Rev. 2016-10-28

IMS2017 Student Design Competition Rules

As part of the technical program, the Student Design Competition (SDC) is one of the most energetic parts of IMS. The SDCs have proven to be very successful events in the past 12 years, as evidenced by the ever increasing student participation and the support it has enjoyed from the organizers, both logistically and financially. The IMS2017 in Honolulu will continue the legendary tradition of enthusiasm with a very strong SDC program.

TC number and name:

MTT-8 FILTERS AND PASSIVE COMPONENTS

The title of Student Design Competition:

Dual-Band Variable-Attenuation Notch Filters

Submission Deadline: Friday, 31 March 2017

Sponsors:

MTT-8 Filter and Passive Components

Primary contact name(s), email address, and phone number (of host or competition leader(s)):

Andrew Guyette: acguyette@gmail.com
Eric Naglich: eric.naglich@nrl.navy.mil

A short abstract or summary describing the competition:

Bandstop/notch filters are most often used to reject undesired signals from propagating further into a circuit. However, some applications use bandstop filters to reduce strong signals to power levels that are within their receiver's dynamic range. The signal at the bandstop center frequency is still desired in these applications, but some attenuation is required in order to prevent compression of the receiver. The goal of this competition will be to design a dual-band bandstop filter for such an application. Entries will be scored based on passband loss over specified frequency ranges, notch attenuation level ability to be set within desired ranges in a defined bandwidth, and creativity.

Design Specification/Rules:

The notch filter may consist of single-layer or multiple layer substrates, varactors, switches, diodes, mechanical trimmer capacitors, tuning screws, and/or lumped elements. It must have traces or wires that are soldered to female SMA connectors on the edges of the substrate. The filter will be evaluated based on the performance measured between the SMA connector interface reference planes. A network analyzer and two voltage sources (0-20 Volts, 0-100 mA) will be available for measurements and filter reconfiguration.

Scoring of entries will be based on a quantitative point system. The entries with the lowest number of points will win the prizes. Points will be assessed according to the following specifications:

1. The two notch bands will be centered at 0.9 GHz and 1.1 GHz with bandwidths of 8 MHz for both bands. Each notch band should have the capability to be reconfigured between three states: as low as possible insertion loss, 10-20 dB insertion loss, or more than 20 dB insertion loss independent of the state of the other notch band. The judges will pick three combinations of attenuation settings that will be announced at the beginning of the competition. An example of three combinations of attenuation settings that could be selected by the judges is:

    a. As low as possible insertion loss from 0.896 GHz to 0.904 GHz and more than 20 dB insertion loss from 1.096 GHz to 1.104 GHz
    b. 10-20 dB insertion loss from 0.896 GHz to 0.904 GHz and more than 20 dB insertion loss from 1.096 GHz to 1.104 GHz
    c. 10-20 dB insertion loss insertion loss from 0.896 GHz to 0.904 GHz and as low as possible insertion loss from 1.096 GHz to 1.104 GHz

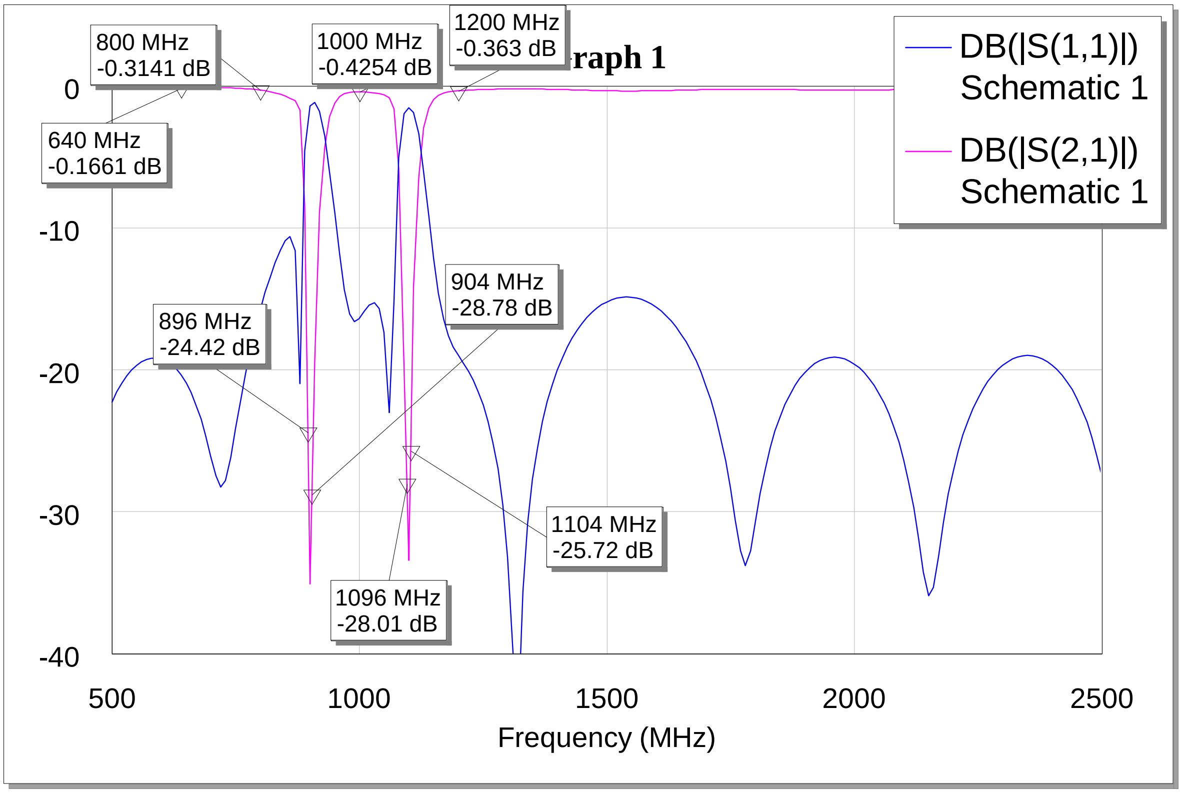
0 points will be assigned whenever a “10-20 dB insertion loss” or “more than 20 dB insertion loss” specification is satisfied over the entire 8 MHz band of interest. 5 points will be incurred for each specification that is not satisfied. When “as low as possible insertion loss” is specified for a particular band, 0.2 points will be incurred for each 0.1 dB insertion loss above zero (2 points/dB insertion loss).

2. In practical filter applications, the passband insertion loss should be as low as possible. For this competition, the passband insertion loss will be measured at 0.8 GHz, 1 GHz, and 1.2 GHz. 0.2 points will be incurred for each 0.1 dB insertion loss above zero (2 points/dB insertion loss) at each of these frequencies for each of the three attenuation settings.
3. Electronic or manual tuning: Electronically tuned/switched filters will incur 0 points, while mechanically-tuned filters will incur 5 points. This is a one-time penalty that will not be assessed for each of the three measurements.
4. When "as low as possible insertion loss" is specified for a band, 3 points will be incurred if the method used to obtain low insertion loss in the band is simply tuning the resonators far away from the 0.8 GHz to 1.2 GHz band of interest. 0 points will be incurred if a more creative method is chosen.
5. After all measurements are made, each judge will have one "bonus" to award to the team that he thinks addressed the challenges in either a creative or commendable way. The bonus will be worth negative 3 points and is a one-time bonus that will not be awarded for each of the three measurements.
6. In order to keep the competition length within a reasonable amount of time, students will have three minutes to tune their filters for each attenuation setting.

Two examples of filter scoring are shown below:

<u>Example 1</u>

The attenuation setting for the first example is for more than 20 dB insertion loss from 0.896 GHz to 0.904 GHz and more than 20 dB insertion loss from 1.096 GHz to 1.104 GHz. A frequency response of a representative filter is shown below:



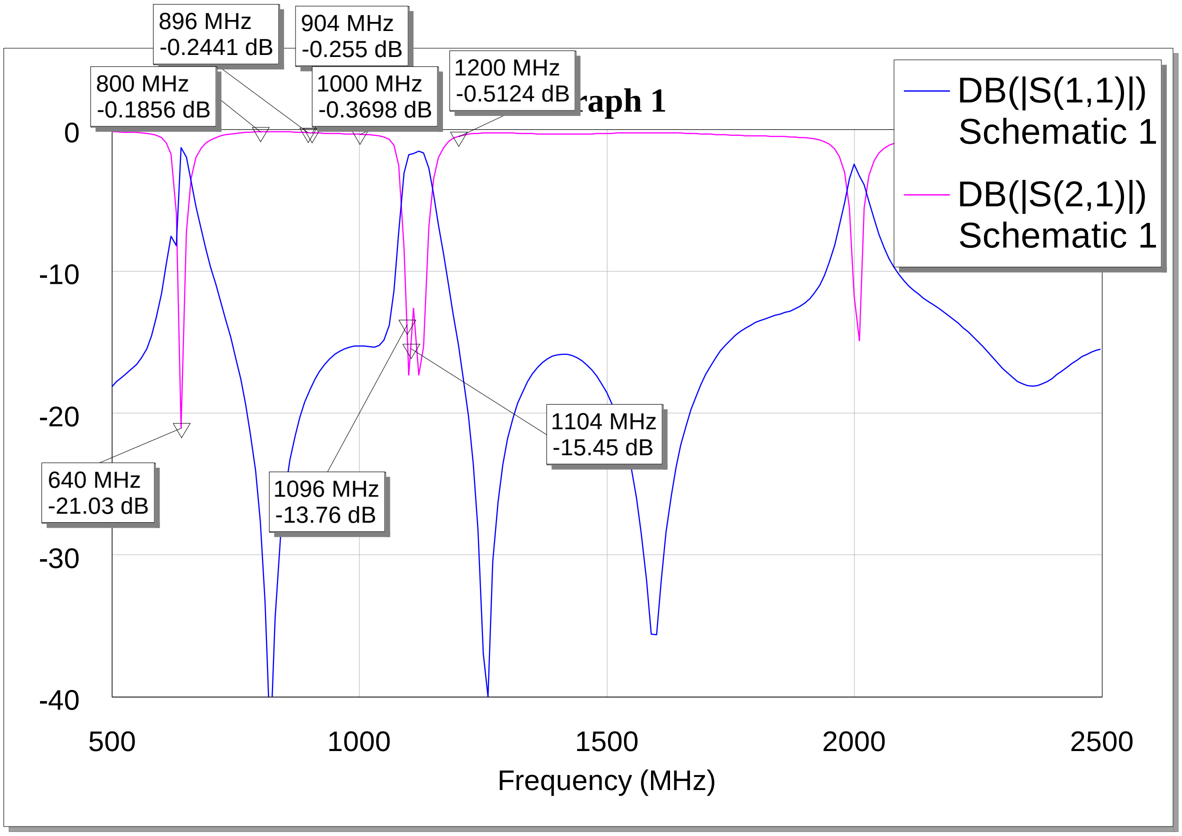
The response meets the more than 20 dB attenuation specifications in both bands. 0 points are incurred.

The response has 0.3 dB, 0.4 dB, and 0.4 dB insertion loss at 0.8 GHz, 1.0 GHz, and 1.2 GHz, respectively. 0.3(0.2) + 0.4(0.2) +0.4(0.2) = 2.2 points are incurred.

2.2 total points are incurred for this measurement, which would be one of three total measurements made during the competition.

<u>Example 2</u>

The attenuation setting for the second example is for as low as possible insertion loss from 0.896 GHz to 0.904 GHz and 10-20 dB insertion loss from 1.096 GHz to 1.104 GHz. A frequency response of a representative filter is shown below:



The response meets 10-20 dB attenuation specification in the 1.096 GHz to 1.104 GHz band. 0 points are incurred.

The response has 0.2 dB, 0.4 dB, and 0.5 dB insertion loss at 0.8 GHz, 1.0 GHz, and 1.2 GHz, respectively. 0.4(0.2) + 0.4(0.2) +0.5(0.2) = 2.6 points are incurred.

In order to achieve low attenuation from 0.896 GHz to 0.904 GHz, one of the filter responses is tuned to 640 MHz. This incurs 3 points.

5.6 total points are incurred for this measurement, which would be one of three total measurements made during the competition.

Note: There are many filter topologies and design methods that are relevant to this competition, and it is impossible to obtain a perfect score of zero points. It could be possible that using a strategy that automatically incurs points (such as mechanical tuning) allows a team to obtain the lowest total score. We hope to see a variety of strategies in this competition and also hope that such an open competition will generate discussions between teams about the benefits of their chosen design methods.

How to Participate:

Student contestants must notify by e-mailing to eric.naglich@nrl.navy.mil of their intention to compete in the contest before Monday, 13 March 2017. This notification should include the university or educational affiliation of the entry, the name and contact information of the contestant's adviser, and the names of all students involved in the design.

Prizes:

The prize money allocated is $2000 per contest. The forecasted prize division is: First place will receive $1500, second place will receive $300, and third place will receive $200. The judges reserve the right to change this allocation based on the number and quality of the entries, as well as score ties or other unforeseen scoring events. This will be a one level competition.

Reference:

The references below serve as examples of variable attenuation or dual-band notch filters. It is not an exhaustive list, and the references below are not recommendations or limitations on what can be done in the competition.

T. H. Lee, K. Lee, G. C. Park, Y. S. Kim and J. Lee, "Bandstop Filter (BSF) Topology With Variable Attenuation," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 64, no. 2, pp. 467-474, Feb. 2016.

S. Toyoda, "Notch filters with variable center frequency and attenuation," *Microwave Symposium Digest, 1989., IEEE MTT-S International*, Long Beach, CA, USA, 1989, pp. 595-598 vol.2.

E. J. Naglich, J. Lee, D. Peroulis and W. J. Chappell, "Switchless Tunable Bandstop-to-All-Pass Reconfigurable Filter," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 60, no. 5, pp. 1258-1265, May 2012.

D. R. Jachowski and C. Rauscher, "Frequency-agile bandstop filter with tunable attenuation," *Microwave Symposium Digest, 2009. MTT '09. IEEE MTT-S International*, Boston, MA, 2009, pp. 649-652.

A. Ghaffari, E. A. M. Klumperink and B. Nauta, "Tunable N-Path Notch Filters for Blocker Suppression: Modeling and Verification," in *IEEE Journal of Solid-State Circuits*, vol. 48, no. 6, pp. 1370-1382, June 2013.

A. C. Guyette, "Intrinsically Switched Varactor-Tuned Filters and Filter Banks," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 60, no. 4, pp. 1044-1056, April 2012.

Y. H. Chun, H. Shaman and J. S. Hong, "Switchable Embedded Notch Structure for UWB Bandpass Filter," in *IEEE Microwave and Wireless Components Letters*, vol. 18, no. 9, pp. 590-592, Sept. 2008.

K. S. Chin, J. H. Yeh and S. H. Chao, "Compact Dual-Band Bandstop Filters Using Stepped-Impedance Resonators," in *IEEE Microwave and Wireless Components Letters*, vol. 17, no. 12, pp. 849-851, Dec. 2007.

C. H. Ko, A. Tran and G. M. Rebeiz, "Tunable 500–1200-MHz Dual-Band and Wide Bandwidth Notch Filters Using RF Transformers," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 63, no. 6, pp. 1854-1862, June 2015.

K. Lee, T. H. Lee, C. S. Ahn, Y. S. Kim and J. Lee, "Reconfigurable Dual-Stopband Filters With Reduced Number of Couplings Between a Transmission Line and Resonators," in *IEEE Microwave and Wireless Components Letters*, vol. 25, no. 2, pp. 106-108, Feb. 2015.