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Evolution of the Zero-Degree Hybrid

Figure 1 is the functional diagram of a common RF circuit, the zero-degree hybrid. In one direction, the signal is divided into two equal outputs, while in the opposite direction, two inputs are combined into a single output. The phase shift from the common port to each of the two divided ports is the same, so the relative phase between those two ports is zero degrees.

The configurations presented here also provide isolation between the two divided ports, as indicated by the term "hybrid," which was first used in the telephone industry to describe special transformers with this isolation characteristic.

Wilkinson divider/combiner [Figure 2(a)]—This well-known topology uses two quarter-wavelength transmission line sections between the common port and the two divided ports. The λ/4 lines provide isolation because they are in series between the two ports—a relative phase shift of 180º that effectively cancels the signal from the opposite port. The resistor across the two-port side dissipates unbalanced energy and provides a load in the event of an open or short circuit at one of the ports.

The Wilkinson circuit has a good useful bandwidth, about an octave, but becomes narrowband if the λ/4 sections are used to provide an impedance transformation to maintain the same impedance at all ports.

Transmission Line Transformer (TLT) hybrid [Figures 2(b, c)]—In circuit of Fig. 2(b), the λ/4 sections are replaced with 1:1 TLTs, usually ferrite-loaded short transmission lines, with both lines wound on the same core, but with opposite winding sense. A signal traveling from one of the divided ports to the other passes through the transformer twice, creating two nearly equal and opposite magnetic flux components that cancel one another. The amount of port-to-port isolation depends on the electrical length of the path and the electrical symmetry of circuit construction. The resistor on the two-port side has the same function as in the Wilkinson divider.

The ground paths in the circuit of Fig. 2(b) are included to show that they are redundant. These ground paths can be combined into a single ground outside the transformer. The result is the familiar simplified TLT structure of Fig. 2(c), also known as the Magic Tee. (This simple circuit diagram may be drawn in at least four different ways!)

Unlike the Wilkinson, the TLT hybrid has no λ/4 lines and cannot provide impedance transformation. A separate matching transformer or a different topology would be needed to achieve the same impedance at all ports. The principle advantages of this TLT hybrid are simplicity and very wide bandwidth—multiple *decades* of frequency range can be covered with the right selection of core and winding.

Finally, note that these circuits can be expanded to *n*-way combiner/divider circuits. The 2-way version was described to allow the simplest explanation.

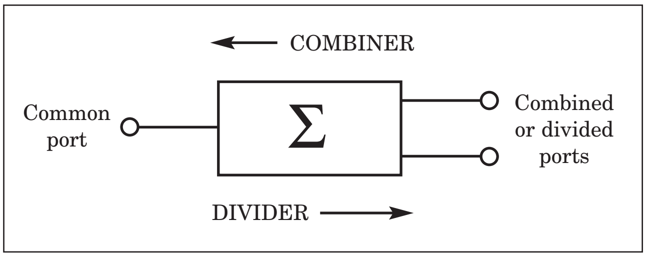
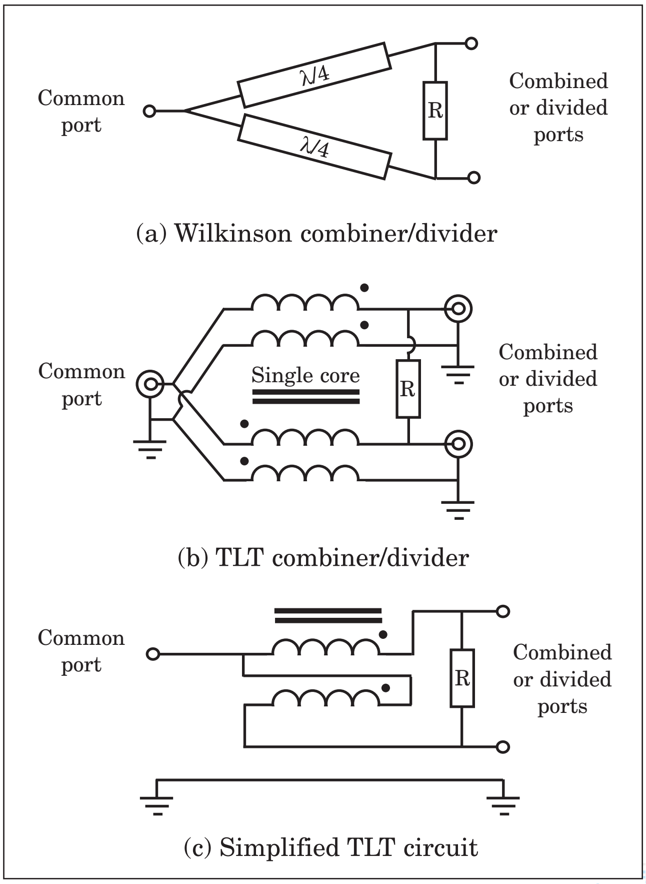


Figure 1 · Block diagram of a 2-way 0° combiner/divider. "Hybrid" circuits implementing this function also provide isolation between the two ports on the right side.



Evolution of the 0° hybrid: (a) Wilkinson divider/combiner, (b) transmission line transformer equivalent, and (c) simplified transformer version.