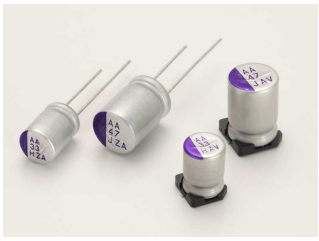
Conductive Polymer Aluminum Solid Electrolytic Capacitors "PZ-CAP" Introduction

Under the concern on depletion of global resources due to global warming, radical growth of developing countries and population increase in cities and developing countries, effective utilization of energy is becoming to the common subject, for which many countries have started projects for smart grid, smart city and smart community.
In electric and electronic field, development of products contributing to global warming and reduction of CO_2 emission is now popular. In such circumstances, the market is demanding downsizing and higher performance of electronic devices including aluminum electrolytic capacitor, which is the main product of Rubycon.
Conductive polymer aluminum solid electrolytic capacitor ("Solid Electrolytic Capacitor") has the advantages such as wide operation temperature range, compact, low ESR and high resistance against ripple current, but the only disadvantage is low working voltage under 35V. Then the applications of the capacitor have been restricted as a component of 25V or lower.
Rubycon has brought PZ-CAP (Photo-1) to the market realizing high withstand voltage with the original technologies, while many capacitor manufacturers have been developing Solid Electrolytic Capacitor at high operation voltage. PZ-CAP Series is described in this paper.



（Photo-1）Winding type Conductive Polymer Aluminum Solid Electrolytic Capacitors "PZA Series" / "PAV Series"

Specifications

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Series	PZA	PAV
Rated Voltage	25~63V.DC	25~63V.DC
Capacitance Range	10 ~ 220μF	22 ~ 220μF
Category Temperature Range	-55 ~ +105ºC	-55 ~ +105ºC
Size(mm)	Φ6.3×8L~ Φ10×13L	Φ8×12L~ Φ10×15L
Load Life	105ºC 3,000hours	105ºC 3,000hours

PZ-cap Standard Size

PZA Series

Size : φD×L(mm), Ripple Current: mA r.m.s./105℃,100kHz
ESR : mΩ,max/20℃, 100kHz

V.DC	Cap (μF)	Size	ESR	Ripple
25	100	8X10	29	2000
	120	8X12.5	27	2400
	180	10X10	27	2400
	220	10X13	26	2800
35	22	6.3X8	64	900
	33	8 X8	55	1200
	56	8 X10	29	1900
	82	8 X12.5	27	2300
	100	10X10	27	2400
	150	10 X13	26	2700
50	12	6.3X8	81	800
	18	8X8	63	1100
	33	8X10	32	1900
	39	8X12.5	29	2200
	47	10X10	29	2300
	68	10X13	28	2600
63	10	8X8	75	1000
	22	8X10	35	1800
	27	8X12.5	33	2100
	33	10X10	31	2200
	47	10 X13	29	2600

PAV Series

Size : φD×L(mm), Ripple Current: mA r.m.s./105℃,100kHz
ESR : mΩ,max/20℃, 100kHz

V.DC	Cap (μF)	Size	ESR	Ripple
25	100	8X12	31	2000
	120	8 X15	29	2300
	180	10 X12	29	2400
	220	10 X15	28	2800
35	68	8X12	34	1900
	82	8X15	31	2300
	100	10X12	29	2300
	150	10X15	28	2700
50	33	8X12	36	1700
	39	8 X15	34	2000
	47	10X12	30	2200
	68	10X15	29	2600
63	22	8X12	37	1700
	27	8 X15	35	2000
	33	10X12	31	2200
	47	10X15	30	2500

Need of High Working Voltage for Solid Electrolytic Capacitor

Conventional aluminum non-solid electrolytic capacitor (“Al Electrolytic Capacitor”) uses liquid electrolyte to work through ion conduction as transfer of electric charges. On the other hand, Solid Electrolytic Capacitor uses electron conduction for such transfer, so that conductivity is 4 or 5 digits higher than that for Al Electrolytic Capacitor, which means superior ESR. It is the reason why Solid Electrolytic Capacitor is good for electronic equipment requiring quick response or high resistance to ripple current.

However conventional Solid Electrolytic Capacitor had poor working voltage not higher than 25V because of less anodic oxide restoration ability of conductive polymer than liquid electrolyte, so that applicable circuits were restricted. Then expectation of high working voltage in Solid Electrolytic Capacitor has been increasing for down sizing and realization of higher performance in electronic equipment.

Features of PZ-CAP

PZ-CAP is the product covering from 25 to 63V, which has realized high working voltage beyond the conventional limit voltage of 25V through Rubycon’s original polymer technology. The capacitors of the series have the values of impedance and ESR at high frequency range much lower than those for Al Electrolytic Capacitors, so that the capacitors are applicable to high ripple current applications. The capacitors also have smaller characteristic changes where ambient temperature varies widely, as well as long life at actual operating temperature.

Expectations of PZ-CAP is as follows:

(1) Smaller size and lower ESR than Al Electrolytic Capacitor realize downsizing of electronic equipment.
(2) Large capacitance relieves electronic equipment from use of multiple Al Electrolytic Capacitors, so as to cut costs.
(3) Less characteristic change allows use of small Solid Electrolytic Capacitor instead of much larger Al Electrolytic Capacitor, so as to contribute to downsizing of electronic equipment.
(4) Stable operation in low and ultra low temperature ranges allows removal of extra circuits required for Al Electrolytic Capacitor.
(5) Long life at room temperature reduces maintenance costs of electronic equipment used in remote locations or at height.
(6) Solid Electrolytic Capacitor is applicable to potting and use of desiccant, both of which have been restricted for Al Electrolytic Capacitor that uses liquid electrolyte.

Technical Elements in High-voltage PZ-CAP

It is necessary to describe why withstand voltage of conventional Solid Electrolytic Capacitor has been low, in order to explain Rubycon’s original technology for improvement in the withstand voltage.

Many polymers have been examined for Solid Electrolytic Capacitor, since Dr. Shirakawa who won the Nobel Prize has discovered conductive polymer. One of such conductive polymers is poly-3,4-dioxithiophene (PEDOT).

In the conventional Solid Electrolytic Capacitor, conductive polymer was synthesized in the capacitor element. The polymerization reaction of conductive polymer is shown in Fig-1. Monomer ethylene dioxithiophene (EDOT) is synthesized into polymer (PEDOT) through oxidation polymerization. A highly acidic iron compound is used as an oxidant for the polymerization.

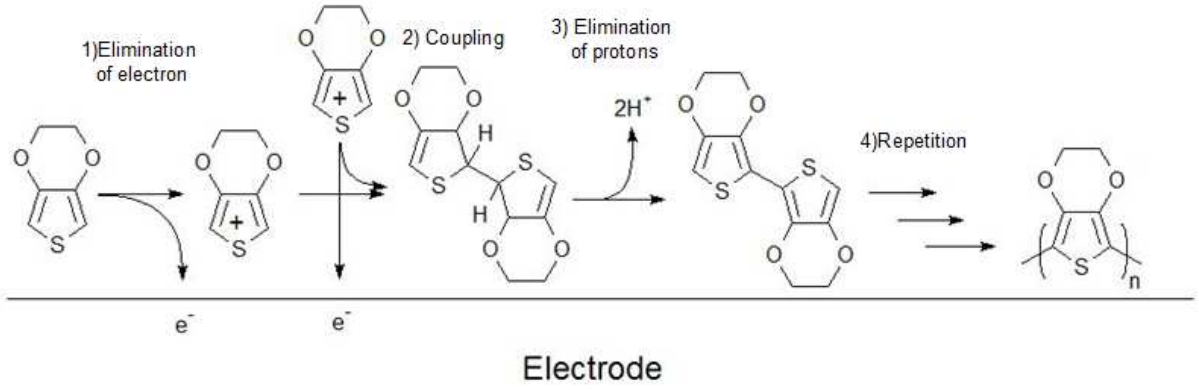


Fig-1 PEDOT Polymerization process

The polymerization affects capacitor's characteristics, reducing withstand voltage and life.

The cause of reduction in capacitor's withstand voltage is considered to be hydrogen ion produced in the polymerization, which attacks oxide film on the surface of anode foil.

The iron compound and the strong acid remain in the capacitor element even after the polymerization, which could cause increase of leakage current or short circuit in hot life test or humid life test. Then methods to remove such risks have been examined.

The key point in production of such capacitor is polymerization of highly conductive PEDOT and filling the polymer over the element. Stabilizing agents and reaction control agents are inevitable to obtain stable capacitor performance. But it is unable to use stabilizing agents and reaction inhibitors hindering such polymerization. Another problem is that addition of stabilizing agents is difficult after polymerization since element is fully covered with polymer.

The concept of development of PZ-CAP is effective filling of PEDOT and retention of high performance of capacitor element together with inclusion of stabilizing agents. Production factors of PZ-CAP Series are as follows:

(a) To remove attack of hydrogen ion to anode foil in polymerization
(b) To use PEDOT not including iron compounds or strong acid as well as residue of polymerization
(c) To effective fill PEDOT over capacitor element
(d) To add stabilizing agents and reaction inhibitors to maintain reliability of capacitor in hot life and humid life tests.

PZ-CAP Series adopting high-purity PEDOT realizes high working voltage with the minimum damage to capacitor element. The new filling method brings high capacitance and low ESR.

In the new series not accompanying polymerization within capacitor element, easy addition of stabilizing agents and reaction inhibitors drastically improves reliability of the capacitor. Such stabilizing agents and reaction inhibitors restore oxide film of anode foil as well as in Al Electrolytic Capacitor, if the oxide is damaged. The image of the new stabilizing agents is shown in Fig- 2.

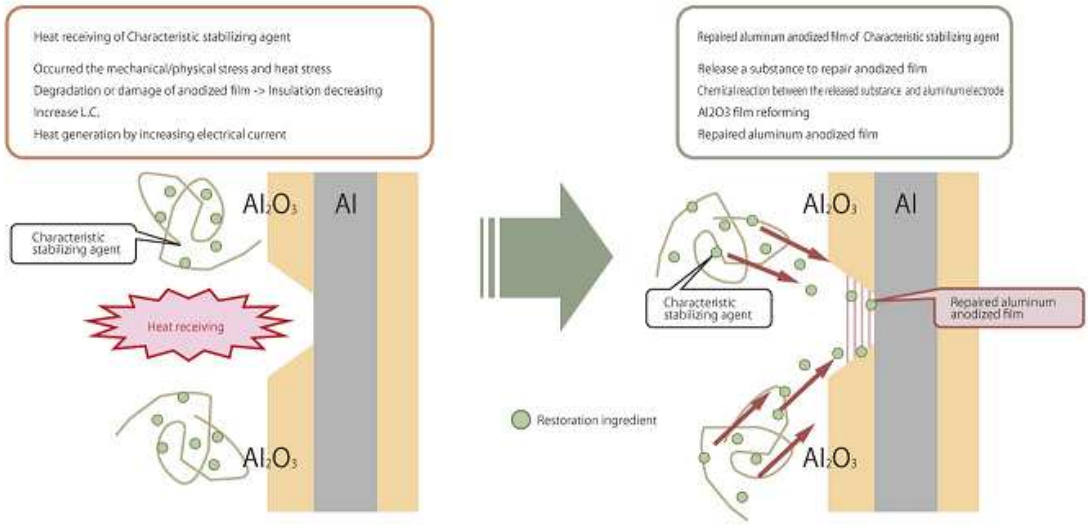
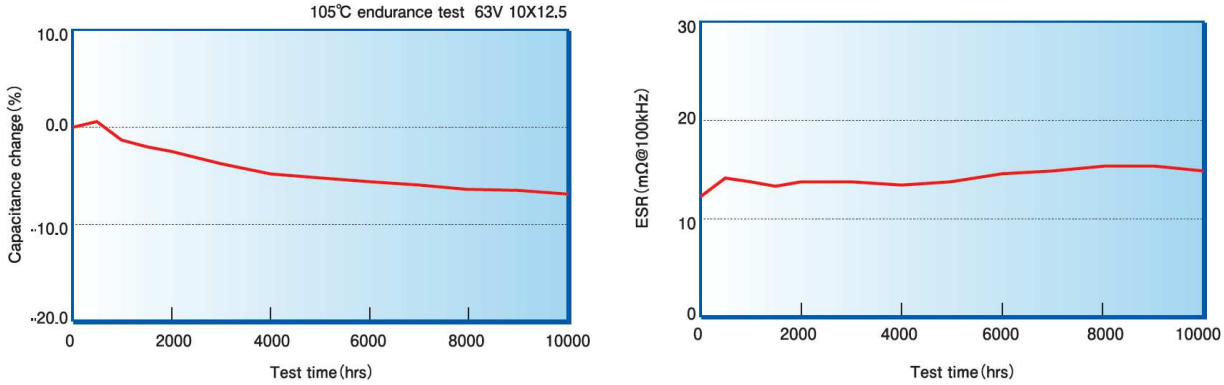


Fig-2 Aluminum anaolized film repair (Image) by characteristic stabilizing agent

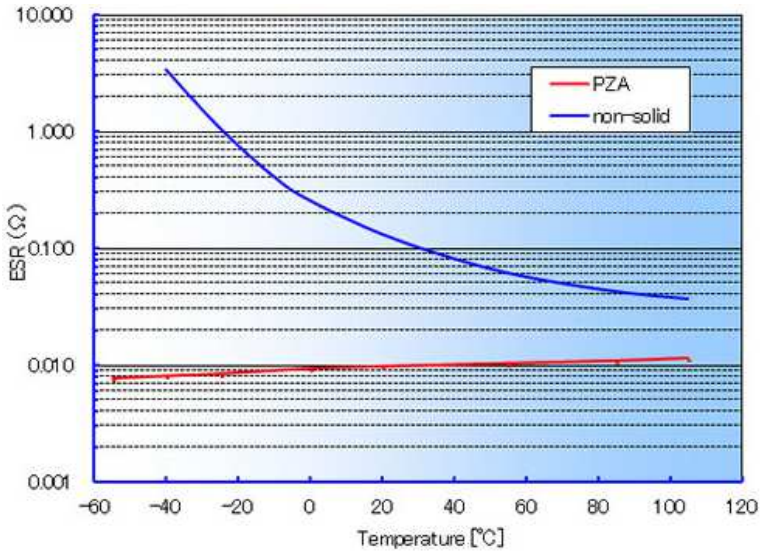
The stabilizing agents and reaction inhibitors have no adverse effect on capacitor in practical use and life tests as well as in initial characteristics, but keep capacitor in good performance. The amount of such agents has carefully been designed to be enough through the life of capacitor even with a severe environment.

Graph-1 shows the data (variation in capacitance and ESR) for 63V capacitors, which have first been realized. The graph reveals stable performance over the long period.



Graph-1 : High temperature load test result of PZ-CAP(Capacitance change/ESR)

Graph-2 shows temperature characteristics from -55 to +105°C. Variation of capacitance and impedance for PZ-CAP is quite small over the temperature range, while capacitance and impedance of Al Electrolytic Capacitor start reducing at -25°C and are very low under -40°C.



Graph-2 : ESR – Temperature Characteristics

We have successfully developed high voltage Solid Electrolytic Capacitor that fully utilizes withstand voltage of capacitor element itself from production process to the end of life, through improvement in resistance to short circuit and provision of high film restoration ability.

Applications of High Voltage PZ-CAP

Downsizing and reduction in component count of electronic equipment are expected as major applications of this series. Then we conducted comparison of output noise for our power supplies.
PZA capacitor (35V-150µF, ϕ10x13L) was used as output filter capacitor, while 3pcs of non-solid electrolytic capacitor (35V-680µF, ϕ12.5x30L) was used in parallel as the control.(Fig-3,Fig-4)
The level of output noise for a PZA capacitor was almost equal to one for the three electrolytic capacitors, so that PZA capacitor can take over conventional electrolytic capacitors. As shown in Photo-2, substitution with PZA capacitor reduces occupation on circuit board so as to contribute to downsizing of the instrument.

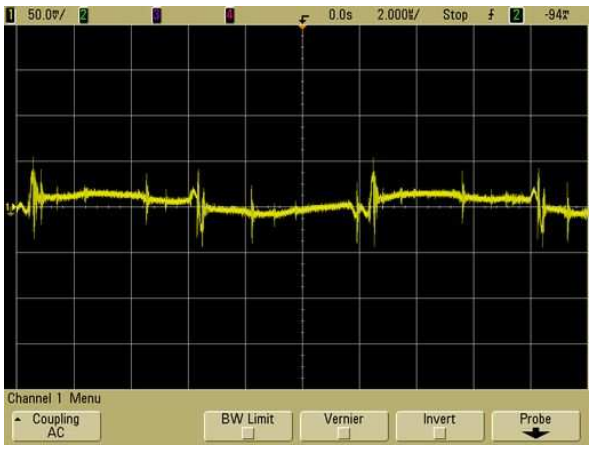


Fig-3: Output noiseof Polymer aluminum Electrolytic capacitors 3pcs
Vp-p = 97mV

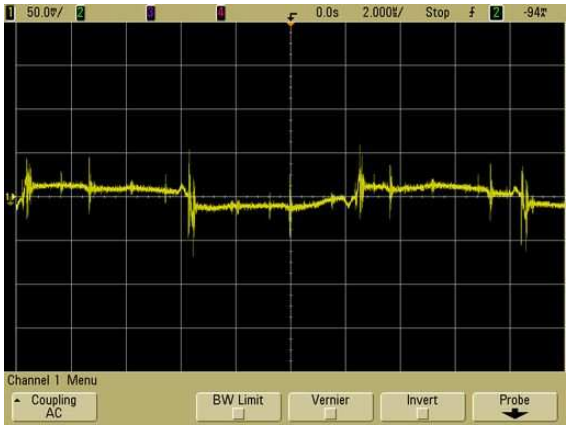


Fig-4: Output noise of “PZA” 1pc
Vp-p=81mV

Photo-2 : Loading example to Rubycon's power supply

Conductive polymer has less characteristic variation as the change in ambient temperature, so that less-volume solid electrolytic capacitor takes over aluminum electrolytic capacitor having much larger size. It also contributes to downsizing of equipment.

Comparison of output noise was conducted with actual circuit board.(Fig-5,Fig-6)
The used circuit is a universal output circuit. A PZA capacitor (35V-82μF, ϕ8x12.5L) was compared with a non-solid electrolytic capacitor (35V-220μF, ϕ10x12.5L).
Level of output noise for the PZA capacitor was equivalent to one for the electrolytic capacitor at, but the difference at -40°C was remarkable such that noise of PZA was almost equivalent to at +25°C, while noise of electrolytic capacitor was 8 times higher.
The temperature of -40°C is reasonably expected as an atmosphere at high altitude or in a high-latitude region. Then it is quite important and advantageous that circuit for lighting unit, outdoor base station and automobile instrument covers from room temperature to -40°C.

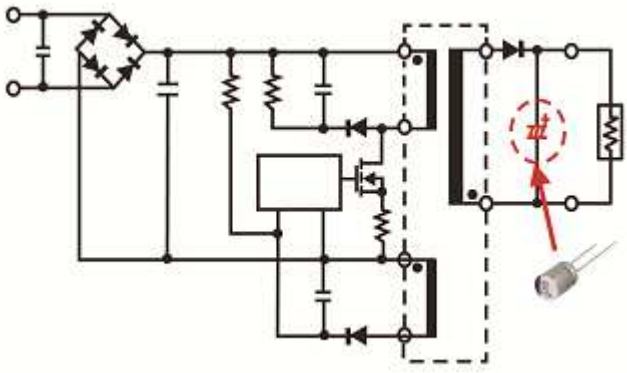


Fig-5: Load output circuit example

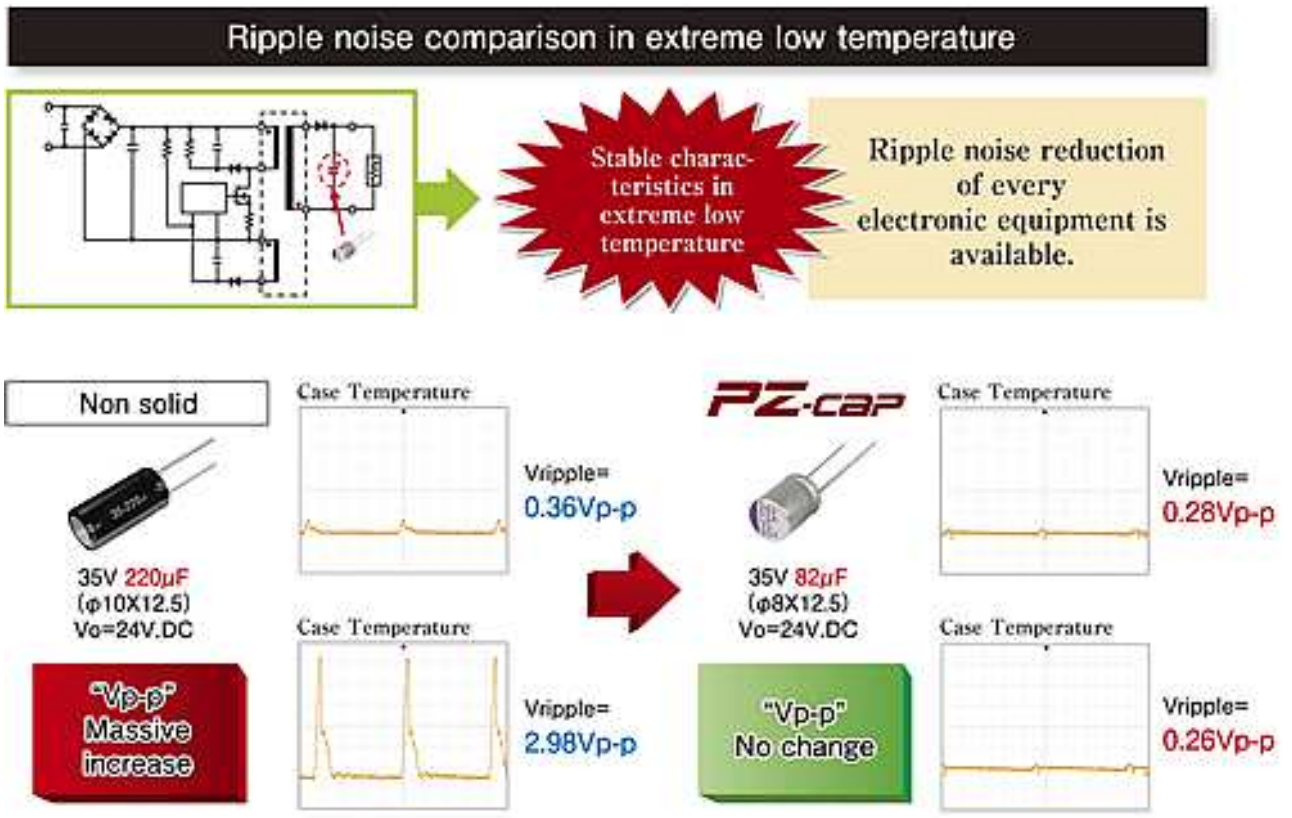


Fig-6: Comparison of Output ripple noise

Circuit drive frequency is increasing, and lower ESR and impedance are required as semiconductor material has been changed into GaN from Si or SiC. PZ-CAP is ideal for such circuits.

An inverter circuit is shown in Fig-7 as an example. PZ-CAP having low ESR and impedance is quite useful to filters of Gate Drive Circuit and DC Brushless Motor, both of which are DC circuits.

In addition to the above applications, PZ-CAP having higher working voltage than conventional conductive polymer capacitor will expand to further fields requiring low ESR, high ripple current and low-temperature characteristics.

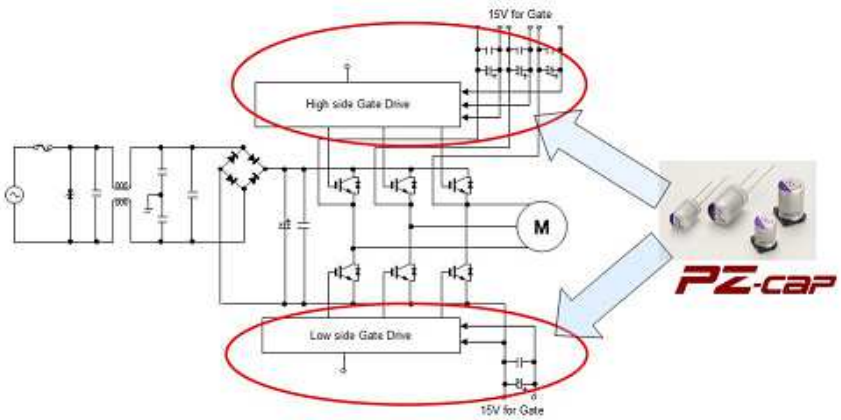


Fig-7 : Proposal example in the inverter circuit by PZ-CAP

Ending

PZ-CAP covers high voltage range that has never been covered by conventional Solid Electrolytic Capacitor, and is expected as a high-performance capacitor for the applications such as low ESR, high ripple current, stability in low temperature and long life.

We, at Rubycon, are expanding lineup of Solid Electrolytic Capacitor as an electronic device for wide applications.

Downsizing of electronic equipment will further advance in the views of costs, performance and environment preservation. Then we are proactively addressing to developments of non-solid capacitor, film capacitor and electric double layer capacitor, in addition to Solid Electrolytic Capacitor.

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