**GENERAL INFORMATION**

The RFCS Component

Thin film MNOS capacitors are a well-established technology for applications with highly demanding performance requirements, but MNOS technology is typically limited to use in hybrid assemblies (chip and wire). The RFCS product is a patented adaptation of Vishay’s mature MNOS process to accommodate surface mount assembly (SMT) and thus go beyond these limitations. Vishay offers RFCS capacitors in 0402 case size in values ranging from 0.1 pF to 27 pF.

The RFCS capacitor is characterized by its bottom-termination (flip chip) configuration. This approach minimizes the parasitics associated with the component terminations, resulting in the surface-mount capacitor with the industry’s highest self-resonant frequency (SRF).

All of the traditional performance characteristics of the MNOS technology can be found in the RFCS product:

- The thin film electrodes provide superior RF conductivity compared to thick film devices
- The robustness of the silicon oxide/silicon nitride dielectric combination is well established and has been in use for decades in the most demanding applications
- The silicon substrate provides excellent thermal conductivity, allowing higher power ratings than alternative technologies
- The dielectric deposition process can be controlled to obtain tight tolerances across wafers, among wafers in a single batch, and between batches. This characteristic allows RFCS components to be manufactured to spec rather than being binned to spec as is the case with alternative technologies.

**RFCS Construction Details**

The RFCS capacitor consists of two MNOS capacitors set in series. The highly conductive silicon substrate forms the common electrode as described in figure 1.

The series configuration provides two significant advantages:

- Improved maximum working voltage characteristics
- A more controllable method of manufacturing small capacitance values

All values of the RFCS components include a stacked oxide/nitride dielectric layer. This combination of dielectric layers provides for robust electrical and mechanical characteristics. The silicon nitride passivation layer further enhances the mechanical integrity of the component.
RFCS - Silicon SMD RF Capacitor

RFCS Performance Benefits
The patented structure of the RFCS component provides a number of benefits over alternative technologies. One such benefit is its ultra-low parasitic series inductance. This characteristic causes these components to self-resonate at significantly higher frequencies than alternative technologies. The following figure demonstrates this aspect:

![Fig. 2 - SRF comparison between RFCS and multi-layered co-fired ceramic alternatives](image1)

Typical parasitic inductance values for RFCS are presented in figure 3.

![Fig. 3 - Typical parasitic inductance of RFCS](image2)

Their high SRF allows RFCS components to maintain their performance to higher frequencies than other technologies. The following plot displays measured impedance vs. frequency of a few select values. All of these measurements were performed on identical test setups.
The mechanical structure of the RFCS components also provides for low losses. Their equivalent series resistance (ESR) is so low, in fact, that measuring it is difficult. The very low values for absolute capacitance make this measurement even harder.

The technique used to measure ESR for the RFCS product was to use a network analyzer to measure the real part of the impedance at self-resonance. Because RFCS components are characterized by their high SRF, the measured values included real losses caused by high-frequency phenomena such as skin effect.

Interestingly, the ESR at SRF values are almost completely value-independent. The higher value components have lower SRF, so the contribution of skin effect related losses is lower. On the other hand, the higher values also have thicker dielectric layers that introduce more loss. These two effects act in opposite directions, canceling each other.
The large tolerance presented in the figure above represents a single standard deviation of a sample of 10 components. The large tolerance is a reflection of the difficulty measuring this parameter (1). This tolerance should not be interpreted as reflecting large deviations between the components themselves. The RFCS product is manufactured using thin film techniques resulting in high levels of uniformity among components. The lot-to-lot uniformity of the RFCs product is excellent compared to alternative technologies that deposit both the electrodes and the dielectric material using thick-film paste deposition techniques.

ESR at frequencies under SRF can be directly measured at frequencies under 3 GHz. The following plot of Q vs. frequency has been created by interpolating between the measured values at lower frequencies and the ESR at SRF results presented above. An ideal model of skin effect was assumed in this process.

Note
(1) Measured ESR values included a large amount of setup related noise. The fitting quality of the presenter linear approximations was $R^2 = 0.2$.

S Parameters
S parameter values up to 20 GHz are available upon request for all values of RFCS product. These measurements were performed in series configuration using the following equipment set:
- Vector Network Analyzer: Anritsu 37247D
- Test Socket: Inter-Continental Microwave (ICM), universal socket for bottom electrode components.

Summary
The RFCS product is an excellent choice for applications operating in the high-GHz frequency range. The advantages of Vishay's patented RFCS technology, compared with alternative technologies, are presented in the following table.

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