Methodology for Computation of Maximum Power Handling in LTCC Low Pass Filters

Purpose:

The purpose of this application note is to describe the procedure used for determining power handling capability of LFCW-Series LTCC Low Pass Filters due to thermal-related failures.

Introduction:

LFCW series filters are made using LTCC (Low Temperature Co-fired Ceramic) technology. Due to low losses and high temperature handling capability of the ceramic material, they can handle reasonably high power levels, even though they are of small size. Testing of power and thermal resistance is required to determine the maximum power handling capability.

Failure Mechanism:

Applying RF power to the LFCW filters will generate heat due to Ohmic and dielectric losses and cause the rise of DUT temperature. LTCC technology uses thin layers of ceramic on which conductors are printed using noble metals. Various layers are bonded to each other by firing around 850°C. In actuality, the DUT is soldered onto a PCB. While the LTCC filter itself can handle very high temperatures, the weak point is the solder joint, whose melting point is much lower than 850°C. Therefore we use the solder melting point (with some margins) as the maximum allowable temperature of the DUT for maximum power computations. Assuming that the DUT is soldered onto a PCB using high temperature solder such as SnAgCu, whose melting point is 217°C, we can allow the DUT temperature to rise to 200°C without melting the solder joint. Note that the procedure described here can be used to compute max power for any user-defined maximum temperature.

Methodology Employed:

1. Determine the thermal resistance of the DUT at a fixed frequency through thermal imaging measurements. See detailed flow chart in Figure 1.
2. Measure small signal insertion loss of the DUT in the pass band with a network analyzer.
3. Use the highest insertion loss in the pass band and the thermal resistance determined from step 1 to compute the power dissipation, and in turn the temperature rise and the max power handling. See detailed flow chart in Figure 2.

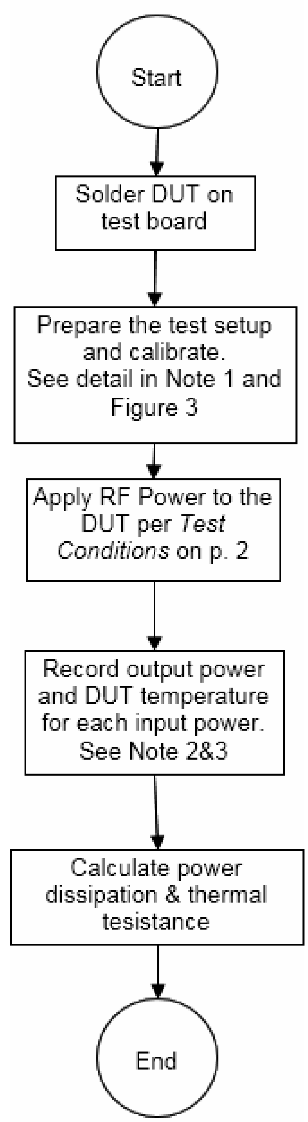

Figure 1: Thermal Resistance Measurement Flow Chart

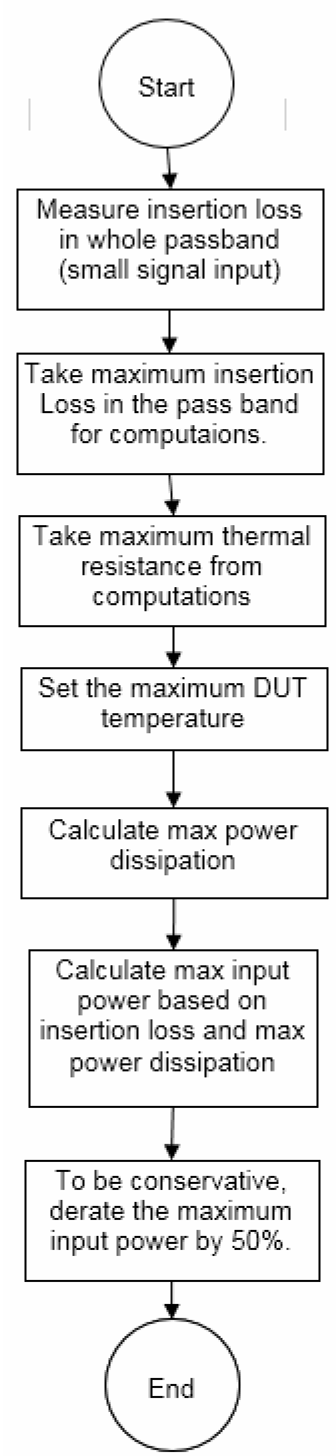

Figure 2: Flow Chart Representing Determination of Maximum Input Power

Test Conditions:

- Room temperature
- RF input: continuous wave
- Frequency = 4 GHz, see note 4
- P_{in} = 30, 33, 35, 36, 37, 38, 39, 40 dBm.

Notes:

1) Calibration method: zero & calibrate each power meter before test, connect the through-line of TB-720+ as DUT, and offset power meter F until it shows the same reading as power meter H at 4 GHz.
2) Take thermal images after applying each power level for 5 minutes, or until the DUT temperature is stable.
3) Record power meter F as input power Pin; record power meter H as output power P_{out}. Insertion loss = $P_{out} - P_{in}$.
4) Choose the frequency at which you have a high power source. In this case, the test was performed only at mid-band frequency, 4 GHz.

Test Sequence:

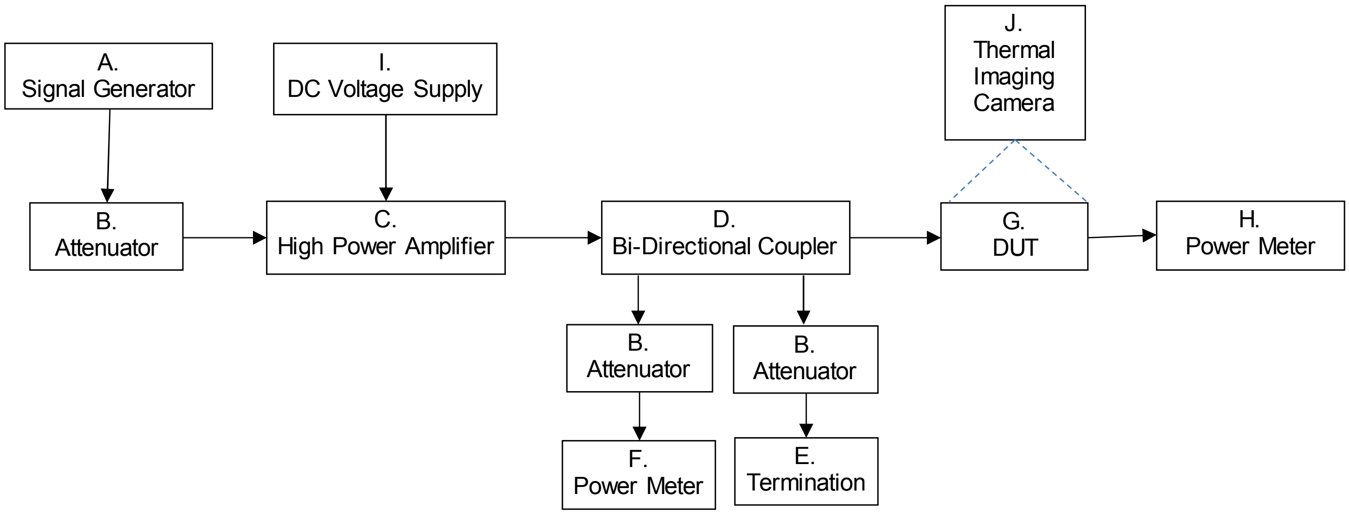

Figure 3: LFCW Series Power Handling Test Block Diagram

No.	Type	Description	MFG.	MFG/Model
A	Signal Generator	ESG Series Signal Generator, 250kHz-4.0GHz	Agilent	E4422B
B	Attenuator	5W, 10dB Attenuator, DC-18GHz	Mini-Circuits	BW-S10W5+
C	Power Amplifier	16W, 45dB High Power Amplifier, 1800-4000 MHz	Mini-Circuits	ZHL-16W-43-S+
D	Bi-Directional Coupler	250W, 35dB Coupler, 900-9000MHz	Mini-Circuits	ZGDC35-93HP+
E	Termination	50-Ohm, SMA Male	Mini-Circuits	
F	Power Meter	RF Power Meter	Boonton	4231A
G	DUT	Solder on Test Board	Mini-Circuits	TB-720+
H	Power Meter	EPM-P Series Power Meter, with E-Series Avg Power Sensor (-30 - +44 dBm), 10MHz – 18GHz	Agilent	E4416A
I	DC Power Supply	30V/50A, 1500W System DC Power Supply	Agilent	N5765A
J	Thermal Imaging Camera	12VDC, 1.25A Thermal Camera	Optotherm	InfraSight EL

Table 1 Power Handling Test Equipment List

Test Data and Calculations:

Below is an example of test analysis for filter model LFCW-1142+. Testing was performed at 4 GHz at room temperature, and prediction was made at 11.4 GHz based on the calculated thermal resistance, assuming thermal resistance is frequency independent.

Thermal imaging test for computing the Thermal Resistance of DUT

Power Handling Test 4GHz (@25°C) TB#1								
Input Power (dBm)	Input Power (W)	Power Out (dBm)	Power Out (W)	Insertion Loss (dB)	Power Dissp (W)	Unit Temperature (°C)	Temperature Change (°C)	Thermal Resitance (ϴda)
0	0.001	-0.38	0.0009	0.38	0.0001	23.0		
30	1.00	29.62	0.92	0.38	0.08	24.6	1.6	19.1
33	2.00	32.60	1.82	0.40	0.18	27.7	4.7	26.8
35	3.16	34.58	2.87	0.42	0.29	31.5	8.5	29.2
36	3.98	35.54	3.58	0.46	0.40	34.8	11.8	29.5
37	5.01	36.52	4.49	0.48	0.52	38.1	15.1	28.8
38	6.31	37.51	5.64	0.49	0.67	44.2	21.2	31.5
39	7.94	38.48	7.05	0.52	0.90	50.9	27.9	31.1
40	10.00	39.44	8.79	0.56	1.21	59.3	36.3	30.0

Calculating the max input power at room ambient temperature, 25°C
To be conservative, we choose the max thermal resistance to do the calculation.

Power Handling Analysis 11.4GHz (@25°C) TB#1								
Input Power (dBm)	Input Power (W)	Insertion Loss (dB)	Power Out (dBm)	Power Out (W)	Power Dissp (W)	Thermal Resitance (ϴda)	Temperature Change (°C)	Unit Temperature (°C)
0	0.001	2.13	-2.13	0.001	0.0004	31.5		25.0
30	1.00	2.13	27.87	0.61	0.39	31.5	12.2	37.2
33	2.00	2.15	30.85	1.22	0.78	31.5	24.5	49.5
35	3.16	2.17	32.83	1.92	1.24	31.5	39.2	64.2
36	3.98	2.21	33.79	2.39	1.59	31.5	50.0	75.0
37	5.01	2.23	34.77	3.00	2.01	31.5	63.4	88.4
38	6.31	2.24	35.76	3.77	2.54	31.5	80.1	105.1
39	7.94	2.27	36.73	4.71	3.23	31.5	101.8	126.8
40	10.00	2.29	37.71	5.90	4.10	31.5	129.1	154.1
41	12.59	2.31	38.69	7.40	5.19	31.5	163.5	188.5
42	15.85	2.33	39.67	9.27	6.58	31.5	207.2	232.2

Calculating the max input power at 100°C ambient temperature

Power Handling Analysis 11.4GHz (@100°C) TB#1								
Input Power (dBm)	Input Power (W)	Insertion Loss (dB)	Power Out (dBm)	Power Out (W)	Power Dissp (W)	Thermal Resitance (ϴda)	Temperature Change (°C)	Unit Temperature (°C)
0	0.001	2.61	-2.61	0.001	0.0005	31.5		100.0
30	1.00	2.61	27.39	0.55	0.45	31.5	14.2	114.2
33	2.00	2.63	30.37	1.09	0.91	31.5	28.5	128.5
35	3.16	2.65	32.35	1.72	1.44	31.5	45.5	145.5
36	3.98	2.69	33.31	2.14	1.84	31.5	57.9	157.9
37	5.01	2.71	34.29	2.69	2.33	31.5	73.3	173.3
38	6.31	2.72	35.28	3.37	2.94	31.5	92.5	192.5
39	7.94	2.75	36.25	4.22	3.73	31.5	117.3	217.3
40	10.00	2.77	37.23	5.28	4.72	31.5	148.5	248.5

Figure 4: Power Handling Test Analysis in Excel

Table 2 below shows the final results of maximum power for models LFCW-1062+, LFCW-1142+, and LFCW-133+.

Model	Max Input Power @25°C (W)	Max Input Power @100°C (W)
LFCW-1062+	4.0	1.6
LFCW-1142+	6.3	3.2
LFCW-133+	12.6	6.3

Table 2: Maximum Power Rating Comparison of LFCW-Series

Max Power Computation at User-Defined Maximum DUT Temperature:

Equations [1] and [2] below can be used to compute maximum power at any maximum DUT temperature defined by the user.

Abbreviation	Description
T_{DUT}	Max. allowed DUT temperature (°C)
T_A	Ambient temperature (°C)
IL	Insertion loss (dB)
Pd	Power dissipation (W)
Θ	Thermal resistance (°C/W)

Table 3: Parameters for Computation of Power Dissipation and Maximum Power Handling

$$Pd(W) = (T_{DUT} - T_A)/\theta \qquad [1]$$

$$Pin(W) = \frac{Pd}{1 - 10^{-\frac{IL}{10}}} \qquad [2]$$

Conclusion:

The method for testing of power handling demonstrated in this application note feasibly predicts the maximum power rating of LFCW-Series low pass filters. Analysis shows that the model with less pass band insertion loss exhibits a higher maximum power rating.

IMPORTANT NOTICE