The electronic circulator made its debut ten years ago (Reference 1). It functioned at VHF as a three-port unit using a Comlinear (now part of National Semiconductor, www.nsc.com) CLC 406 operational amplifier. The circuit in Figure 1 extends the circulator's performance to four-port operation at low frequencies, using the readily available 941 (equivalent to the ubiquitous 741) and LM318 op amps. Table 1 shows the measured data for the 741-equivalent op amp. Table 2 shows the measured data for the LM318 op amp. The four-port circulators in Figure 1 use 50Ω impedance levels. The circuit can readily accommodate other impedance levels, such as 75 and 600Ω. You can see that for typical circulator operation at frequencies below 50 kHz, you can use the 741-equivalent op amp. For typical operation at speeds as high as 1 MHz, you would use the LM318 op amp. The resistors in Figure 1 are metal-film units with ±1% tolerances. The circulator breadboards use open (not shielded) construction, and the components are soldered to the vector board. The ICs use commercially available sockets soldered to the vector board.

You can use the electronic four-port circulators in various applications with the fourth port terminated. You can configure baseband-amplitude and group-delay equalizers using the electronic circulator (references 2 and 3). You can also use the circuit as a low-frequency return-loss bridge or as an electronic isolator. Low-frequency op amps are available as quads with four independent op amps. You can configure a miniaturized, low-cost version of the circulator using surface-mount pc-board techniques.


References