HiQ-CBR RF & MICROWAVE

Electronic Components KEMET CHARGED.

FREQUENTLY ASKED QUESTIONS
RF & MICROWAVE PRODUCTS

WHAT IS RF?

RF stands for Radio Frequency, which has a frequency range of 30KHz - 300GHz. RF capacitors help tune antenna to the correct frequency. The technical term is resonator circuit, which consists of an Inductor + an RF Capacitor

WHY IS ESR SO CRITICAL IN HIGH FREQUENCY APPLICATIONS?

ESR is a summation of losses in a capacitor. In MLCCs, these losses are mostly Rsd / Dielectric Loss and Rsm / Metal loss (electrode, termination, and electrode-to-termination connection). ESR is a critical electrical parameter in KEMET's Tantalum $Mn0_2$ and Tantalum Polymer product lines. For standard MLCCs in low frequency applications (<<10 MHz), the ESR is typically so low (due to the multilayer chip construction, and the application frequency) that ESR is not even measured in routine testing; rather, DF (Dissipation Factor) is typically used.

Modeled ESR for standard MLCCs in lower frequency applications is available in KEMET's SPICE program. ESR varies with frequency.

In high frequency applications (>30 MHz), ESR is critical, as the added resistance can lead to undesirable component heating, thermal breakdown, or worse, catastrophic failure.

WHAT IS Q?

Q also varies with frequency, and is referred to in two different terminologies:

- $Q = \frac{|Xc|}{ESR}$ *where* |*Xc*| is the absolute value of the reactance in Ohms, or
- $Q = \frac{1}{DF}$ where *DF* = Dissipation Factor

DF is calculated as $\frac{1}{2*\pi*f*c}$ where *f* is the frequency in Hertz, and *c* is the capacitance in Farads.

KEMET measures ESR and Q in our own test labs in Simpsonville, SC.

P.O. Box 5928, Greenville, South Carolina 29606 U.S.A.
Tel: 864.963.6300 Fax: 864.963.6521

POWER DISSIPATION

Power is calculated as follows:

- $P = I^2 * ESR$ where *I* is the current passing through the capacitor, and *ESR* is the Equivalent Series Resistance.

Power Dissipation is a term used to describe the power dissipated *within the capacitor*. Since ESR is directly proportional to power, low ESR is critical to ensure the highest efficiency and stability.

CURRENT FLOW

The maximum allowable peak current flow through a capacitor is calculated as follows:

$I = \frac{V_r}{Xc}$ where V_r is the component's rated voltage, *I* is the peak current flow in amperes, and *Xc* is the capacitor's reactance.

DELTA T (ΔT)

ΔT is a term that is graphed to show the temperature rise as current increases. Capacitor manufacturers strive for low ΔT numbers by optimizing Q and ESR, as an undesirable increase in temperature can lead to component failure.

VOLTAGE RATING

Voltage Rating (Vr) is determined by the inherent dielectric strength (and associated breakdown voltage – DWV) of the dielectric material. In all dielectric classes, MLCC manufacturers strive to achieve the highest capacitance, the highest rated voltage, in the most reliable, smallest package (and at a market competitive price). This is true for RF capacitors as well.

DWV

Dielectric Withstanding Voltage, DWV, can be expressed as capability in volts/mil of dielectric thickness. Due to the material set and manufacturing techniques, RF capacitors have inherently higher volts/mil capability than standard Class 1 and Class 2 capacitors.

Voltage breakdown can occur either inside the capacitor, or outside (across the two terminals). Voltage breakdown typically is a higher risk in higher V_r devices, typically above 3kV. This external voltage breakdown is sometimes called "flashover".

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During testing at KEMET, higher voltage devices are submerged in an insulating fluid to ensure testing measures the actual voltage capability of the dielectric itself.

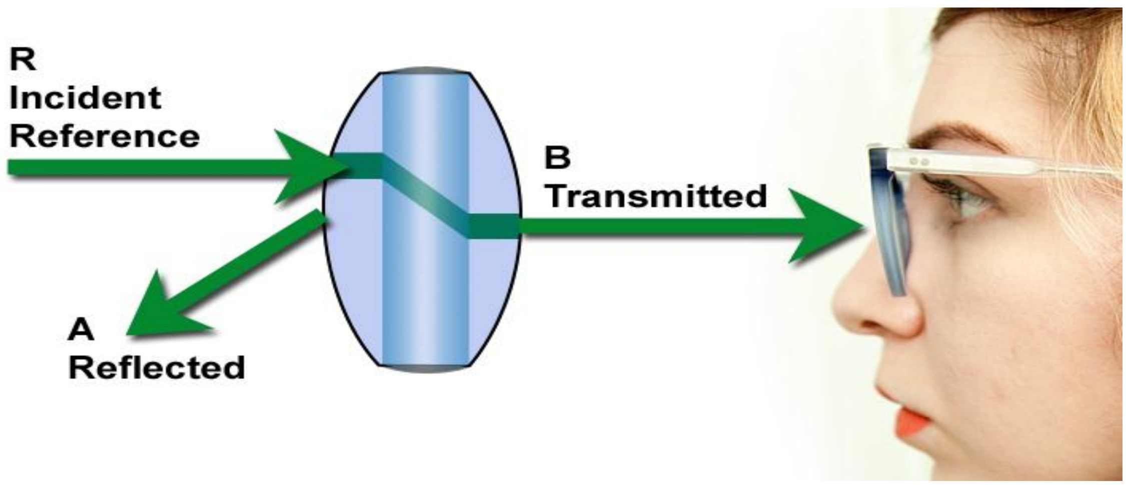
S-PARAMETER

S-Parameter (scattering matrix) is a tool that quantifies how RF energy propagates through a multi-port network. S-Parameters can be used to describe a very complicated network as a simple “black box”.

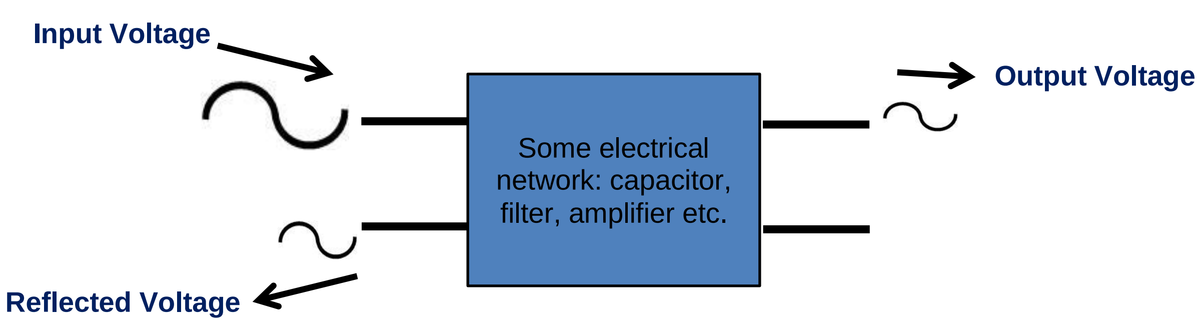
RF engineers uses S-Parameter as a primary quantity to design RF circuits. The quantities describe how much RF energy is injected into the network versus:

1. How much energy actually gets through
2. How much energy is absorbed, and
3. How much energy is reflected back to the source.

Here is an analogy using light through a lens:



Here is a visual for S-Parameter data in an electrical circuit:



KEMET will offer S-Parameter data at www.kemet.com/rf. Care should be taken when making calculations on the provided data, as many factors in individual designs can impact the true S-Parameter as measured in the final application. These factors include, but are not limited to:

- Tracer width
- Pad dimensions
- Board type
- Board thickness
- Solder type
- Solder thickness

S-PARAMETER AND ESR MEASUREMENT TECHNIQUE

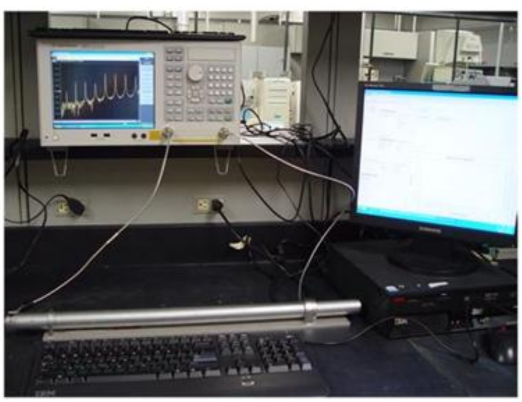
KEMET tests S-Parameter and ESR using the equipment specified, and pictured, below:

S-Parameters

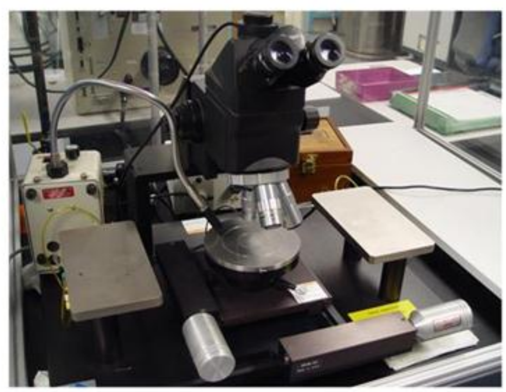
- Agilent E5071C Vector Network Analyzer (300kHz - 20GHz)
- Gore OTD01036 Cables
- RHM-06 Probe Station
- Cascade Probe Positioners
- GGB 350um GSG Probes
- Rogers 4003 20mil Substrate

ESR

- Boonton 34A Coaxial Resonant Line



ESR Station:
- Hi-Q ESR Measurements
- 130 MHz – 1.5GHz
- Custom Software



S-Parameter Test Set:
- 300kHz – 20GHz
- Full S-Parameter Measurements
- Probe station compatible for high accuracy

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WHAT IS SRF AND PRF?

SRF (Series Resonant Frequency) is a very common electrical parameter used in RF design. PRF (Parallel Resonant Frequency) is less commonly used. Due to the high variability of PRF (based on chip orientation on the PCB), KEMET will specify a minimum value upon request.

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