse is applied to PML CAP to short-circuit it, insulation will be recovered through heating by current concentrated into short-circuited point, oxidation and evaporation of deposited metal layer, and spreading of dielectric and deposited metal. This self recovery ability is higher for the capacitor with higher deposition resistance and thinner deposit film. It is the evidence of safety of PML CAP.

The result of self recovery on a PML capacitor after forcible short circuit with excessive pulse voltage is shown in Photo 2. Photo 2 (a) is the waveform of the pulse ($186V_{peak}$ for 1ms). The waveform between terminals of a PML capacitor is shown in Photo 2 (b) when the pulse is applied through a resistor of 2Ω. Self recovery phenomenon is observed.

The capacitor once short-circuited should be replaced as soon as possible, since insulation resistance after the recovery isn't as high as the original value.



(a) Applied Pulse (Waveform at open) (b) Self Recovery Phenomenon

Photo 2 Self Recovery upon Excessive Pulse Voltage

- Allowable Ripple Current

Examples of allowable ripple current for PML CAP are shown in Fig. 8.

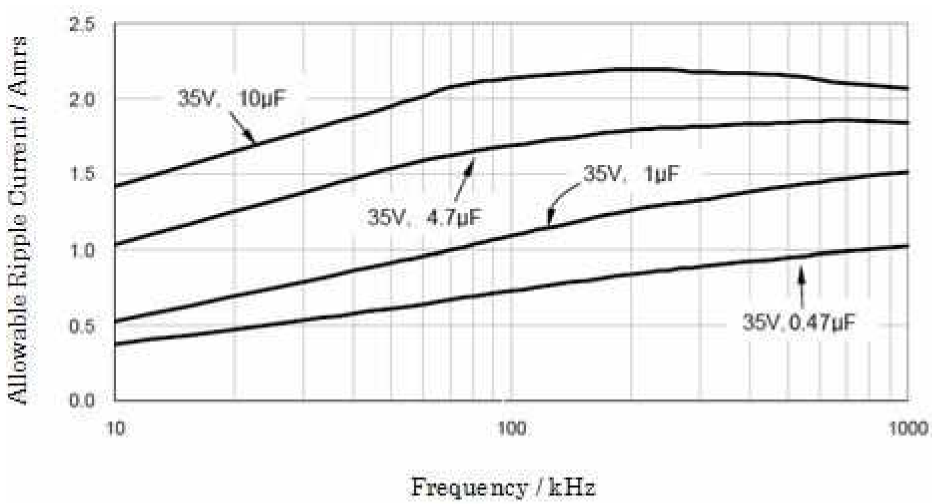


Fig. 8 Allowable Ripple Current for PML CAP

- Low leakage current characteristic
  PMLCAP employs thin plastic film as dielectric which has excellent characteristic of low leakage current compare to other capacitors. Graph.9 shows the comparison of leakage current among various capacitors. (16v 22uF)

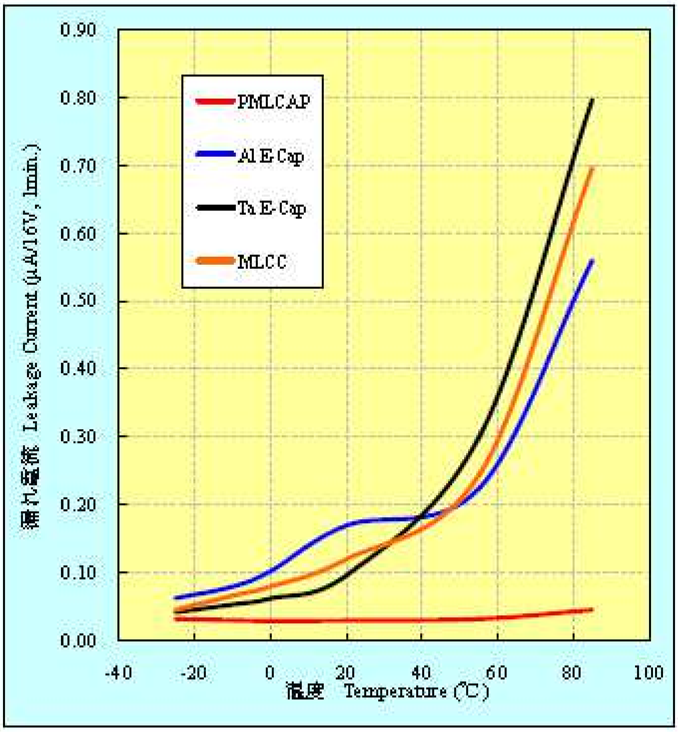


Fig. 9 Comparison of leakage current

TYPICAL APPLICATIONS

Typical applications of PML CAP include acoustic equipment making use of high sound quality, passing capacitor for power supply making use of less howling and loop filter for PLL (Phase Lock Loop) making use of less dielectric absorption and a storage capacitor for Energy Harvesting making use of low leakage current.

- Acoustic Equipment

An example of application in Class D Amplifier is shown in Fig. 10. PML CAP is good for DC-cut coupling capacitor and output filter. In sound quality, transparency in middle and high frequency range will increase. Use of PML CAP to output filter reduces filtering fluctuation, because capacitance variation is quite small.

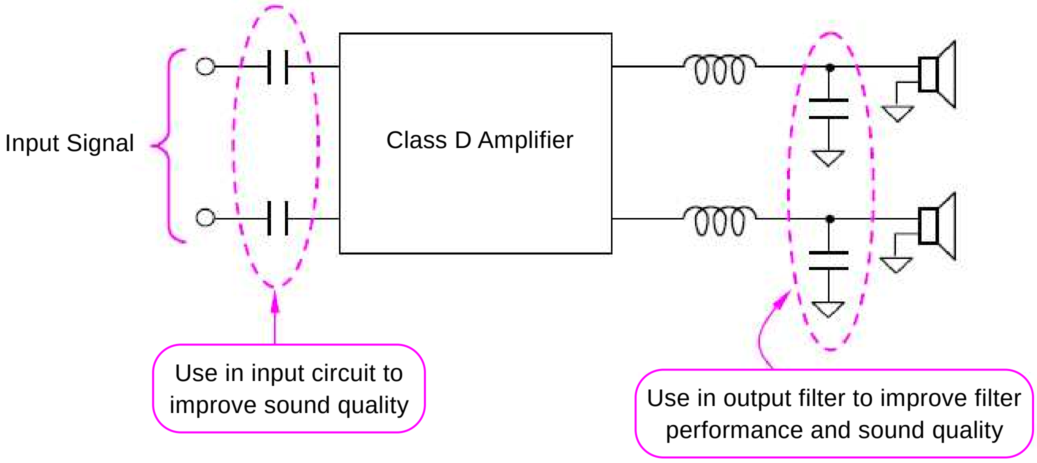
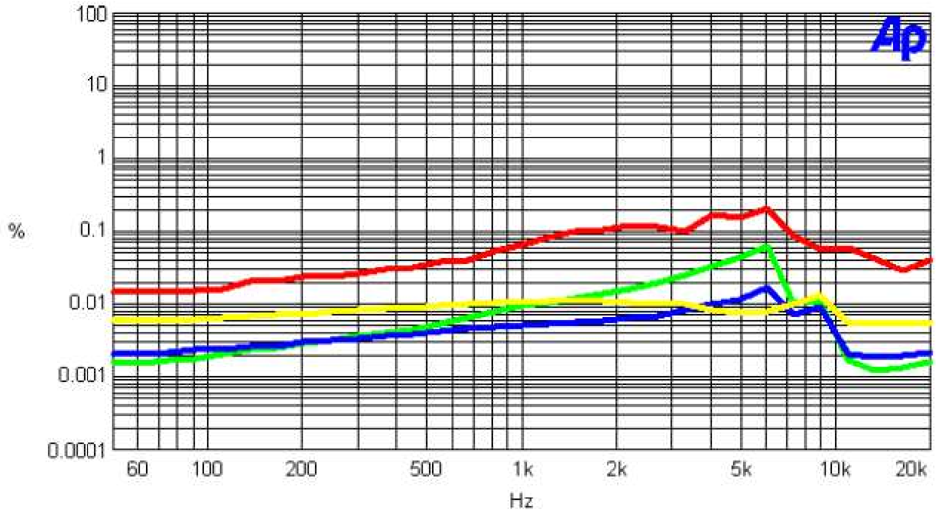


Fig. 10 Application in Class D Amplifier

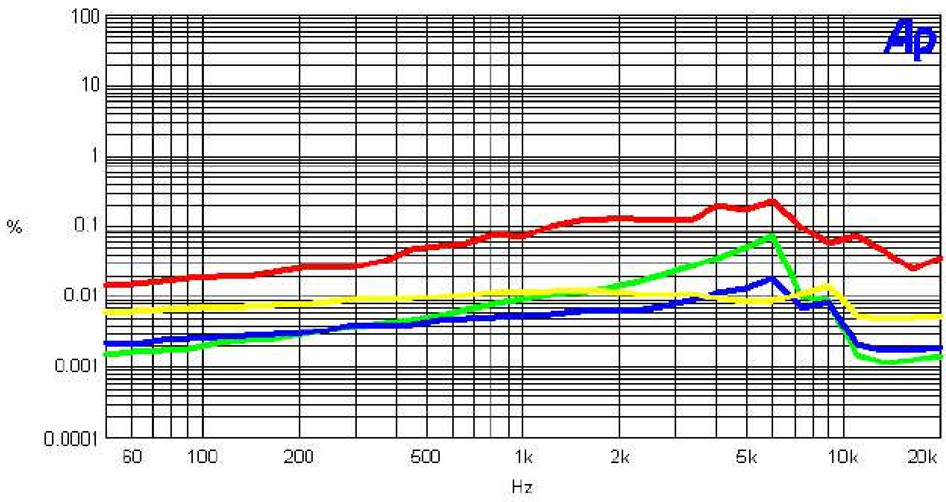
The results of THD+N (Total Harmonic Distortion + Noise) in wide frequency range measured with an actual Class D Amplifier are shown in Fig. 11.

PML CAP 35V 1μF (3.2x2.5x1.4mm) and MLCC 50V 1 μF (X7R, 3.2x2.5x1.8mm) were replaced with the original polypropylene film capacitor (630V 0.47μF, 17.5x18.0x9.0mm) for measurement.



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Red	Solid	4	Anlr.THD+N Ratio	Left	Original 100W
3	1	Green	Solid	4	Anlr.THD+N Ratio	Left	Original 50W
5	1	Blue	Solid	4	Anlr.THD+N Ratio	Left	Original 10W
7	1	Yellow	Solid	4	Anlr.THD+N Ratio	Left	Original 1W

Fig. 11 (a) THD+N of Film Capacitor



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Red	Solid	4	Anlr.THD+N Ratio	Left	35ST105 100W
2	1	Green	Solid	4	Anlr.THD+N Ratio	Left	35ST105 50W
3	1	Blue	Solid	4	Anlr.THD+N Ratio	Left	35ST105 10W
4	1	Yellow	Solid	4	Anlr.THD+N Ratio	Left	35ST105 1W

Fig. 11 (b) THD+N of PML CAP

Fig. 11 (c) THD+N of MLCC

These results reveal that PML CAP is equivalent to conventional film capacitor and superior to MLCC.

- Application to LED Backlight Driver

Thin film as the dielectric of PML CAP has no piezoelectric effect so that howling is much less than MLCC. This property is ideal for passing capacitor in power supply handling large ripple current.

Sites of PML CAP in a DC-DC converter for LED backlight are shown in Fig. 12. In LED backlight using PWM (Pulse Width Modulation) in audible frequency range, use of MLCC causes howling.

In Fig. 12, PML CAP is used as passing capacitor for input and output, since the circuit is a boosting converter. In voltage reducing converter, PML CAP` can be used to input passing capacitor.

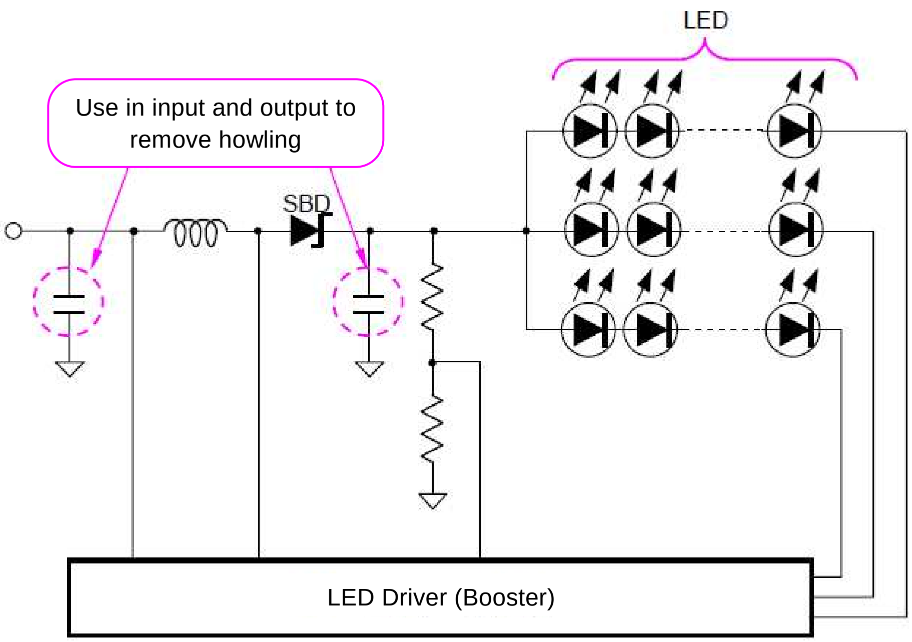


Fig. 12 Application to Input/Output Capacitor in LED Backlight Driver

➢ Loop Filter for PLL

Application to loop filter for PLL is shown in Fig. 13. PML CAP with less dielectric absorption than high-permittivity MLCC drastically reduces "Lockup Time" (frequency change time).

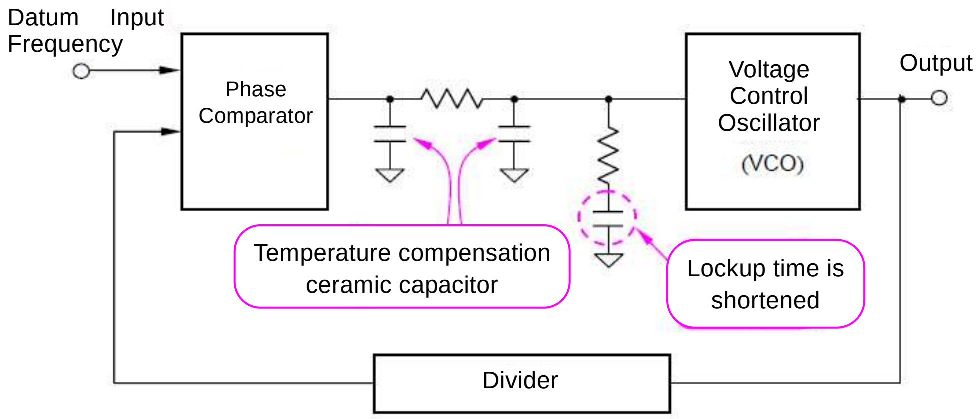


Fig. 13 Application to filter capacitor for PLL Synthesizer

- Energy Harvesting(Scavenging)

PMLCAP has a feature of low leakage current, and addition to that, small size and large capacitance compare to conventional film capacitors.

It is very effective for a storage capacitor of Energy Harvesting applications (Fig. 14) which collect and save the tiniest amounts of energy from environment.

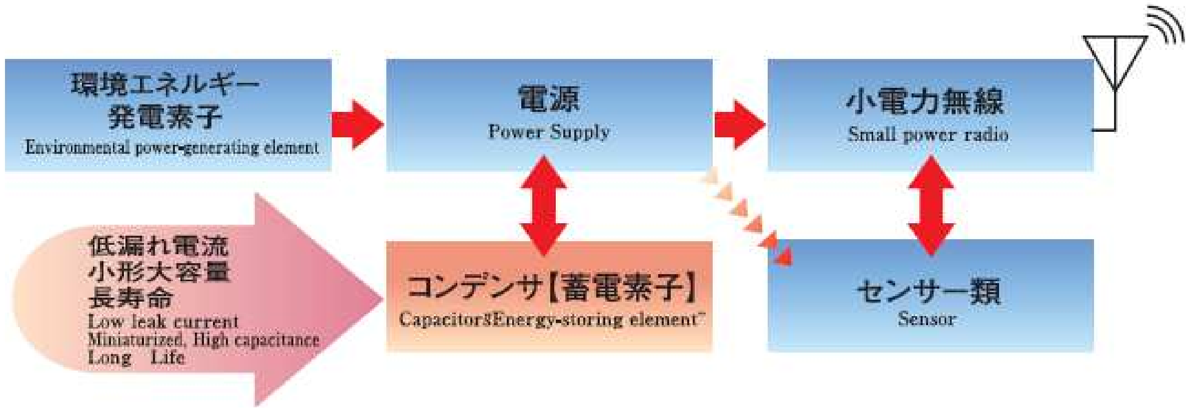


Fig. 14 Energy Harvesting system

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