ALTEC ENGINEERING NOTES

TECHNICAL LETTER NO. 228

UNDERSTANDING AND USING HYBRID CIRCUITS

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General

This technical letter supplements Technical Letter No. 222 with more detail about hybrid circuits. Hybrid circuits are interesting and, on occasion, can be quite useful. Basically, a hybrid circuit allows signals on two two-wire circuits to be combined in a common two-wire circuit without interfering with each other. When properly balanced, a high degree of isolation is present between the two legs on the four-wire side of the hybrid, and very low isolation occurs between either of these legs and the common, or two-wire, side of the hybrid. This may be easier to understand with a diagram. Figure 1 is a vector diagram representing a hybrid circuit. The arrows represent signal flow. A signal may be transmitted from A to B and A to C or from B to A and C to A, but not from B to C or C to B without a high insertion loss. Z is a balance network, or resistor, and must complement the impedance of A for proper operation of the hybrid.

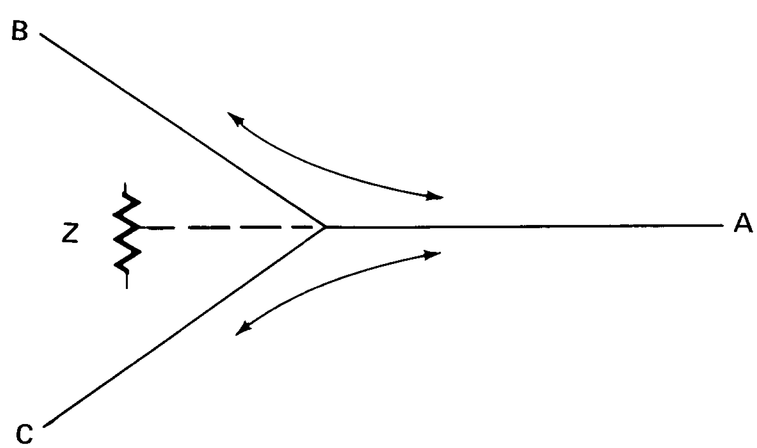

Figure 1

Litho in USA CP-1173-2.5K

15067 Hybrid Circuit

The ALTEC 15067 Transformer used in the 1603A SEQUR Amplifier Coupler is a good example of a hybrid circuit. Relating the 15067 to Figure 1: **B** and **C** represent inputs from two power amplifiers, **A** represents the speaker load, and **Z** is the balance resistor in the 1603A. The value of **Z** is determined by the output impedance of the amplifiers used, and is twice the rated load impedance of one amplifier. Since no signal is transmitted from **B** to **C** or from **C** to **B**, neither amplifier presents a load to the other. Figure 2A is a simplified diagram of the hybrid in the 1603A.

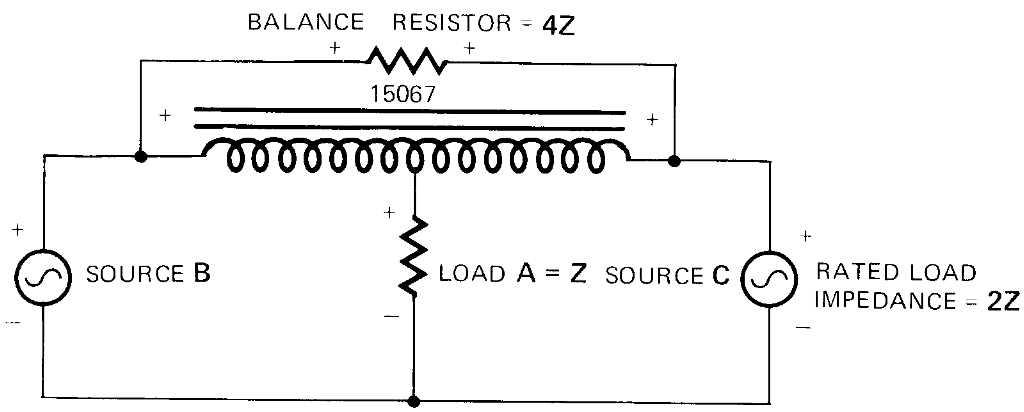

Figure 2A

Analysis of Figure 2A shows that signals developed across the balance resistor are self-cancelling. When, at the balance resistor, equal and in-phase signal levels are present from sources **B** and **C**, no current flows in the balance resistor, no voltage is developed across it, and **no loss occurs** in the balance resistor. The output voltage developed across the load remains constant, but with twice the current available a 3 dB power advantage is realized. The load on each source is one-half the total load; thus, each source is properly matched.

If the signal disappears from either source **B** or **C**, one-half of the remaining power is developed across **A** and one-half across **Z**. This results in a 6 dB power loss (a 3 dB loss due to the absence of one power source, and a 3 dB loss due to one-half of the remaining power being developed across Z). Figure 2B shows this condition.

With a signal present at one source only, no current flows from (a) to (b) and it does not matter whether source **B** is open or short circuited. By autotransformer action, the balance resistor reflects the load impedance (an impedance ratio of 4 to 1) and is effectively in series with load **A**, presenting an impedance of 2Z to the remaining source.

15036 Hybrid Circuit

The ALTEC 15036 Transformer may also be used as a hybrid. The circuit arrangement is shown in Figure 3. In Figure 3, consider a signal originating at B and assume the balance resistor value equals the impedance across transformer winding 11-12 (one-half Z_A is reflected). Voltage developed across transformer winding 11-12 is duplicated across transformer winding 9-7. The apparent voltage induced in Z_C is equal in amplitude to the voltage drop across the balance resistor but has **opposite** polarity, therefore no voltage is available to cause current flow through Z_C, and no signal is developed there. Since one-half of the input voltage is dropped across Z_{BAL}, 6 dB of signal level is lost between B and A. Similarly, a signal originating at **C** develops across Z_A with a 6 dB loss without causing a current flow through Z_B, and no signal is developed at Z_B.

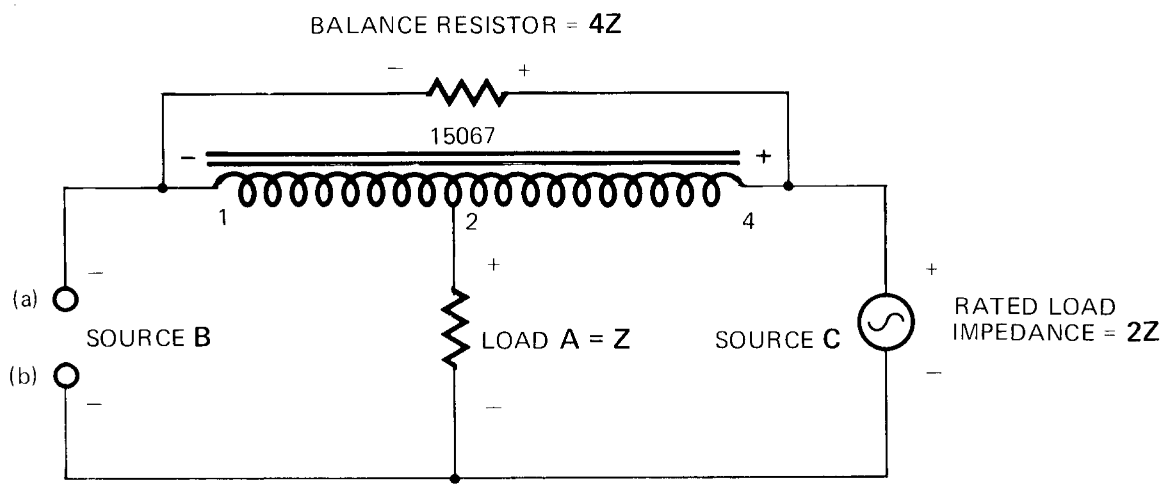

Figure 2B

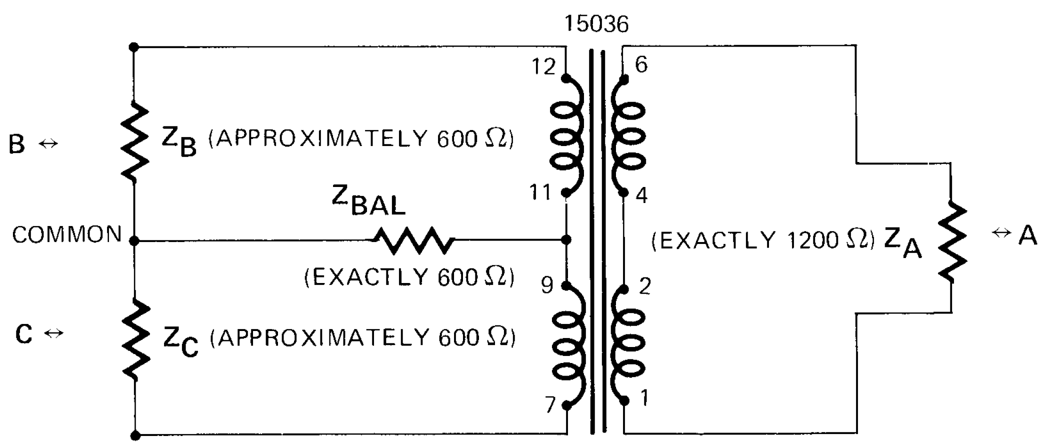

Figure 3

Direction of signal flow in Figure 3 can be reversed. A signal originating at A is developed across transformer windings 1-6 and 7-12. In this case, Z_B and Z_C are equal series loads and no voltage is developed across Z_{BAL}. With no loss in Z_{BAL} and with no transmission loss in the circuit, each load (Z_B and Z_C) receives 3 dB less power than the input level at A because power is equally divided between the loads.

15337 Hybrid Circuit

Another hybrid circuit, using two ALTEC 15337 Transformers, is shown in Figure 4. This arrangement is typically used in telecommunications, but may also be used in other commercial audio applications.

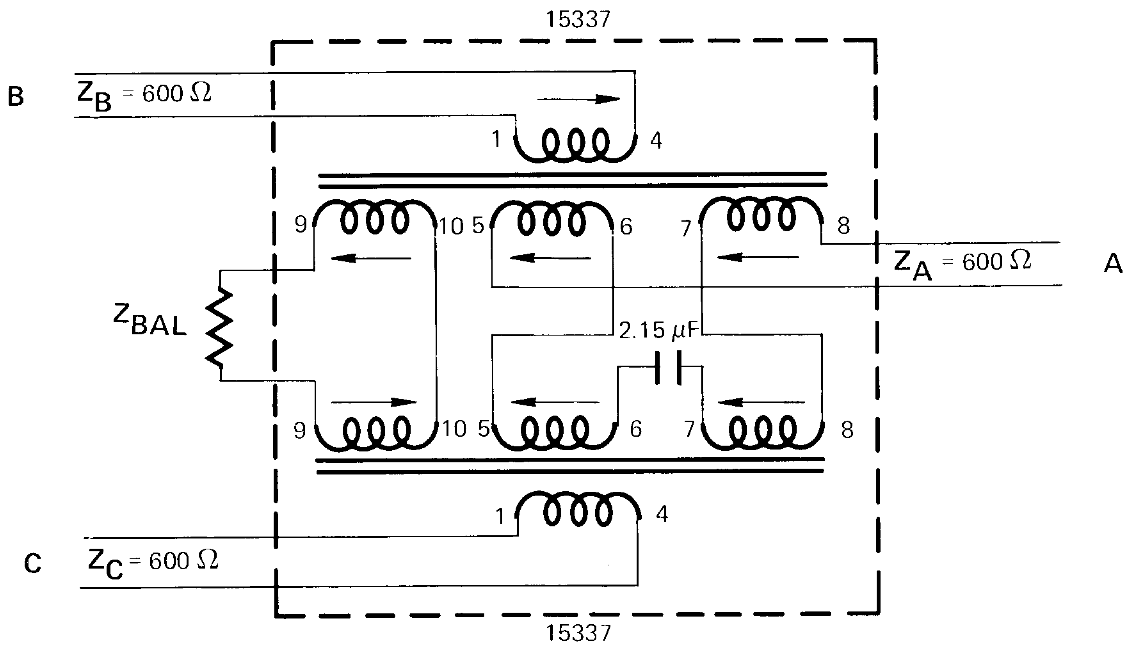

Figure 4

Windings 5-6 and 7-8 are identical and winding 9-10 is equal to windings 5-8. Z_{BAL} must equal Z_A for perfect balance.

A signal originating at **B**, for example, is developed across winding 1-4, and by induction through windings 5-8 and 9-10 on the **B** side of the circuit. The signal is simultaneously developed across windings 5-8 and 9-10 on the **C** side of the circuit due to the series arrangement of windings 5-8 and 9-10 in both transformers, and is also simultaneously developed across Z_A. Current flow through winding 5-8 is in the same direction in both transformers but current flows in opposite directions through windings 9-10 of each transformer. This is shown by arrows in Figure 4 for a given polarity of input signal.

If Z_{BAL} and Z_A are equal, the current through windings 5-8 and 9-10 are equal and the voltage drop across windings 5-8 will equal the voltage drop across windings 9-10. On the **C** side of the circuit, these voltages cancel one another (see arrows) and no signal is developed across winding 1-4; thus, no signal is present across Z_C.

Similarly, a signal originating at **C** is developed across Z_A but not across Z_B.

Direction of signal flow in Figure 4 can also be reversed. A signal originating at **A** is developed across windings 5-8 of both transformers. This signal is also developed across windings 9-10 of both transformers by induction, but now current flows in the same direction through both these windings and self cancels; thus, no signal is developed across Z_{BAL}. The signal induced in both 1-4 windings is developed across both Z_B and Z_C.

Hybrid Circuits in Paging Systems

A typical application of hybrid circuits in a paging system is shown in Figure 5.

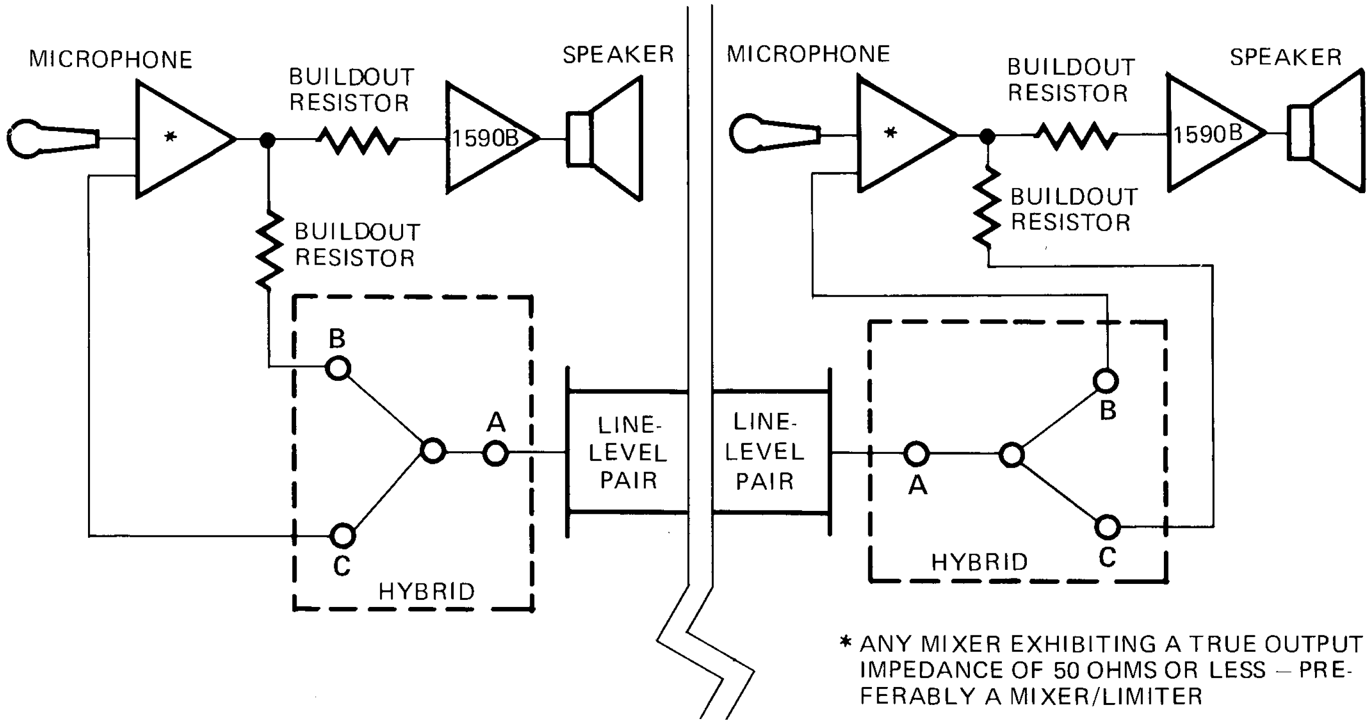

Figure 5

Two distinct paging systems are represented, but each microphone location is required to page both systems simultaneously. Hybrids allow this to be accomplished in both directions over a single line-level pair (which could be a leased telephone line). The hybrids prevent the occurrence of a feedback loop from the mixer outputs back into the mixer inputs. Proper impedance matching and use of buildout resistors, in conjunction with a low source impedance, allows easy matching of the hybrid. Neither hybrid develops a significant return signal at its respective 1590B input.

Each hybrid shown in Figure 5 is identical to the hybrid shown in Figure 4. Referring to Figure 4 and Technical Letter No. 224, note that a simplex voltage may be applied on the line-level pair link in Figure 5 through terminals 6-7 on the **C** side of the circuit. The simplex voltage may be used for any additional control, signaling or powering function desired.

Hybrid Details and Specifications

Physical details of the 15036 Transformer are shown in Figures 6, 7 and 8. Two 15337 Transformers are used to form a hybrid. Physical details of the 15337 Transformer are shown in Figures 9, 10 and 11. Transformer specifications are shown in Table I.

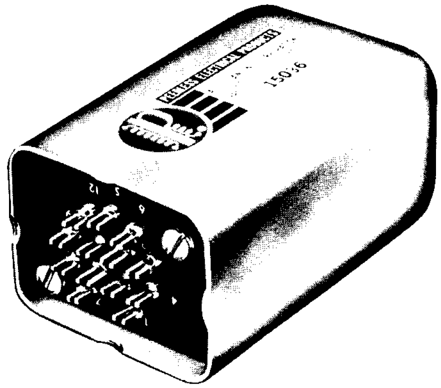

Figure 6

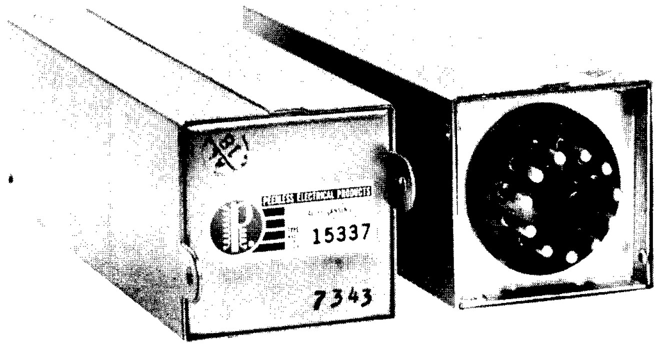

Figure 9

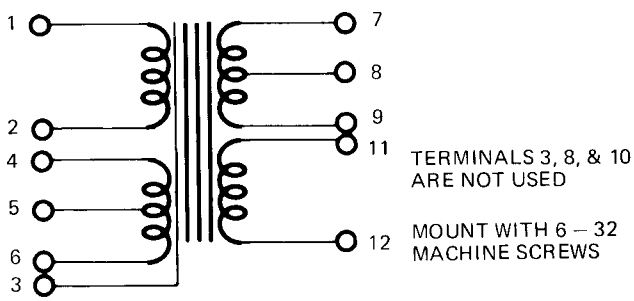

Figure 7

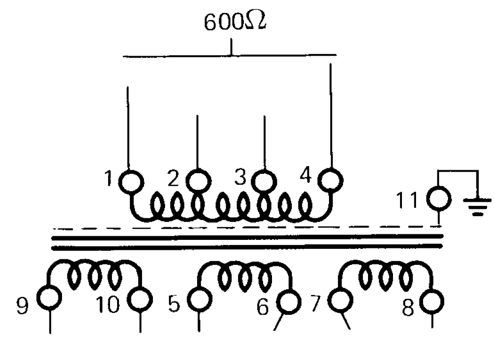

Figure 10

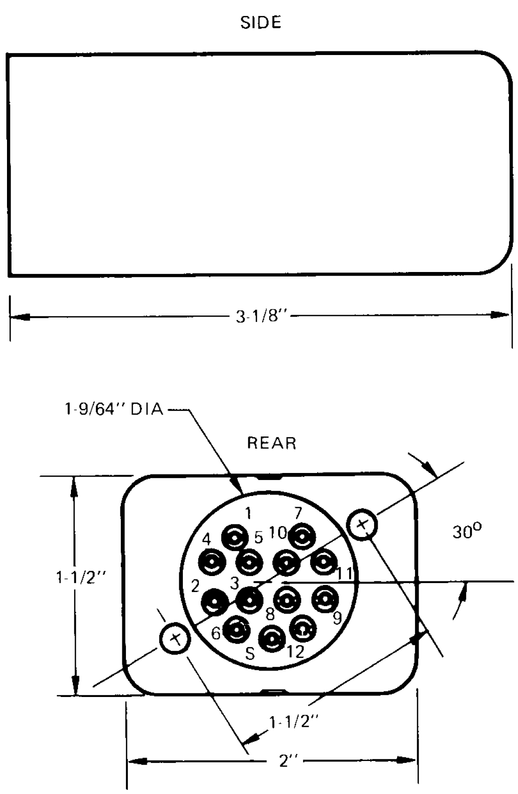

Figure 8

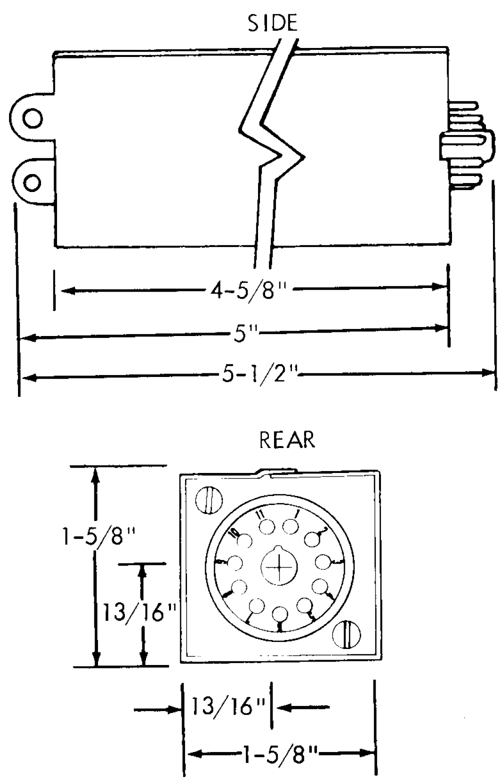

Figure 11

Table I. Transformer Specifications

Transformer Model Number	15036	15337
Type	Hybrid Transformer	Hybrid Transformer
Primary Impedances	500/600Ω, 125/150Ω	600Ω, 900Ω, 300Ω, 450Ω, 1200Ω, 1800Ω
Secondary Impedances	500/600Ω, 125/150Ω	600Ω
Insertion Loss	— — — — —	3.8 dB from 300 to 6000 Hz 4.2 dB at 200 Hz 5.0 dB at 100 Hz
Frequency Response	±1 dB from 20 to 20,000 Hz	±1 dB from 200 to 6000 Hz
Maximum Operating Level	+23 dBm	+10 dBm
Maximum Current in Line Winding	150 mA	100 mA
Maximum Out-of-Balance Current in Line Winding	(not applicable)	100 mA
Dimensions — Height Width Depth	3 1/8" (8.00 cm) 1 1/2" (3.81 cm) 2" (5.08 cm)	5" (12.70 cm) 1 5/8" (4.13 cm) 1 5/8" (4.13 cm)
Mounting Socket	None (not plug-in)	Amphenol 78-S11
Weight	15 ounces (424.5 g)	1 pound (453.6 g)