Ročník 2013 electroscope Číslo I

FREQUENCY BANDPASS FILTER IN HYBRID THICK FILM TECHNOLOGY

J. Pulec [1], I. Szendiuch[1]
[1] Department of Microelectronics, Faculty of Electrical Engineering and Communication, BUT, Technická 10, Brno
E-mail: xpulec@stud.feec.vutbr.cz

Abstract:
In current electronics technology, important devices are frequency filters. These devices are used in many applications, mostly in communication technology, e.g. splitters, ADSL modems etc. In technology of manufacturing of these devices, mostly the discrete components soldered on main substrate, mostly its components are realized in SMD. This is good solution for commercial field, because this technology is well known. For industrial and military and industrial, high reliability is required. This article describes the design of planar frequency bandpass filter and results of its testing. The attention is devoted to the differences between the device theoretically designed and the device which was actually realized.

INTRODUCTION

Although in modern electronics mostly the monolithic technology and technology using SMT on organic substrate is used, is here still great field, where the thick film technology is used [1]. This field includes the industrial and military, where the reliability is crucial and where is necessary the good exhaust of heat. In addition, here is often handled with devices, that are produced in small series, so here is also important the acceptable cost in that case. So, the thick film technology offers low cost for small series and prototypes and good reliability in general, therefore this is the useful way for device manufacturing [3]. It possible to combine this technology with some another approaches [7].
As mentioned above, the thick film planar filters are the important part of many electronic systems. The manufacturing of these devices has some aspect, which should be considered.

MOTIVATION

Because the thick film technology is cheap and reliable, it is still used for many applications. In critical applications, the technology is used because of high reliability and low cost of prototype and small series manufacturing as mentioned in [4]. The advantages are exploited in fields including:

- Military
- Aerospace
- Industrial
- Communication
- Railway
- Many other

Once the device is designed, the next thing is the realization. The parameters of realized device are demanded to be predicable, according to the design. The basic question is: Will the parameters of realized device correspond to parameters considered in connection with the design.
So, the goal of presented work is the design of planar filter for realization fully in thick film technology. This filter is consequently realized and its parameters are measured. Herewith the differences between designed and manufactured device will be observed.
The thick film technology has certain limitations (e.g. resolution), so the properties of this technology have an important influence on ability of various systems to be manufactured.

BASE OF DESIGN

For the manufacturing and testing, the planar filter will be designed, the type of bandpass, Chebyshev approximation, the third order. This type of circuit was chosen because of because of wide usage in electronics technology, where the applications cover the use in industrial, aerospace, military, railway, as mentioned above. The chosen center frequency is 150 MHz and 100 MHz bandwidth (wideband), schematic is shown on Fig. 1. These values are chosen because of the demands of today electronics, where frequencies in wide range are used. The band of hundreds MHz is widely used in commercial sphere. The filter should be designed with ideally lumped parameters, the design should content passives with parameters (inductance and capacitance). In the design, rectangular inductors are used, as described in [2]. These inductors use the basic conductive layer for the very inductor structure, next the dielectric layer for terminal escaping isolation from the very inductor structure and second conductive layer for terminal escaping.

The capacitor structures is created using the stacking of layers: conductive-dielectric-conductive. This stacking is performed by the fashion similar to that described in [6]. The filter is completely passive and fully in thick film.

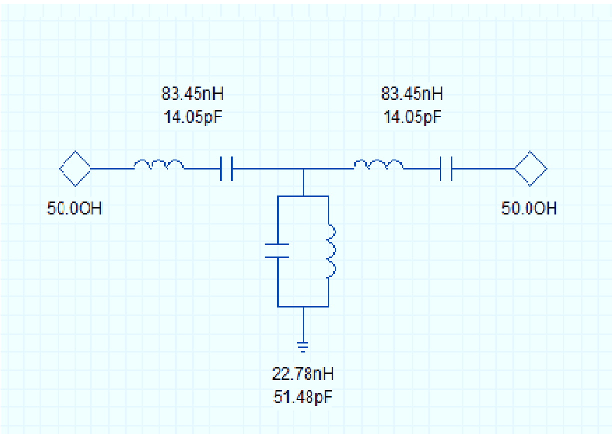

Fig. 1: Schematics of the design

FILTER REALIZATION

Realization was performed on the basis of thick film technology. The conductive paste was printed using screen onto alumina ceramic substrate. After thick-film paste leveling, and after drying, the paste was fired. Once each layer was printed the complete process was performed, as it is described. The dielectric paste was fired on temperature of 850°C and the conductive paste was fired on 900°C.
Because of this multiple process thick film process, pastes with recrystallization properties had to be used, otherwise the pattern once printed could be broken in the subsequent cycle printing-firing during firing.
This substrate material is the alumina ceramic (Al_2O_3) with thickness of 650 µm with dimensions 50 x 50 mm. The roughness of substrate is approx. 2 µm.
The thick film technology has certain limitations (e.g. resolution), so the properties of this technology have an important influence on ability of various systems to be manufactured.

In overall, the design consists of four layers in following disposition (from bottom):

- conductive layer for conductors, bottom capacitor electrodes and inductors
- dielectric layer for capacitors dielectrics
- dielectric layer for inductor overglaze
- conductive layer for inductor connecting and top capacitor electrode

Planar rectangular inductors and film capacitors are used. Width of printed conductor is here 400 µm. Conductive paste ESL 9695 - G was used for conductors, and for dielectric, the dielectric paste 4917 was used. Parameters of applied materials listed in the table (Table 1).

Parameters of materials

ESL 9695 - G	
Resistivity	3 – 6 mΩ/square
Thickness (measured after firing)	10 µm
ESL 4917	
Dielectric constant (according the datasheet)	8 – 11
Thickness (measured after firing)	12 µm

So, the schematic design was converted into layout of planar layers intended to be implemented using thick film processing technology. So, the capacitors were designed with regard to dielectric constant of assumed dielectric paste ESL 4917. The design is shown on Fig. 2.

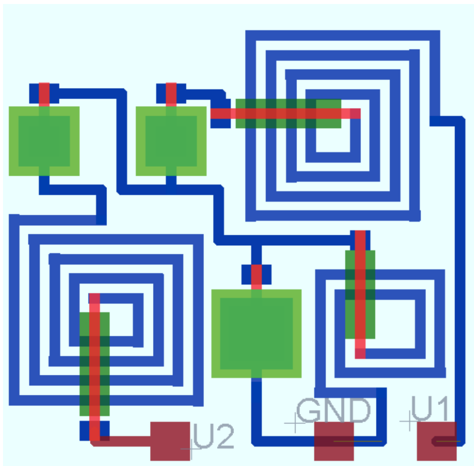

Fig. 2: Pattern of the designed device

The layout pattern is fits into the square with edge of 25 mm, so on one substrate 50 x 50 are localized four such patterns. After the design, the filter was manufactured using standard thick film processing, where each layer was printed once, with an exception of inductor overglaze, which was printed three times. The firing of each layer followed immediately after printing and leveling. Three substrates were processed, each with four design patterns, so there were twelve test samples. , such as displayed on Fig. 3.

The thickness of printed layer was measured. So, thickness of the conductive layer is 10 µm and thickness of dielectric is 12 µm, as above in Tab. 1. Thickness of three times printed dielectric overglaze is 35 µm. The roughness of surface is 3 µm.

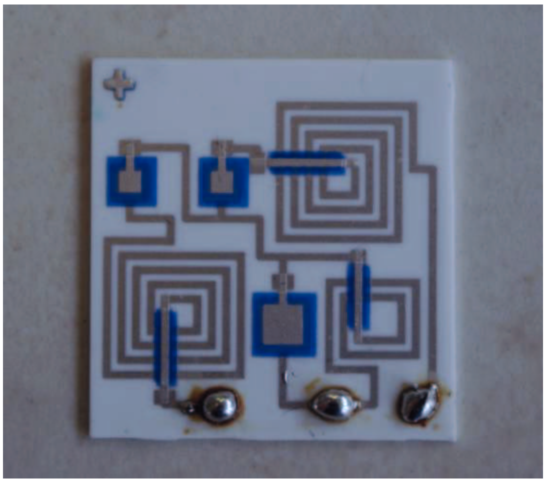

Fig. 3: The realized sample

MEASUREMENT

For measurement of characteristics, the samples were equipped with the metal case with SMA connectors, as pictured on Fig. 4. This case prevents the influencing of the measurement by the adjacent EM field and protects the measured sample from mechanical damaging during manipulation.

Fig. 4: Metal case for characteristics measurement

The measurement was performed using vector analyzer on frequencies varying from 10 MHz to 300 MHz. On this setting , the complete frequency characteristics was drawn. The main purpose was capture the frequency characteristics of realized filters, when the desired was such that has the bandpass extending from 100 MHz to 200 MHz .

RESULTS

The core of the measurement is the frequency characteristics drawing. The purpose of this is to determine, how the parameters of realized device differs from those, for that the filter was designed. The characteristic is pictured on Fig. 5.

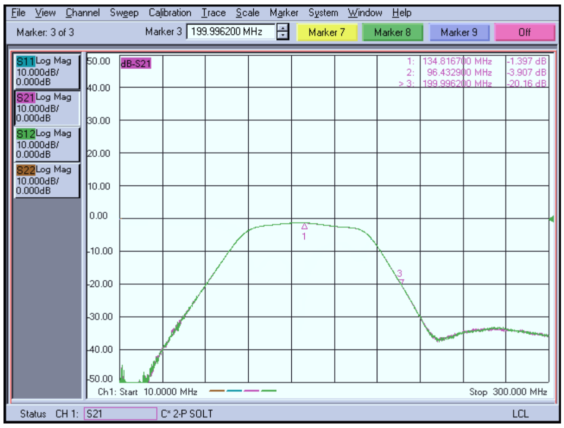

Fig. 5: The measured frequency characteristics

The intended pass should originally extend from 100 to 200 MHz. According to the characteristics measured, the pass begins on 100 MHz as desired. But the drop is approximately on 170 MHz instead on 200 MHz: so the pass band is more narrow; its actual width is 70 MHz. The highest gain is on 135 MHz. The gain on 200 Mhz is now 20 dB. The steepness in the sides of pass band is approximately 7 dB/10 MHz.

Fig. 6: The S11 parameters

Fig. 7: The S22 parameters

Next, the S11 and S22 parameters were measured. Because the system is fully passive this parameters should be identical . The results is on Fig. 6. ; here is shown that the measured parameters are almost identical. The charts are shown on Fig. 6 and Fig. 7.
Important is the capacitance of manufactured capacitors. This capacitance, which depends on geometry and dielectric material was on from three capacitors intended to be 14,05 pF. According the capacitance measurement, capacitance ranges from 15,3 to 15,7 pF. This results are good, but the measurement also showed that not each capacitor was properly manufactured. From the overall set of 36 capacitors (three on each substrate), ten capacitors were short-circuited. The reason are the micro-holes in dielectric layer, which was, in order to obtain desired capacitance, printed only once.

CONCLUSION

The realized device has the correct properties of bandpass filter, steepness of characteristics on sides of pass band is good, the attenuation in pass band is low. That are results for the device as it has been realized, without any additional treatments, such as trimming, for example. The pass band is more narrow, which shows necessity for additional trimming or another parameter shifting, in order to obtain the desired characteristics.
For realization of passive frequency filters, the thick film technology is suitable. The attention must be devoted also to the capacitor design and realization, to avoid the short circuitry, as mentioned above. Next, the But it is necessary to design the capacitors with regards to the fact that more than one dielectric layer is necessary to avoid the short circuit occurrence.

ACKNOWLEDGEMENT

Funding for this research was obtained through grant project FEKT-S-11-5/962 “Research of excellent technologies for 3D packaging and interconnection“ supported from Czech Ministry for Education, and Sport...

REFERENCES

[1] BROWN, R., Materials and Processes for Microwave Hybrids. Reston, VA: ISHM, 1991, 294 p., ISBN: 0-930815-31-9.

[2] ULRICH, R. K., SCHAPER, L. W., Integrated Passive Component Technology. Piscataway, NJ: IEEE Press, 2003, 377 p. , ISBN 0-471-24431-7

[3] PODPROCKY, T., VANDERCASTEELE, B., DE BAETS, J., VAN CALSTER, A., BANSKY, J. Integration of Thick Film Resitors in a Multilayer Structure. 26th International Spring Seminar on Electronics Technology. May 8 – 11, 2003.

[4] ISHIDA, A., HATAGI, K., Hybrid IC Packaging Technology for Microwave Communication Systems. Proceedings of the 1982 International Microelectronics Conference, IMC 1982, May 24 - 26, 1982, Keio Plaza Hotel, Tokyo, Japan. 445 p.

[5] NISHIKI, S., YUKI, S., Thick Film Microstrip Loss in Microwave Region. Proceedings of the 1982 International Microelectronics Conference, IMC 1982, May 24 - 26, 1982, Keio Plaza Hotel, Tokyo, Japan. 445 p.

[6] MUNAWAR, A., RIAD, M. S., RIAD, A.A.R, STEPHENSON, F. W., An ALL Thick-Film Stripline Conduction. IEEE Transactions on Components, Hybrids, and Manufacturing Technology, Vol. CHMT-5, NO. 3, September 1982

[7] CONN, D. R., NAGUIB, H. M., ANDERSON, C. M. Mid-Film for Microwave Integrated Circuit. IEEE Transaction on Components, Hybrids, and Manufacturing Technology, Vol. CHMT-5, No. 1, March 1982

[8] ILGENFRITZ, R. E. , MOGEY, L. E. , WALTER, D. W. A High Density Thick Film Multilayer Process for LSI Circuits, IEEE Transactrions on Parts, Hybrids, and Packaging, Vol. PHP-10, No. 3, September 1974