Jensen AN-005

THEORY AND CONSTRUCTION OF MIC "SPLITTERS"

by Bill Whitlock

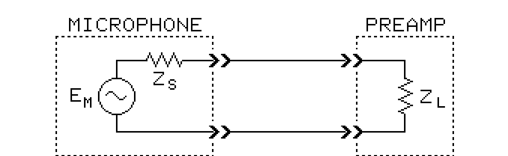
0 OVERVIEW

The Jensen JT-MB-x series transformers, commonly called "mic splitters", are designed to "bridge" the output of a 150 Ω to 200 Ω microphone. The "MB" in the part number stands for Microphone Bridging. They are available in 2, 3, and 4 winding versions and are generally used to provide additional, isolated outputs from a single microphone. The microphone is *directly* connected to the first preamp input, which provides "phantom power" if required, and also connected to the primary winding of the MB transformer, which now "bridges" the mic to first preamp line. ***The direct output is the ONLY output which will pass phantom power to the mic.*** The MB transformer secondary windings are then connected to additional preamp inputs. Since the transformer magnetically couples the signal to each winding, each preamp now "sees" the microphone's output signal while having no problematic direct connection to the other preamps. To a preamp, each isolated MB transformer output "looks like" a normal floating (ungrounded) microphone.

1 THEORY

1.1 Level Loss

The input circuitry of a microphone preamp is normally designed to recover as much of the available microphone output voltage as possible. Since the noise floor of the preamp is essentially a constant, signal to noise performance is improved by making the input voltage as large as possible. It is very important to understand that the fraction of available mic voltage actually delivered to the preamp depends on both the output impedance of the mic itself and the input impedance of the preamp input.



$$\text{INPUT VOLTAGE AT PREAMP } E_P = E_M \times \frac{Z_L}{Z_S + Z_L}$$

Figure 1 - **Voltage Divider Formed by Mic and Preamp**

As shown in Figure 1, these two impedances effectively form a voltage divider. The voltage lost in the internal (source) impedance of the mic depends on the (load) impedance at the preamp input. ***Loading loss***, usually expressed in dB, compares the output voltage with a specified load to that under "open circuit" or "no load" conditions. For example, a 150 Ω (source) mic will deliver 91% of its open circuit voltage when loaded by a preamp with 1.5 kΩ input (load) impedance. The loading loss is then 20 x log 0.91 or 0.8 dB. As a general rule, loading losses are negligible if the load impedance is ten or more times the source impedance.

Therefore, it is certainly not desirable or necessary for the preamp input impedance to "match" the impedance of the mic. If we did connect a 150 Ω mic to a preamp with 150 Ω input impedance, only half the mic voltage (6 dB of loading loss) would appear at the preamp input, degrading signal to noise ratio. Such "impedance matching" transfers maximum power from source to load, but this is ***not*** what we want our mic preamp to do.

The simplified schematic of a typical splitter system, Figure 2, is accurate for losses and bandwidth, but ignores CMRR and balance issues which are covered in next section. It uses a Shure SM57 dynamic mic and its built-in transformer, which are represented by equivalent resistance R_M and inductance L_M. The Jensen JT-MB-D transformer winding resistances are shown as R_T and leakage inductances as L_T. Preamp input impedances are shown as R_L and C_L, and cable capacitances are shown as C_C.

Inspection of Figure 2 shows how the input impedances of the preamps or mixers effectively parallel to load the microphone. This loading loss decreases the "direct" mic output level and the small additional ("insertion") losses due to transformer resistances further reduce "isolated" output levels. These losses are shown in Table 1, which is a "worst case" situation where the mic is 150 Ω and each preamp is a pessimistic 1 kΩ. In most situations, losses will be less than those shown.

1.2 Frequency Response

Inspection of Figure 2 will also reveal a number of low-pass filters. Generally, the most dominant filter is formed by the equivalent

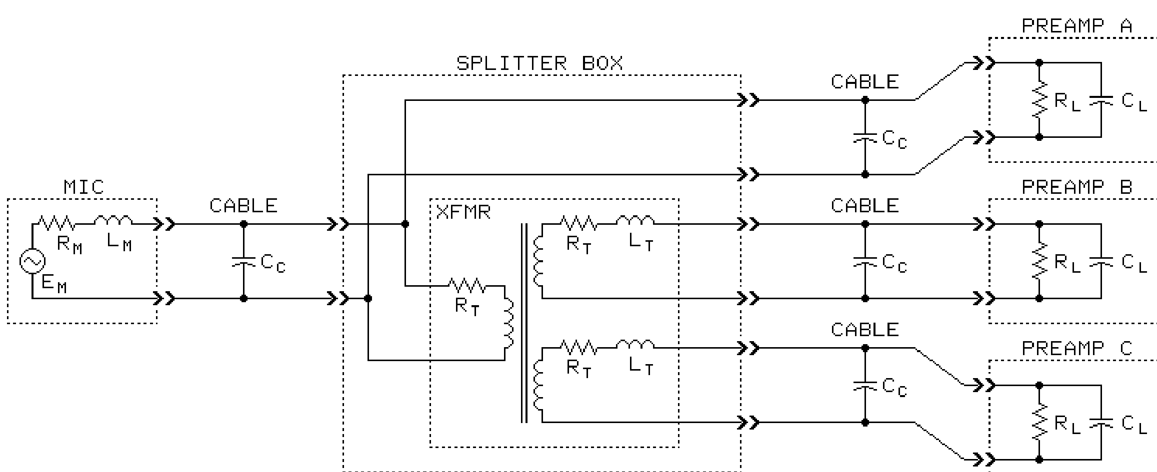


Figure 2 - **Simplified Schematic for Estimating Losses and Bandwidth**

Table 1
Splitter Losses (dB) vs Loading

Loaded Outputs	Direct	Sec 1	Sec 2	Sec 3
MBC *direct only*	0	x		
MBC direct + 1 sec	1.0	1.8		
MBD *direct only*	0	x	x	
MBD direct + 1 sec	1.0	1.8	x	
MBD direct + 2 sec	1.8	3.0	3.0	
MBE *direct only*	0	x	x	x
MBE direct + 1 sec	1.0	1.5	x	x
MBE direct + 2 sec	1.7	3.4	3.4	x
MBE direct + 3 sec	2.3	4.5	4.5	4.5

resistance R_M and inductance L_M of the mic and its total effective capacitive load. Since the splitter transformer effectively parallels all the cable capacitances and preamp input capacitances, the mic "sees" the sum total of all this capacitance. In most situations, cable capacitance will place an upper limit on total cable length. Most common mic cable has a capacitance of about 25 pF per foot (between the two shielded conductors). So-called "star quad" mic cable, although it has amazing freedom from magnetic pickup problems, has about twice the capacitance per foot of standard cable. This fact must be seriously considered in large systems.

Anyone familiar with low-pass filters knows that the shape of the rolloff curve is strongly affected by "damping". The energy absorbing resistive components in any filter control its "Q" or the steepness of it characteristics, especially at or near its "cutoff" frequency, where response is −3 dB. In most systems, the input resistance of the mic preamps is the dominant system damping. Figure 3 shows the effect of preamp input resistance (and capacitance) on frequency response of a Shure SM57 with 100 feet of common cable. The upper curves, 10 kΩ and 3 kΩ, are typical of transformer-less mic preamps while the lower curve, 1.5 kΩ, is typical of a transformer input mic preamp. Note the ultra-sonic peaks in response caused by insufficient damping.

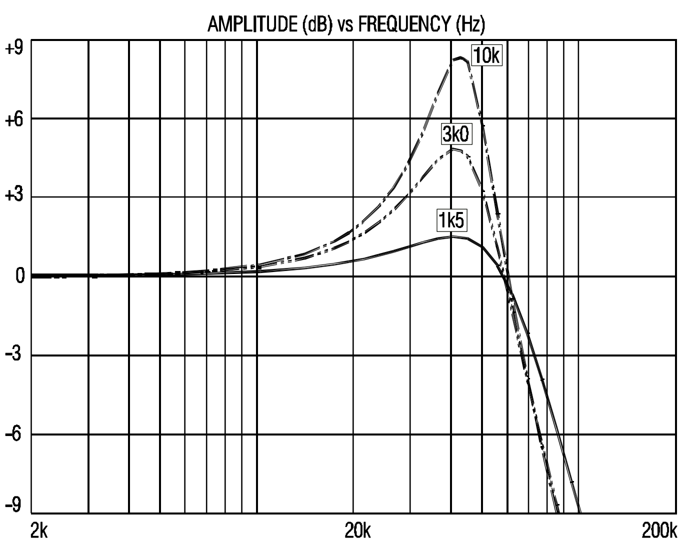


Figure 3 - **Damping Effect of Preamp Input Impedance**

Frequency response is most strongly influenced by the total cable length (capacitance). Figure 4 shows the response of an SM57 mic and a 150 Ω resistive source, both with cable lengths of 100 and 1000 feet. Of course, the peaks (some might call it desirable "sizzle") would be damped or "flattened" with a lower impedance preamp input. To maintain good response to 15 or 20 kHz, it's generally a good idea to keep the ***total*** cable length, which includes all the direct and isolated output cables, to under 500 to 1000 feet of standard cable or 250 to 500 feet of "star quad" cable. Generally, this limit can be extended if the mic is a condenser type with a lower, and primarily resistive, output impedance.

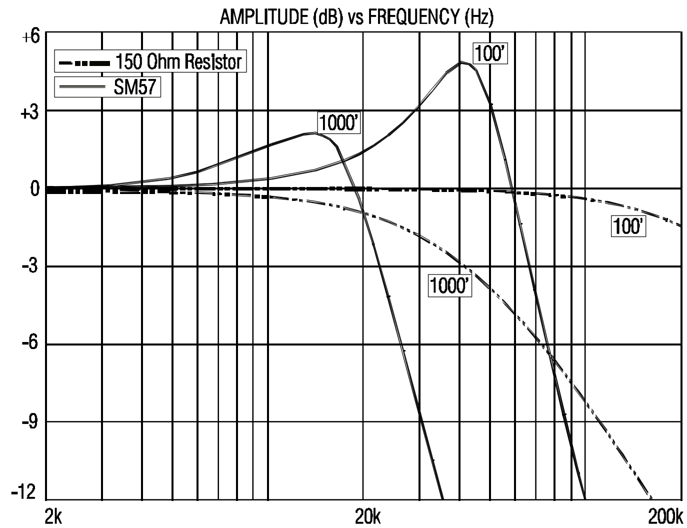


Figure 4 - **Effect of Cable Length on Response**
Cable = 25 pF/ft and preamp Z_{IN} = 3 kΩ for all

1.3 Common-Mode Rejection Figure 5 shows the more complex equivalent circuit which takes into account the impedances, mostly capacitances, which must be balanced to achieve good CMR (Common-Mode Rejection) of ground noise.

A microphone is a rather unusual signal source. Unlike most line level sources, it electrically "floats" since it has no ground connection of its own. The mic and cable are grounded at only one point — at the preamp via the cable shield conductor. The two signal lines have small capacitances to this ground, making its common-mode source impedances quite high, especially at low frequencies. As I have stressed in previous papers, it is these ***common-mode*** impedances which must be balanced to reject common-mode voltages such as ground noise hum and buzz [1].

In 1974, Jensen introduced the individually Faraday shielded "MB" series splitter transformer designs to solve the tough ground noise problems in mobile recording and touring concert sound systems. Faraday shields are layers of thin copper foil placed between transformer windings to prevent capacitive coupling of ground noise voltages. In conventional designs, one Faraday shield is placed between two windings. But if this single shield is connected to the ground reference for the signal on one winding, the other winding (which has a different ground reference) can capacitively pickup the ground noise. Designs using an individual "shield per winding" solve this problem, leaving ground noise voltages to exist only harmlessly between the shields.

When a splitter transformer primary "bridges" the "direct" line from mic to preamp 1, small capacitances (30 pF to 150 pF, depending on model) are added from each signal line to cable shield ground. In the Jensen "MB" series, these capacitances are so well matched that they have insignificant effect on system CMR. The tight match is achieved by careful design and unit-to-unit consistency

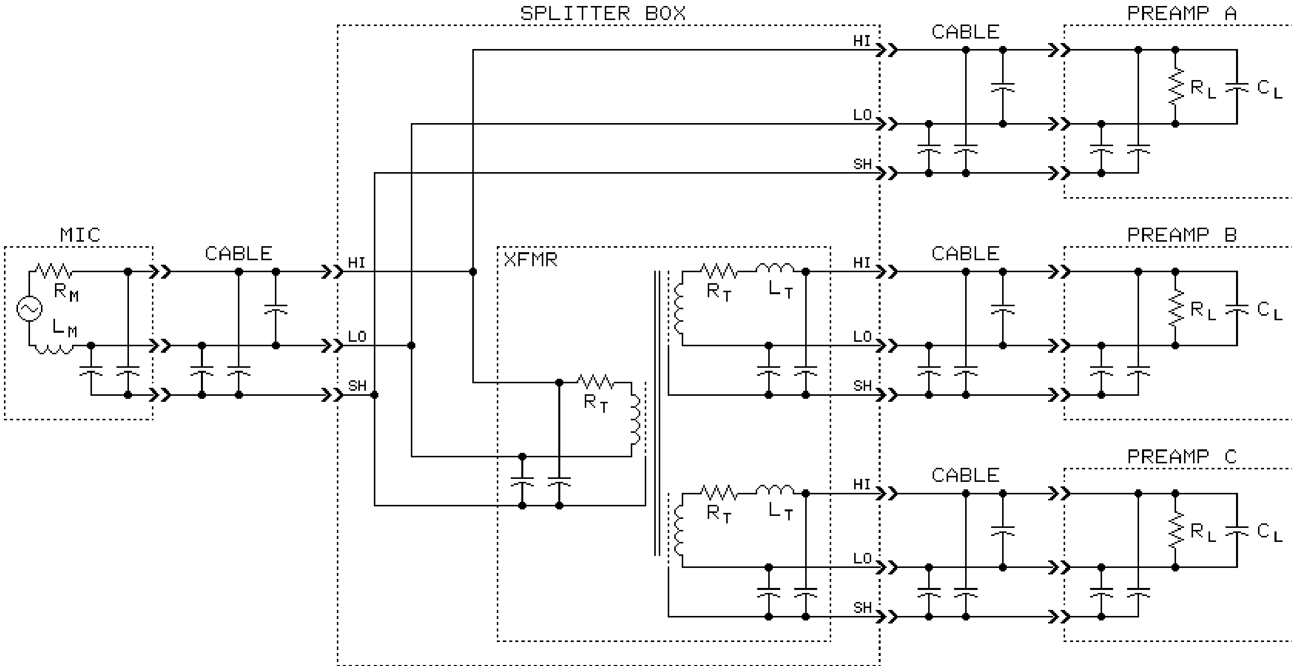


Figure 5 - **Simplified Schematic for Common-Mode Rejection Purposes**

maintained through automated winding and testing.

Likewise, each splitter secondary has small matched capacitances (40 pF to 200 pF, depending on model) to the output cable shield ground. Because the capacitances are comparable to those of most mics, each "isolated" output "looks" just like a mic to its preamp, and its CMR is not degraded by capacitive imbalances.

It should be noted here that mic cable itself can cause capacitive imbalances. Although I have never seen a manufacturer specify this, I have measured 4% capacitance imbalances in popular commercial cable. Such an imbalance can significantly degrade system CMR, especially when used with "transformerless" mic preamps whose CMR is much more sensitive to source impedance imbalances than transformer input designs. The CMR is degraded most at high frequencies and the result is usually heard as a "buzz" with most of its energy above a few kilohertz.

1.4 RFI and EMI Issues

Audio cables, including mic cables, can act as effective antennas for RF energy. In strong fields, such as those near broadcast sites or nearby portable transmitters, high RF voltages can appear at the ends of audio cables. Although these voltages are essentially equal in all conductors or "common-mode", the aforementioned capacitive imbalances will convert a portion to a differential RF "signal". Preamps vary widely in their tolerance of RF signals. Many transformerless designs can become radio receivers at rather modest RF levels, but all will eventually complain if fed enough RF.

In a high performance splitter system designed to avoid "ground loop" problems, cable shields "float" at one end. The down side is that this also makes each cable an effective whip antenna. If the cable length and ambient RF frequencies are just right (Murphy will attend to this), the whip becomes tuned, producing very high RF voltages at its floating or ungrounded end. However, this voltage can be drastically reduced by "terminating" the floating end at RF frequencies. A series network consisting of a 0.01 µF (10 nF) ceramic capacitor and 51 Ω resistor terminates the line at frequencies above about 300 kHz but looks "open" at audio frequencies, avoiding a "ground loop" [2].

Since a multi-channel splitter box brings many cables to one physical location, it presents an opportunity to further reduce antenna effects by connecting all shields together, via the above network, at RF frequencies. This tends to "average" the pickup of the multiple cables and behave as a local mesh network or "ground plane". The RF equivalent of such a splitter system is shown in Figure 6. Large conductive objects, including steel reinforced concrete slab floors and equipment racks, also tend to behave as local ground planes with reduced RF energy near them. For this reason, cabling should be routed in or very near such areas.

Hum can also enter the signal path magnetically. Basic physics tells us that any conductor (wire) exposed to a varying (AC) magnetic field will have an AC voltage "induced" in it. A balanced system has two signal conductors and, if the magnetically induced voltages are not exactly equal in the two conductors, the difference voltage will appear as a signal — hum.

Since the strength of magnetic fields falls rapidly with distance from the source, the two signal conductors must have exactly the same distance to the magnetic source to avoid hum pickup. Tight ***twisting*** of balanced signal conductors helps to make the average distance of each conductor to any outside magnetic field source the same. "Star quad" improves on this by effectively averaging the magnetic pickup of four twisted conductors. Bear in mind that a mated pair of XLR connectors leaves almost 2 inches of signal conductors ***un***twisted and very vulnerable to magnetic hum pickup. It would certainly be a bad idea to lay such a pair of mated connectors on top of a power amplifier and the typically strong magnetic field from its power transformer.

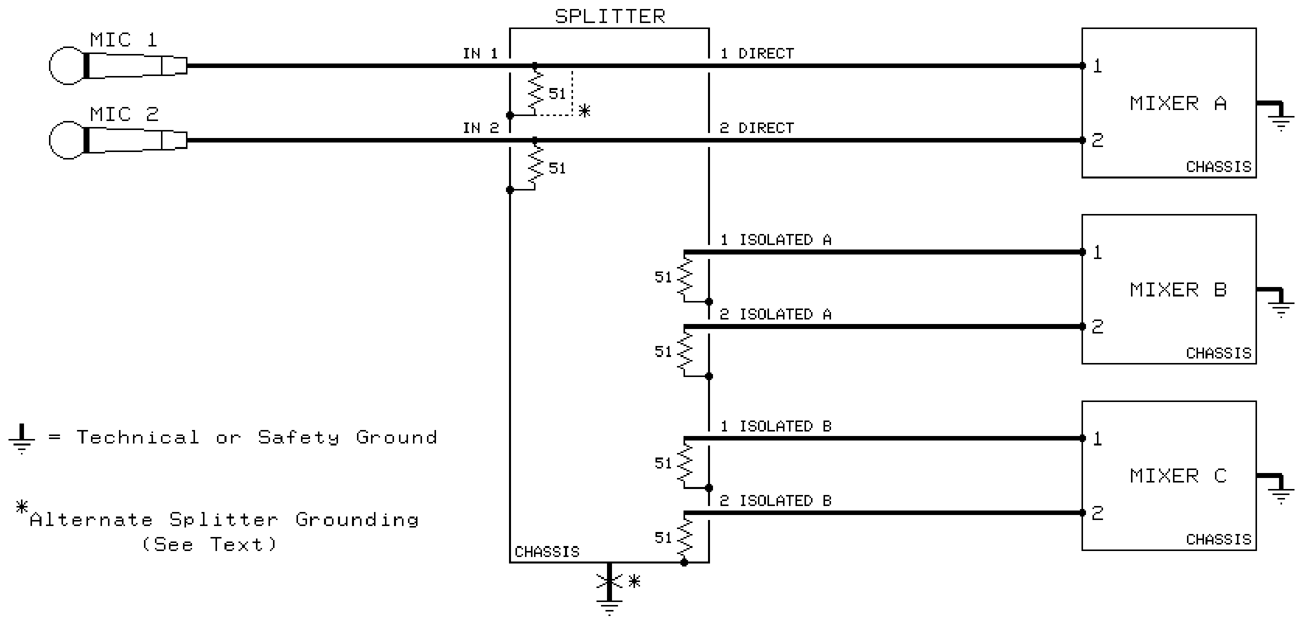


Figure 6 - **Simplified System to show RF "Antenna" Effects**

2 CONSTRUCTION

2.1 The Schematic Diagram

Figure 7 is a complete schematic of a 3 channel, 3-way mic splitter. It's important to understand that the ground symbols used in schematics are not pictorial representations of actual wire paths, but merely a *convenience* to simplify the drawing. All similar symbols are understood to be somehow connected to each other via wires or circuit board traces, or via the chassis in the case of the chassis ground symbol.

2.2 Basic Construction Decisions

Basic specifications like number of channels, number of splits per channel, type of connectors, and mounting configuration will largely define any given splitter box design. Although most splitters designed by large, experienced sound companies share a number of features, there is no real standardized design [3].

The next decision might be whether to use conventional "point-to-point" internal wiring or a printed circuit board. Both the JT-MB-C and JT-MB-D are available from Jensen in PC mounting versions. If you opt for point-to-point construction, you may want to use solder lug type terminal strips. The Cinch "50 series", having from 1 to 8 insulated terminals on 0.375" centers, is still available through Newark and other electronics distributors. These were very widely used in electronics prior to the advent of PC boards.

2.3 Wiring, Grounding, and Options

The "typical application" schematic on the "MB" series data sheets shows a single channel as it would be constructed in its own individual chassis. If you intend to build more than one channel in a chassis, follow these guidelines:

1. Mount the "input" and "direct output" connectors close to each other so their pins 1 can be connected with a short length of heavy gauge solid tinned copper wire. This bare jumper becomes a tie point for the primary shield (GRY for MB-C and MB-D, WHI/ORG for MB-E) and the 51 Ω + 10 nF RF network.

2. If the chassis will not be intentionally grounded by rack mounting or otherwise, connect the tie point mentioned above directly to the chassis and omit the RF network, but only at channel 1. This allows the chassis to be grounded through the shield of direct output 1. This scheme assumes that, regardless of the actual number of channels used, channel 1 would always be connected to a grounded mixer or preamp input.

3. Do not wire mating (cable end) connectors to connect the metal shell to pin 1. If plugged into the splitter, connectors so wired will connect pin 1 to the chassis — defeating the float of the "input" to "direct out" shield grounds. The only way to deal with connectors wired this way is to insulate the chassis mounted XLR shells from the chassis.

4. Keep the leads on the RF network 51 Ω resistor and 10 nF capacitor as short as possible. It is desirable for this network to have a flat impedance up to several hundred MHz. To do this, the parasitic inductance of the leads must be minimized by keeping them very short and grounding the capacitor to a solder lug at the connector.

5. Mount the transformers securely, especially if the splitter will be used "on the road". Do not rely on the mounting bracket alone to support the MB-C or MB-D in "road" applications. The WHI wire of the transformer is internally connected to its case. If the transformer mounting insulates it from the chassis, connect the WHI wire to the chassis. If the mounting connects it to the chassis, the WHI wire may be clipped off.

6. Tightly twist (3 to 5 twists per inch) the wire pairs for each transformer winding. For example, twist BRN and RED together, twist ORG and YEL together, and twist GRN and BLU together. Note that a twisted pair should be just that — do not include shield or case leads with the signal pairs. Do not twist all the transformer leads together in one bundle — this is guaranteed to degrade CMR.

7. Each isolated output should have its signal wires tightly twisted and the RF network installed (as in 4 above).

8. "Ground Lift" switches are optional. There are many opinions regarding to the need for them:

   If all the isolated outputs feed mixers or preamps which are adequately grounded to a system ground, it should never be necessary to close a "lift" switch.

   If however, there are large ground voltages between the "direct" and "isolated" outputs, closing a "lift" switch may reduce the voltage. There is a risk that, if this is done, heavy currents will flow in shields/pins 1 and, under these conditions, some equipment will produce hum through an unrelated internal mechanism [4].

   If an isolated output feeds battery powered equipment which floats (without a ground reference of its own), closing the "lift" switch will eliminate possibly large ground voltage differences.

9. If the splitter will not always be used in a fixed configuration, where any of isolated outputs may not be used, it is recommended to install 2.7 kΩ damping resistors across HI and LO (pins 2 and 3 for XLRs) output pins. If an output is unused, and especially if it has a cable attached which is open at the far end, the unloaded secondary of the "MB" transformer will exhibit an undamped resonance which can adversely affect frequency response of the system.

3 INSTALLATION

To prevent magnetic hum pickup, locate the splitter away from strong AC magnetic fields, such as those produced by lighting or other cabling operating at high current, power transformers, motors, computer CRTs, or TV receivers. All mic cabling, especially at the connectors, should be routed to avoid the areas.

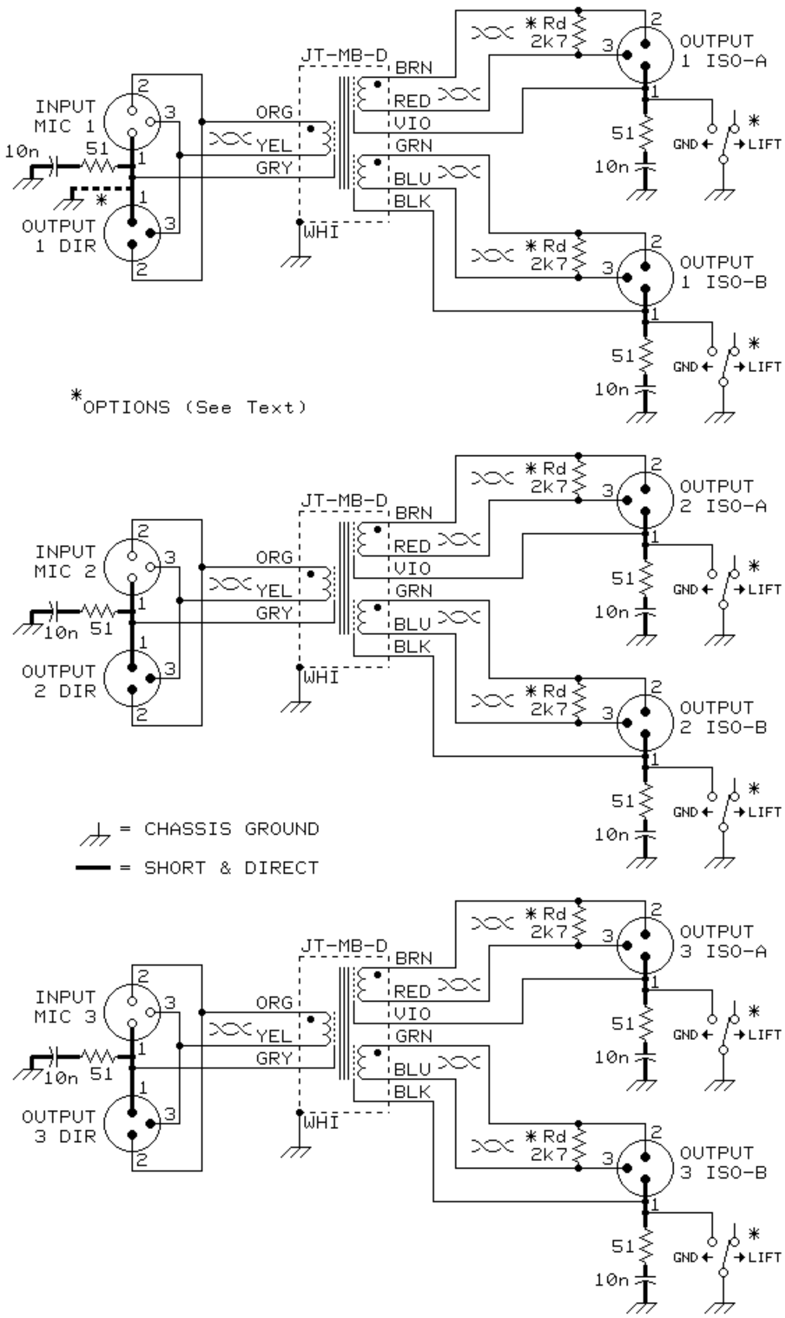


Figure 7 - **Complete 3-Channel, 3-Way Splitter**

REFERENCES:

[1] B. Whitlock, "Balanced Lines in Audio - Fact, Fiction, and Transformers", Journal of the AES, Vol 43, No 6, June, 1995.

[2] R. Morrison, "Grounding and Shielding Techniques in Instrumentation", Third Edition, Wiley & Sons, 1986, p. 86.

[3] C. Michie, "A Standardized Mobile Snake Splitter System", Recording Engineer/Producer, October, 1980, pp. 124-128.

[4] N. Muncy, "Noise Susceptibility in Analog and Digital Signal Processing Systems", Journal of the AES, Vol 43, No 6, June, 1995.

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