# Crystal Filters with Variable Bandwidth and Constant Center Frequency

*The author presents a new approach to variable-bandwidth crystal filters allowing the center frequency to remain constant while bandwidth is changed.*

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This new filter was inspired by the Ten-Tec Jones filter (Lee Jones, WB4JTR, US patent #5051711). The Jones filter achieves variable bandwidth but with a shift in the center frequency of the filter. Depending on the application, this may be good or bad.

For a simple receiver, the Jones filter could be used to advantage by setting the frequency shift so that the wide and narrow bandwidths are on either side of the BFO frequency. The narrow side would be for CW and the wide side for SSB[1]. Fig 1 shows the Jones filter. As can be seen from the figure, the shunt varactors are

[1]Notes appear on page 17.

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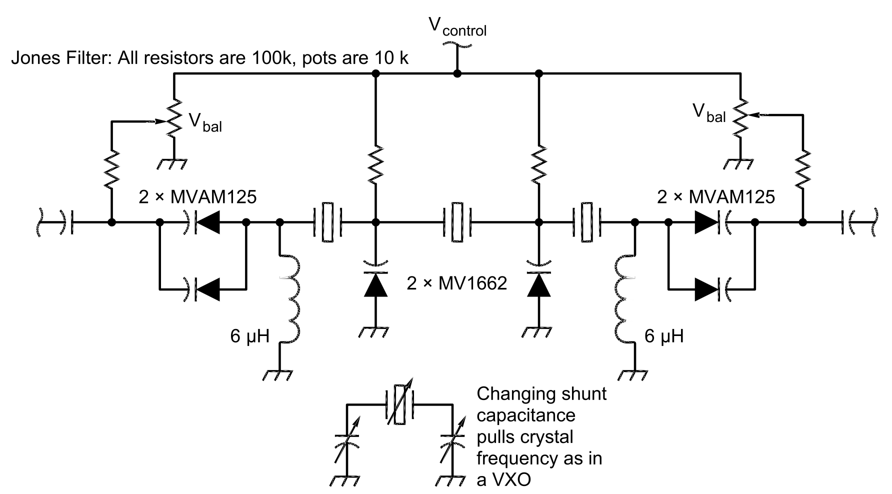


**Figure 1—A typical Jones filter with voltage-controlled matching networks, plus a simple diagram illustrating the capacitive pulling effect on a crystal.**

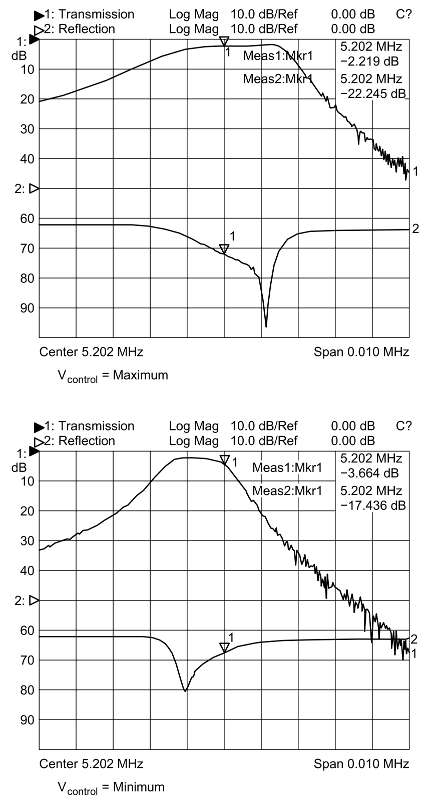


**Figure 2—The measured insertion loss vs. frequency (vs. Vcontrol) of a three-crystal Jones filter. Top—maximum bandwidth, bottom—mimimum bandwidth.**

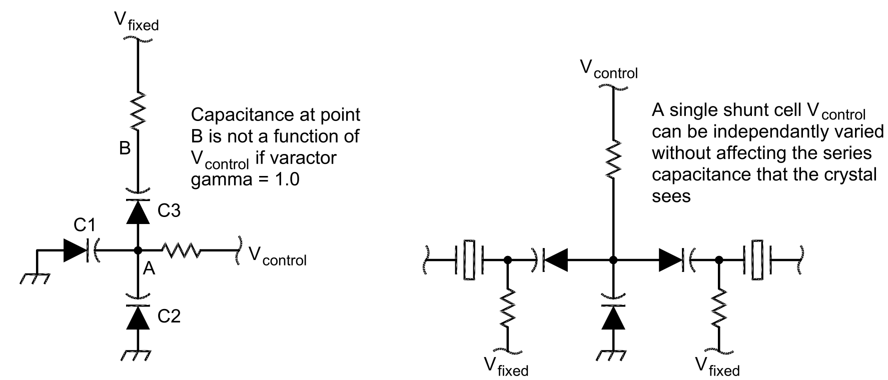


**Figure 3—Diagrams to illustrate the independence of Vcontrol on the series capacitance presented to a crystal.**

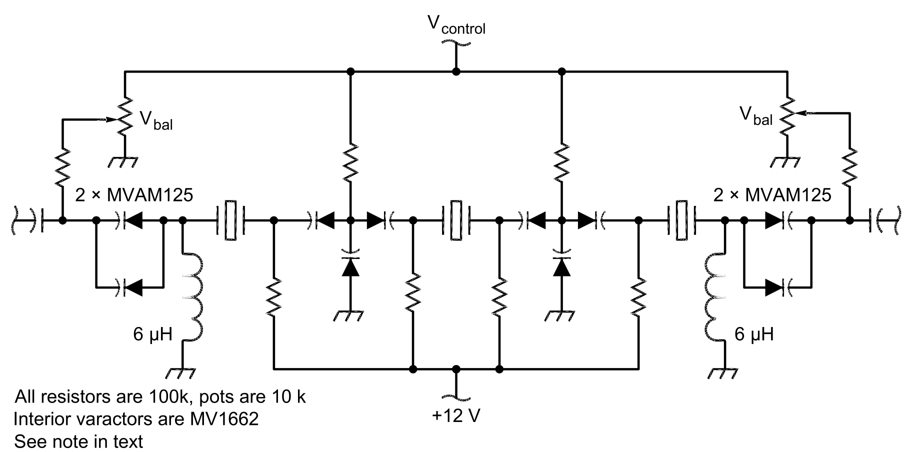


**Figure 4—The schematic diagram of the new filter. Notice the voltage-controlled matching networks. These were borrowed from the Jones filter and work very well.**

pulling the frequency of the crystals, much as in a VXO. Fig 2 shows the response of a Jones filter at minimum and maximum usable bandwidth. Refer to Fig 6 for the test setup. Notice the shift in center frequency. For applications needing a fixed center frequency (eg, spectrum analyzers and more sophisticated receivers), the frequency shift of the Jones filter may not be a good match for the application.

The key to developing the new filter was the realization that certain varactors had novel properties when connected in series. To get to this understanding, we need to discuss the C vs. $V_r$ curves for varactors. For any varactor one can express the capacitance vs. reverse bias by the equation:

$$C = \frac{C_o}{(V_r + V_\varphi)^\gamma} \qquad (1)$$

Gamma (γ) is a function of the doping profile of the diode. $V_\phi$ is the turn-on voltage of the diode. $C_o$ is a constant depending on the diode geometry.

It is particularly interesting if the gamma of two series-connected diodes is close to 1.0. In that case, one can show algebraically that the capacitance of two series connected varactors is no longer dependent on the voltage on the middle node. Referring to Fig 3, simply substitute the varactor equation into the equation for series-connected capacitors, adding Cshunt to the second capacitor (i.e. C3 in series with C1+C2). C1 is the shunt cap, which normally would shift the filter center frequency. Now only the voltage at point B sets the capacitance at B. The equation is:

$$C_{fixed} = \frac{C_o}{(V_r + 2V_\varphi)} \qquad (2)$$

Where $V_r$=$V_{fixed}$. The Vcontrol terms cancel out.

What this means is that by using varactors with a gamma of nearly 1.0, a network can be constructed which allows for the bandwidth adjustment of a filter without upsetting the center frequency of the filter. Many varactors have been found to have gammas close to 1.0 over at least part of their ranges. For example, the MVAM125, MMBV109L and MMBV609L may be usable. Some of these are smaller-value SMT types, so they would have to be paralleled. The varactors chosen for this project are particularly good in this regard. Although the retailer (Hosfelt[2]) is marking them as matched triplets of MV1662s, the diodes are much too hyperabrupt to be of that type. Hyperabrupt refers to the diode doping profile. Abrupt junctions tend to have a smaller ratio of maximum to minimum capacitance whereas the hyperabrupt diodes have a large ratio.

Fig 4 shows the entire test filter. The potentiometers on each end are adjusted for flattest passband response. Each 6 µH inductor is simply four turns on a BN61-202 balun core. A smaller core will work just as well with a few more turns added. The crystals used in this project are all 5.200 MHz, taken from carrier filters on a surplus ATT FDM unit. The filter cans were opened and the crystals

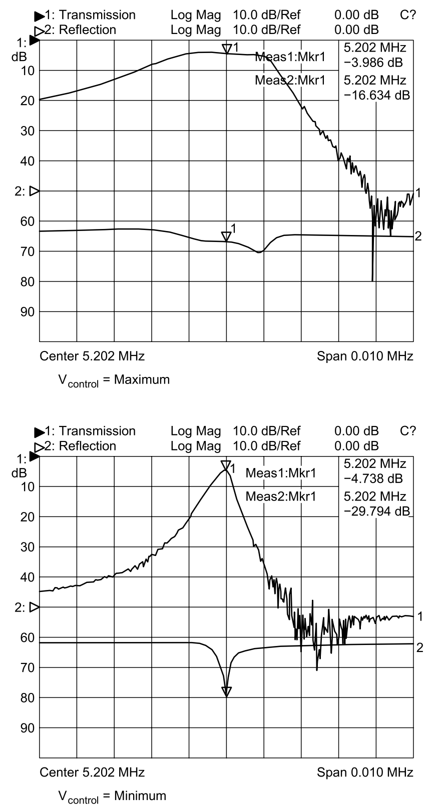


**Figure 5—The measured insertion loss of the new filter as a function of Vcontrol. Top—maximum bandwidth, bottom—mimimum bandwidth.**

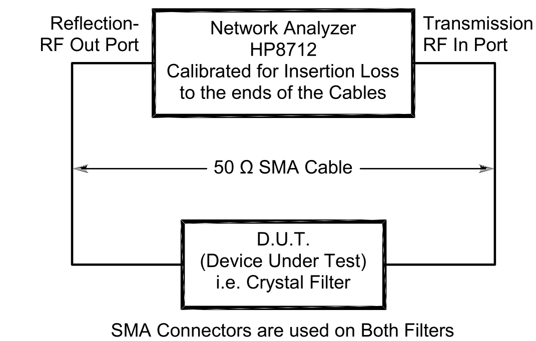


**Figure 6—The test setup used to measure the insertion loss of the filters.**

extracted. Crystals for other frequencies can be used, with varactors of an appropriate $C_o$ .

Fig 5 shows the passband response of the new filter at minimum and maximum usable bandwidth. See Fig 6 for the test setup. Notice that the center frequency remains fairly constant. The second trace on each plot is the filter input return loss (add 10 dB).

In conclusion, a new type of variable bandwidth crystal filter has been developed that maintains a constant center frequency and may have uses in test equipment and radio receivers.

**Notes**

[1]Conversation with W7ZOI.

[2]Hosfelt Electronics, 2700 Sunset Blvd, Steubenville, OH 43952, 800-524-6464, p/n MV1662/S. At last count they had over 5000 of these left. There are three diodes per package.

*Rob Lytle was originally licensed as a ham as WN3YXB at the age of 12. At the age of 16 he became an Extra Class ham with call sign N3FT. A few years later, he graduated with a BSEE from the University of California at Berkeley. Most recently he had been employed as an Applications Engineer at TriQuint Semiconductor in Hillsboro, OR. Rob still enjoys the hobby with emphasis on construction projects, antenna projects, and working 6 and 160-m.* □□