Notes on Power Combiner and Splitter Circuits

Popular inductive circuits used for power combiners/splitters have the appearance of transmission line transformers — but are they?

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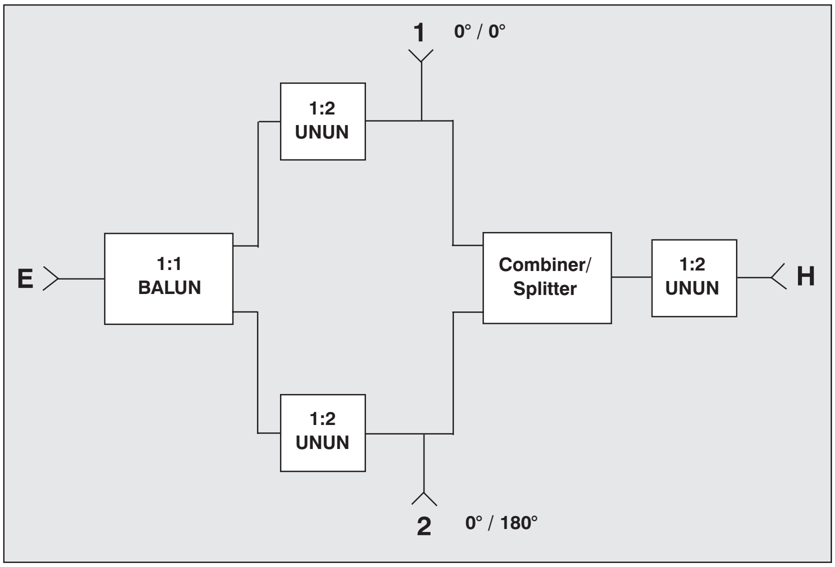
A power combiner/splitter is either a combiner or a splitter depending upon the direction the source of power takes. In one direction, it sums multiple sources into a common output; in the other direction, it divides a single source into multiple outputs. Figure 1 is a block diagram of a popular logic circuit. If power is applied to terminal H on the right, then half of the power will appear at terminals 1 and 2. Also the voltages will have same phase as that of the source (1 = 2). Terminal E is isolated from the rest of the circuit because of the choking action of the balun (balanced-to-unbalanced transformer). In-phase (common mode) currents are suppressed. [*Some readers may recognize this circuit as an RF version of the classic telephone hybrid — ed.*]



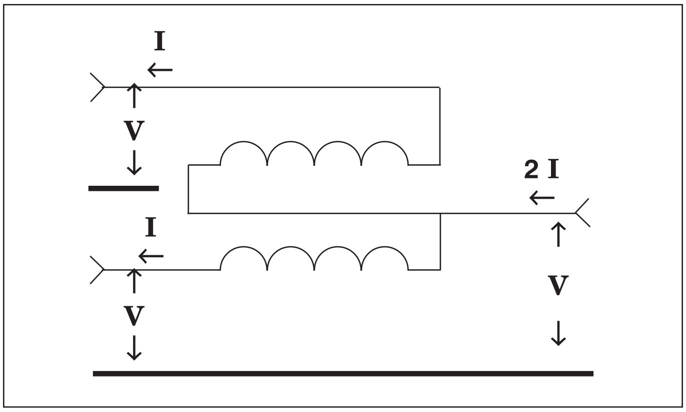
▲ **Figure 1. Block diagram of a popular logic circuit.**

If power is applied to terminal E, then half of the power will appear at terminals 1 and 2. But in this case, the voltage at terminal 2 is 180 degrees out-of-phase with terminal 1 (1 = 2). Terminal H is now isolated from the rest of the circuit because the power splitter now becomes a high impedance choke for the balanced output of a balun.

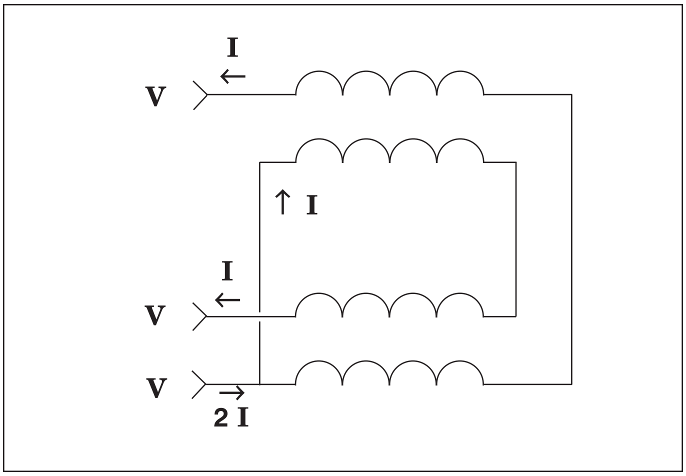
Notes — The 1:2 unun (unbalanced-to-unbalanced transformer) between H and the splitter is necessary since the splitter also performs as a 4:1 transformer with the loads at terminals 1 and 2 in series and grounded at the center. The other two ununs are needed because terminals 1 and 2 would only see half of the output impedance of the 1:1 balun. It is suggested that these two ununs be replaced by one unun between E and the balun. The characteristic impedance of the balun in this case should be twice that of the loads at terminals 1 and 2. For very high frequency applications, where thin wires and small toroids are used, a 100-ohm balun would be easier to achieve than a 50-ohm balun.

New models

There are basically, two models of combiners/splitters. Type I is shown in Figure 2. Assuming the power is applied to the right side, it splits equally to the upper and lower ports on



▲ **Figure 2. Type I power combiner/splitter circuit.**



▲ **Figure 3. Type II combiner/splitter circuit.**

the left. Therefore, all ports have the same magnitude and phase of voltage. Also, the input current to the splitter is twice that of the output currents. The output of the splitter sees two loads in series and grounded at the center. In a sense, a power splitter is a 4:1 transformer and hence, requires a 2:1 unun connected to the low impedance side.

The two wires in a Type I combiner/splitter are usually twisted together for closer coupling. Invariably, these devices are called "transmission line-type transformer." But they are *not* transmission line transformers. Except for Guanella's 4:1 balun/unun, which has one of its transmissions lines acting as a delay line, all transmission line transformers have voltage drops along the length of their transmission lines due to their choking action. The Type I combiner/splitter doesn't have this voltage drop. The reason for the lack of this voltage drop is, simply put, the two currents cancel out the flux in the core resulting in no inductive reactance. But, if one traces the currents when the source of power is the balanced output of a balun on the left side, it can be seen that the currents are in series-aiding. This results in a high impedance to the flow of current and the isolation of the device from the rest of the circuit.

Figure 3 shows the Type II combiner/splitter. As can be seen, the voltages and currents are the same as that of the Type I combiner/splitter. Again, by tracing out the currents, it can be seen that the flux is canceled out in the cores resulting in no voltage drops along the lengths of the transmission lines.

It has been said that the Type I combiner/splitter has better VSWR performance but poorer isolation than the Type II device. This can be explained by noting that the Type II circuit has two cores in series with series-aiding currents, resulting in better isolation because of its greater choking action. The Type II combiner/splitter is also more prone to parasitics because of its extra wiring. This very likely accounts for its poorer VSWR performance.

Recommended reading

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5. H. O. Granberg, "Broadband Transformers and Power Combining Techniques for RF," *Motorola Applications Note AN-749*, 1975.

6. E. Rotholz, "Transmission Line Transformers," *IEEE Trans. MTT*, Apr. 1981.

7. S. E. London, S. V. Tomesevich, "Line Transformers with Fractional Transformer Factor," *Telecommunications and Radio Engineering*, Vol. 28/29, Apr. 1974.

Author information

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