



TECHNICAL INFORMATION

BENEFITS OF THIN-FILM DIELECTRIC CHIP CAPACITORS AT VHF, UHF AND HIGHER FREQUENCIES

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Abstract

Present and future cellular networks and satellite telecommunications systems demand unique performance characteristics from the SMD capacitors incorporated into their designs. To meet these requirements, single layer surface mount capacitors have been developed on the basis of thin film technologies.

The capacitor's single layer thin film construction provides several major performance advantages relative to multilayer chips. These are much improved Q (low ESR), consistent and repeatable Q/ESR/Ceff/SRF parameters, superior power capability, no secondary resonances up to a frequency of 40GHz and very tight tolerance on capacitance value. By virtue of these characteristics and excellent mechanical features, this thin film capacitor is the ideal surface mount chip for high frequency applications.

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Benefits of Thin-Film Dielectric Chip Capacitors at VHF, UHF and Higher Frequencies

In high frequency designs capacitors have traditionally been given little consideration compared to other circuit components, particularly semi-conductors.

However, the increasing use of higher frequencies in the 450MHz to 3GHz region for applications such as Cellular Communications, and the use of the 10GHz to 18GHz spectrum for Satellite video and data transmission have emphasized the need for surface mount (SMD) chip capacitors exhibiting very high Q, consistent performance and very tight tolerance of capacitance value.

The ACCU-Series Solution

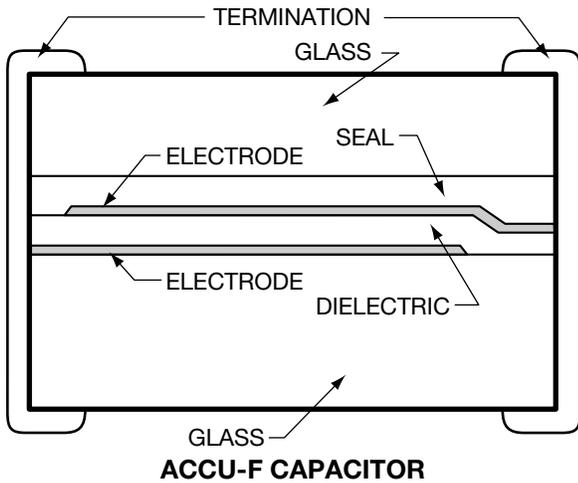
Aware of the high frequency designer's dilemma to receive reasonably priced production quantities of high performance, consistent, tight tolerance SMD capacitors, AVX/Kyocera has developed a capacitor based on thin film technology which meets all of these demands. Currently, there are two series available in high volume production: the ACCU-F for low power applications and the ACCU-P for high RF power circuits.

Construction of the ACCU-F and ACCU-P Capacitors

The basic manufacturing process of the ACCU series capacitors is drawn from the technology of the semiconductor industry. Advanced magnetron sputtering systems are used for metal layer preparation. State-of-the-art PECVD (plasma enhanced chemical vapor deposition) systems are used to produce the dielectric. Class 100 clean room work areas (<100 particles of $0.5\mu\text{m}/\text{ft}^3$) provide the necessary environment for defect-free deposition of these thin films (0.5-4 micron thick).



The capacitor is built on a special glass substrate using ultra-pure aluminum-copper alloy electrodes and extremely low loss, highly insulating silicon oxide and nitride dielectrics. The metal electrodes are formed by photolithography, thereby maintaining dimensional control to $\pm 2.5\mu\text{m}$. The final chip size is also held to very tight tolerance ($\pm 0.03\text{mm}$) by micro-processor controlled diamond dicing for chip separation from the substrate.

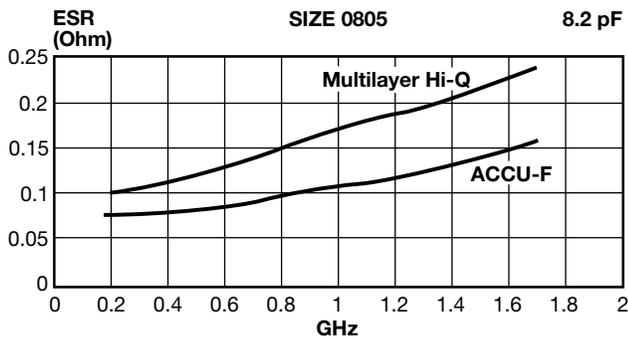


ACCU-Series Characteristics

The main characteristics of the ACCU series capacitors provided by the thin film manufacturing process may be summarized as follows:

1. Ultra-pure, high conductivity electrodes provide for very low ESR with excellent consistency.
2. Pure, defect free dielectric of low dielectric constant providing high breakdown field strength, high insulation resistance and low loss to frequencies up to 40GHz.
3. Very tight dimensional tolerance of the chip provides consistently low unit to unit inductance.
4. Precise dimensional control of the electrodes and uniformity of the dielectric enables very tight capacitance tolerances ($\pm 0.05\text{pF}$ for $\leq 5.6\text{pF}$), ideal for various signal applications.
5. ACCU-P uses thermally conductive materials to effectively remove heat from the capacitor at very high RF current levels.

The electrical performance of the ACCU-series capacitors is depicted graphically in Figure 1.



Measured on Boonton 34-A

Figure 1

The thin film process is also ideal for manufacturing very small chip capacitor sizes in addition to standard chip sizes. 0403 is available and 0402 will be marketed shortly.

ACCU-P For Power Handling

The ability of a capacitor to handle high RF currents is basically determined by two factors: (a) how much heat is generated by internal losses and (b) how effectively heat is transferred out of the capacitor.

ACCU-F has low internal losses but its power handling is limited by the thermal conductivity of its all glass construction.

ACCU-P capacitors incorporate thermally conductive materials to significantly boost the heat dissipation capability of the capacitor. The combination of low losses and very high thermal conductivity allows RF power handling capability unmatched by multilayer chips (Fig. 2). These capacitors are utilized in a wide range of power applications.

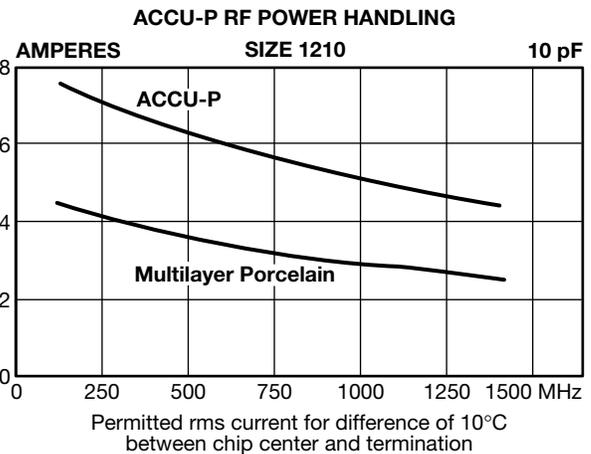


Figure 2

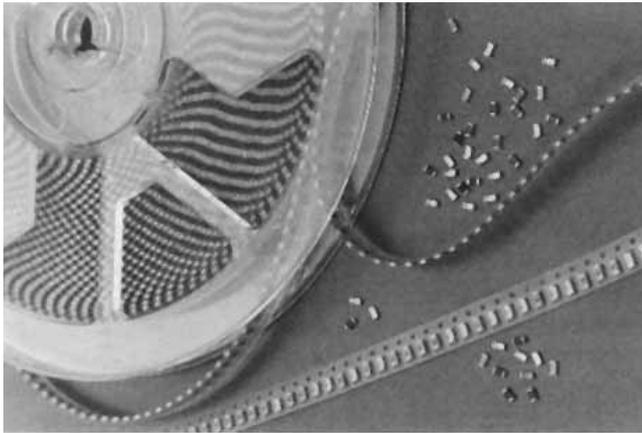
ACCU Series General Data

ACCU series thin film chip capacitors are available with capacitance values from 0.1pF to 220pF. This covers the great majority of values required at VHF/UHF and higher frequencies.

D.C. voltage ratings are from 50V to 400V but even the 50VDC rated parts have a 500VDC repetitive peak rating. Extensive tests have indicated that breakdown will generally not occur below 1500VDC peak.

Every batch of ACCU-F and ACCU-P manufactured is life tested on a sample basis under test conditions of +125°C with twice rated voltage applied, and THB testing @ +85°C under 85% RH at rated voltage; both tests are of 1,000 hours duration.

Additionally, every batch is tested at high frequency for Q, ESR and effective capacitance on a Boonton 34A resonant coaxial line system (EIA Standard RS483), and a summary of the results is available to the customer.



AVX/KYOCERA ACCU-F CAPACITORS

Performance Above Self-Resonant Frequency

At microwave frequencies, many capacitors are called upon to function beyond their Self-Resonant Frequency (SRF). Although the capacitor's impedance is primarily inductive beyond SRF, the device is still a capacitor. Of particular concern is the insertion loss behavior of the capacitor beyond SRF and the consistency of the insertion loss on a capacitor-to-capacitor basis at the specific frequency range of interest (e.g. Ku band for satellite transmissions).

Multilayer capacitors, because of their variable physical structure, generally perform poorly and inconsistently at these frequencies.

Figure 3 demonstrates the typical resonances which occur in a High-Q Multilayer chip capacitor beyond SRF. In the laboratory it is possible for a designer to compensate for the insertion loss increase of a specific frequency. However, this cannot be sensibly done on a production basis as every capacitor will have a different insertion loss characteristic curve, i.e. the resonances will occur at different frequencies.

Comparing the ACCU-F insertion loss curve with that of the multilayer capacitor (Figure 3), it can be seen that the ACCU-F curve is close to that of the "ideal" or calculated capacitor, exhibiting virtually no resonance "dips". This smooth curve is repeated by ACCU-F capacitors lot-to-lot, thereby assuring the designer of the repeatability of performance of his equipment on a production basis.

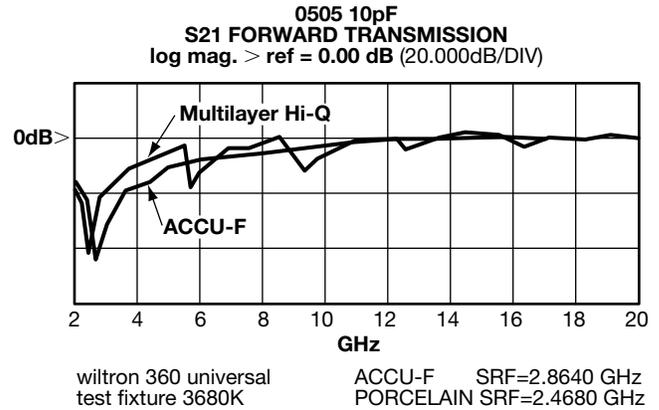


Figure 3

Applications

The ACCU series characteristics give the circuit designer new possibilities to design circuits for higher frequency applications, tighter performance requirements, lower costs and ease of mass production.

The ACCU series capacitors are used in applications requiring low losses at frequencies up to 40GHz such as in satellite TV systems, LNB's (low noise blocks 11-12.5GHz) and receivers.

A typical application is in cellular telephones (450MHz to 900MHz) where the low ESR and high Q factor of the ACCU-F has resulted in elimination of amplification stages and hence a considerable saving in costs. Additional cost savings have been realized due to the consistency of characteristics of the ACCU-F which minimizes the necessity of tuning elements and reducing drastically the "tweaking" of the final product – an important factor in high volume production.

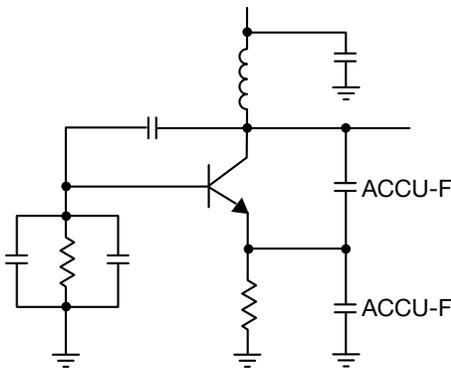
The easy availability of tight capacitance tolerances makes the ACCU series the ideal choice in design of filters, VCO's and matching networks (see diagrams of common applications).

The inherent reliability of the ACCU series capacitors make them suitable for severe environment applications such as in military communications, airborne systems and for space usage.

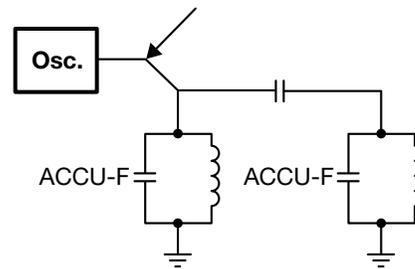
The following are some major applications of the ACCU-F and ACCU-P:

<u>Application</u>	<u>Frequency</u>
Cellular Communication	450MHz and 900MHz
CT2	900MHz
PCN	1.7GHz to 2.3GHz
Satellite TV	11GHz to 18GHz
Cable TV	800MHz to 900MHz
GPS	1.5GHz to 1.6GHz
Vehicle Location Systems	UHF
Paging	VHF-UHF
Military Communications	up to 40GHz
Test and Measurement	DC to 40GHz
Filters	VHF to UHF
RF Amplifiers	VHF to UHF
VCO's	VHF to UHF
Matching Networks	VHF to UHF

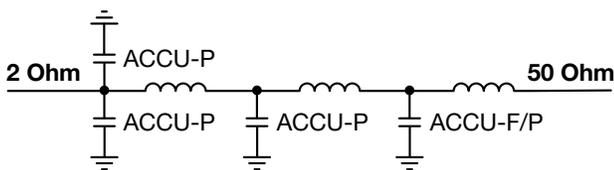
1. VCO



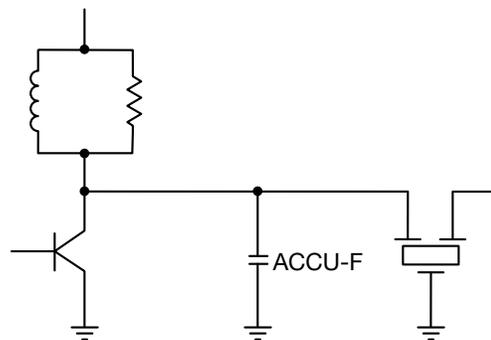
2. Harmonic Suppressor



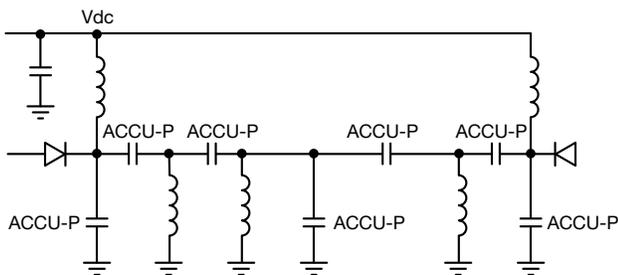
3. Matching Network



4. Front End Filter



5. RF Power Filter for Matching Network



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