

Mic Splitters

by Jim Brown

Some interesting discussions about mic splitters on the Theater Sound list prompted me to post a “mini-tutorial” on the topic a few days later. Several of us on that list are also members of the AES Standards Committee Working Group on EMC and are working on a new standard to address the treatment of shields within splitters. Discussions on the Syn-Aud-Con list, the ChurchSoundCheck list, and the Theater Sound list were an important catalyst for much of my recent EMC work, and these discussions on splitters are turning out to be equally helpful in our standards work. With that in mind, and with Pat’s encouragement, I’ve chosen to devote this column to mic splitters.

There are two basic types of splitters – active (with a mic preamp) and passive (hard-wired or using a split transformer). The vast majority of splitters are passive, so we’ll study them first.

Figure 1 shows the simplest type -- a hard-wired Y, without a transformer. All outputs are direct outputs – that is, there is a dc connection between the mic and the mix console inputs. Note that Pin 1 (the shield) from the mic is also connected to the pin 1 of all outputs at the splitter, but some outputs may have a “lift” switch that disconnects the shield. There is no connection between pin 1 and the shell at the splitter. At one console, the shield must always be connected to pin 1 so that console can provide phantom power. Pin 1 might not be

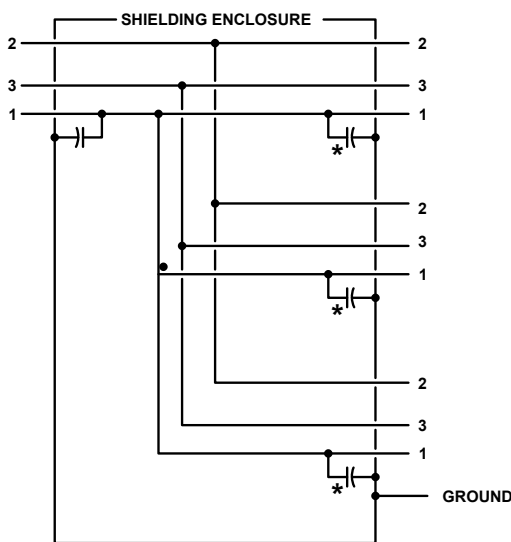


Figure 1 – A Hard-Wired Splitter provides no isolation but is inexpensive

connected at the console end of the other split outputs if the receiving console has a pin 1 problem. I often use hard-wired splits in a facility with a tight budget, because I’ve already made sure that they have a good isolated-ground power system. The low cost hard-wired splits work well, because the isolated ground system greatly reduces the likelihood (and the magnitude) of any shield current. All of the capacitors are optional, and are there to prevent RFI in severe conditions – we’ll talk about those issues later.

The second type of passive splitter, shown in Figure 2, requires a transformer that has a Faraday shield for each winding (that is, one for the primary and one for each secondary). There is only one direct output, and it is hard-wired to the mic (that is, pins 1, 2, and 3 carry straight through). Pins 2 and 3 of the mic also go to the primary of a split transformer. Note that the shield of each split output goes to the Faraday shield associated with the secondary of the transformer driving that output. Also, note that the number of windings is equal to the total number of outputs.

Figure 3 shows the third passive type. Because it has its own phantom power supply, the mic can be isolated from all three consoles, providing the greatest degree of isolation possible with a passive splitting system. Because it has no direct outputs, the transformer must have one more winding than the number of outputs (that is, a primary plus one secondary for each output), so the same 3-winding transformer used in the three-output split of Figure 2 provides only two outputs in this configuration. In this configuration, pin 1 of the input (the mic XL) goes to the shielding enclosure of the splitter, and the enclosure is bonded to mains power ground and the building at the splitter.

Figures 4 and 5 show two flawed splitter designs based on inferior transformers. The Type 4 splitter has no Faraday shields, while the Type 5 splitter has only one. There are two major limitations of these designs. First, cable shields for all outputs must be directly connected together at the splitter (the blue wires in the drawings) and also connected at the console providing phantom power. The basic limitation of these two transformer types is that there is no good placed to connect

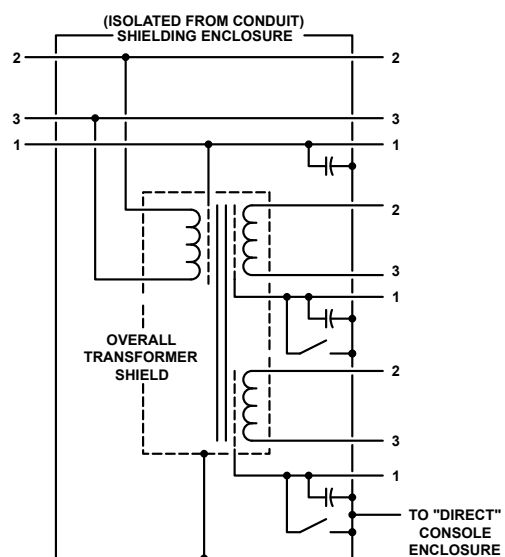


Figure 2. A splitter with one direct output and two isolated outputs, and with a Faraday shield per winding. This configuration provides very good isolation.

those shields! So the most important shortcoming of these splitters is that the only way to isolate shields between consoles is to break the shield at the consoles that don't provide phantom power. This makes them no better than hard-wired splitters! The other limitation of these transformers is that they provide relatively poor common-mode isolation between windings. So while these types appear to be "el-cheapo" variations of the splitter in Figure 2, they actually have far more in common with the hard-wired split of Figure 1, because their shields cannot be isolated.

Now, let's study how the first three types work. ALL passive splitters put all of the mix consoles connected to them in parallel across the mic. That is, the mic is driving two or three consoles in parallel, depending on how many are connected. The mic sees the parallel combination of the input impedances (mostly R and parallel C) of all three consoles, and the capacitance of all the cable that connects them! In many (most?) systems, the cable capacitance dominates the equivalent circuit, especially at high audio frequencies, with only one console connected. But add one or two more consoles and the resistive loading can cause many condenser mics to produce lots of distortion. We'll talk more about that later.

It should be obvious that these three main types of passive splitters also vary widely in cost. The first type is least expensive – the only costs are the box, the connectors, and the labor to assemble and wire it. The second type is more costly because of the transformer. The third type is the most costly, first because it includes a phantom supply, but also because of the additional transformer winding that is required. Each Faraday shield also makes the transformer, and thus the splitter, a bit more expensive. As with all engineering problems, the obvious question is, what do you get for your money?

When a transformer is used, especially one with a Faraday shield for each winding, the transformer provides common mode isolation on the signal pair between consoles and isolation of the shields -- in other words, it prevents noise transfer both via the shield and via the signal pair. A transformer also functions as an effective low pass filter to block the differential-mode transfer of RF (radio frequency) inter-

ference between inputs and outputs.

Now, let's look at our simple hard-wired split (Figure 1). The mic cable, including the shield, is a continuous run from the stage to the console providing phantom, and it isn't grounded until it hits that console. This means that the entire length of the cable from the mic to each console is an antenna for any RF that is floating around. The longer the cable, the better it will work as an antenna for AM broadcast signals and dimmer noise, so more RF will get onto the signal pair by SCIN. It also means that unless there is an isolated ground system, the only way to prevent audio-frequency shield current between consoles is to lift the shield at one end. Since Bill Whitlock has shown that the receiving end is where to lift the shield, this means no shield connection at the consoles that don't provide phantom power (or a connection of the shield through a capacitor). And finally, any AM broadcast RF on that signal pair will show up at all the consoles.

Another downside of the hard-wired split is that a few poorly designed consoles aren't happy if both they and another mix console are providing phantom power. Rick Chinn has a prepared very nice applications note about this, which you can find on his website. See <http://www.uneeda-audio.com/#phantom>

Our second type of splitter (Figure 2) still has the mic cable running all the way from the mic on stage to the console providing phantom, so that entire cable is still the antenna. But the transformer, with its Faraday shields, prevents the other consoles from seeing the RF. Even better, since the cable shield for each split output is tied to the Faraday shield of each output transformer and isolated from all other shields, it can be connected at the receiving end but still not pass audio-frequency shield current. Not only that, the output cables to the other console(s) is (are) a shorter antenna and thus less able to pick up RF (AM broadcast or light dimmer noise).

The third type of splitter (the one with its own phantom supply) is even better, because it breaks the antennas up even more effectively, and it allows all the shields to be connected at both ends with no audio-frequency connection between the console enclosures. From an RF point of view, the cable con-

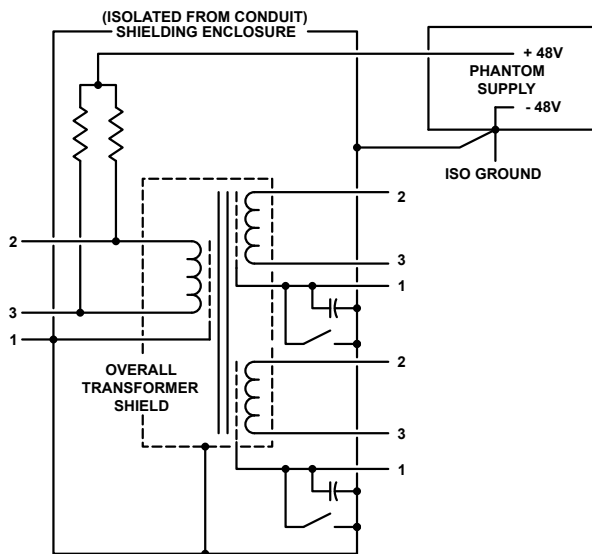


Figure 3 – A splitter with its own phantom power supply provides the greatest isolation.

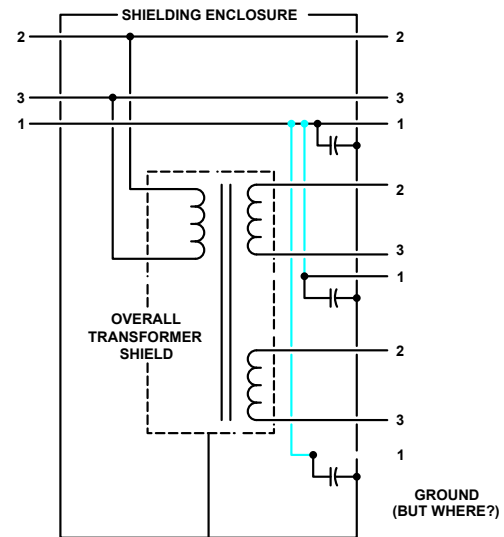


Figure 4 - A split transformer with no Faraday shield

ected to the mic stops at the splitter and is grounded at the splitter, so it is much shorter. Likewise, the cables running to each console have been made as short as possible. This further minimizes any problems with light dimmer RF and AM broadcast stations.

Radio frequency shielding can be improved by adding a capacitor between each cable shield (which is already connected to its Faraday shield) and the splitter's shielding enclosure. These are the capacitors shown in all the drawings – they are optional, but there's no good reason not to use them other than cost. To be effective at higher frequencies, these capacitors must have very low parasitic inductance, which means that it must have very short leads (what my old EE profs called "zero-length" for emphasis). We don't want a DC connection, because that would allow audio-frequency shield current between consoles.

The switches in shown in Figure 2 and Figure 3 should generally be open (no connection), because closing them will usually cause shield current to flow. When the capacitors are used, they provide that connection at RF but not at audio. When the switch is closed (that is, the connection is made), the mix console is tied to the splitter enclosure (and to anything else connected to the splitter enclosure). On rare occasions (a poorly grounded console, for example) this might help things. Most often it has the opposite effect of allowing shield current, which then excites a pin 1 problem. Closing one or more of the switches might occasionally put a "band-aid" on noise problems caused by a poorly grounded console. But if money is tight, I would far rather see these switches omitted, with the cost of the switch (materials, labor, and panel space) spent instead on transformers that have a Faraday shield for each winding. The additional isolation provided by the better transformers is likely to solve more problems than the switch.

All of which brings us back to the major reason why isolation is so critical to mic splitters – the pin 1 problem! Bruce Olson reports that he has tested many vintage consoles

in conjunction with a project and found that they all have pin 1 problems. He emphasized that all were on the order of 5-10-year old designs, not newer products (but some may still be in production). Bear in mind that Neil Muncy's landmark paper throwing light on the pin 1 problem was published in 1994. Indeed, nearly all consoles designed before 1999, even the most expensive ones with the most "respected" names, and nearly all active mic splitters fall into this category, including the British product Neil described as having a "screaming" pin 1 problem. New versions of these products may (or may not) be fixed – it costs money to make changes in a product that is currently being manufactured, and some designers "never get the word." In 2002 Ray Rayburn asked a very highly respected designer of extremely expensive outboard microphone pre-amps used in high end recording studios if his products had the pin-1 problem, and got a blank stare. He had never heard of the problem. Later after he had read the June 1995 AES Journal, he told Ray that most of his products had the problem (which he still did not think was a major issue!).

All splitters should be in a shielding (conductive and ferrous) enclosure, and that enclosure must somehow be grounded. Conductive enclosures provides RF shielding, steel provides magnetic shielding as well. RF shielding is generally important only if the splitter will be connected to one or more consoles by a very short cable run (less than about 25 ft of digital cable, or about 5 ft of analog cable). The reason is simple. Because the breaks in shielding at a splitter are small, they only allow VHF and UHF RF to get onto signal wiring. Balanced cables are quite lossy at these frequencies, so longer runs won't let enough RF reach the console for detection to occur.

The enclosures of Type 3 passive splitters and of all active splitters must be grounded via the phantom power supply (via the isolated ground system if there is one). Enclosures of portable splitters without phantom power supplies should be grounded via the console providing phantom power. This connection must be independent of the shields of individual pairs. Good choices are an overall shield, a dedicated "ground" conductor, or even one or more unused pairs. Enclosures of fixed splitters must generally be grounded via the conduit system, and must not be allowed to contact the isolated ground system or the shields of output cable shields.

Output connectors should have their shells isolated from the panel so that ground loops are not created when output cables having a short between pin 1 and the shell are used to patch the outputs to consoles at widely separated locations.

Earlier, we noted that an active splitter is one that includes a mic preamp that then drives the attached consoles. It may do it either directly (hard-wired), via a resistive splitter, via a split transformer, or even with additional line amplifiers for each output. Active splitters must, of course, have their own phantom supplies. [The excellent Benchmark mic DA includes a world-class mic preamp and a single power amp having fractional ohm output impedance with a resistive splitter. I've used it for years in the most critical applications. Al Burdick, the designer and owner of the company and a long-time Syn-Aud-Con supporter, was quite proud of this preamp when he first showed it to me more than 20 years ago. It was the first time I had seen common mode chokes in audio.]

In an active splitter, the mic drives the preamp in the splitter, and the mic cable shield must be connected directly to the shielding enclosure of the splitter. The isolation provided

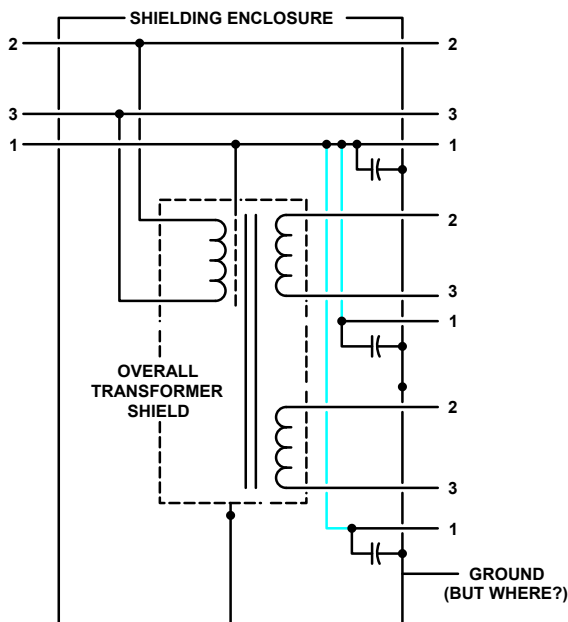


Figure 5 A split transformer with only one Faraday shield

by the various output configurations between consoles is the same as for a passive split, except that all variations isolate the mic from the outputs. If there is no split transformer, the shields of the split outputs should be connected directly to the shielding enclosure of the splitter. If the shields need to be interrupted to band-aid a pin 1 problem, they should be interrupted at the console that has the pin 1 problem. And if a split transformer with a Faraday shield for each winding is used, the shields should be connected as in a passive splitter that uses the same type of transformers.

The principal virtues of an active splitter are that 1) it shortens the RF length of the cables in the same manner as in the passive splitter with a phantom power supply; 2) it allows the mic to drive only one preamp (the one in the splitter) and only the lower capacitance of the shorter cable between the mic and the splitter, so it sees a much higher load impedance; 3) the longer run between the splitter and the mix consoles is generally at a higher signal level, so it takes a stronger interfering signal to cause audible interference.

Item #2 (loading of the mic's output stage by multiple input stages and cable capacitance) can be quite significant, especially with poorly designed condenser mics whose output stages are current starved. Ray Rayburn observes, "Take the example of a three way split where each console has a 1500 ohm input impedance (1,000 - 2,000 ohms is typical). The resulting resistive load is 500 ohms which will drive these mics into distortion. One popular podium mic loses 15 dB of headroom as the resistive load goes from 1000 ohms to 700 ohms." For a three way split, each console would need an input impedance of 3000 ohms or higher to work with that microphone. David Josephson (Josephson mics, and chair of the AES Standards Committee Working Group on microphones) makes it his business to know what is going on with his competitors. He says that his mics and the better pro mics of his major competitors are designed with considerably more robust output stages. One clue that a mic can't drive multiple consoles is its phantom current - in that it doesn't draw much phantom current.

Ray also notes that the most common inline (barrel) pads were designed to load the mic to 150 ohms. When you added one of them inline to solve an overload problem, things got worse rather than better, because it demanded far more current than the mic could supply. Rick Chinn reports that a new A15AS he recently bought has been redesigned so that it now loads the mic to a safe impedance. Rick has looked at a lot of console designs, and reports that all of those he's looked at have been careful to maintain a constant resistive load the mic with and without the pad. Certainly if you're going to pad a mic like the one Ray had trouble with, you'd better use the right kind of pad and put it ahead of the split! Another inexpensive way out of this mess (cheaper than an active splitter) is to add a decent preamp for the problematic mic(s) and feed the split with the output of the preamp(s).

But this discussion, which has (so far) involved Josephson, Whitlock, Rayburn, Olson, Chinn, and myself highlights a VERY important issue - many manufacturers need to do a much better job of understanding the big picture with respect to how their products are used. In most churches and performance facilities, every microphone is working into at least two mix consoles, and often three (I specify both an automix and a live mix console for nearly every church and public venue, and many of these facilities also have another console

for on-stage monitor mixing). Add a recording console and you're up to three or four! Virtually none of these facilities can afford an active splitter, so ALL microphones need to be designed to work into at least three consoles - especially the podium mics!. And the corollary is also true - mix consoles need to be designed to present the greatest practical load impedance at their mic inputs consistent with good performance! I would like to see 3K ohms as a minimum input impedance of a mic stage.

And then there's capacitance. In large facilities there is lots of high capacitance cable (most analog cables) hanging across each mic (remember, all the split outputs are in parallel). 1,000 ft of 8451 looks like 240 ohms at 20 kHz, and 120 ohms at 40 kHz, well below the 1,000 ohm rated load of most mics. (Current microphone standards define the impedance of a mic as one-fifth of its rated load impedance, so a 200 ohm mic should not be loaded below 1,000 ohms.) The output stage of a condenser mic is very likely to clip or slew limit on high frequency transients (cymbals, snare, hat, muted trumpets, etc.) when working into a load like this. Simply switching to cables designed to carry AES3 audio reduces this capacitance by more than half as compared with the best analog cables, and by a factor of 1:3 as compared to older cables like 8451. Star quad cables are real dogs for capacitance, and I've always avoided them. Since more than 90% of the cost of snakes and tie lines system is in the panels, connectors, and the labor to terminate them (and pull the cable in a permanent installation), using top quality cable with low capacitance is the only good decision.

Active splitters have one major disadvantage in addition to their cost - someone needs to be available to adjust their gain trims during a live performance, and do so very quickly. But even that isn't enough - everyone mixing from the split must make equal and opposite gain changes in their mix precisely in sync with the gain trim at the preamp! Not easy, which, combined with their added cost and pin 1 problems have confined active splits mostly to high-budget studio operations. For at least ten years, I've been suggesting to the manufacturers of digital snakes that effective remote control of mic preamps with logic that protected each mixer from losing track of the mix was an important part of any successful system. Lots of digital snakes have come and gone, but I've yet to see that problem solved (or even addressed).

In summary: The main reason for using the best mic splitters is to prevent hum and buzz with mix consoles that have pin 1 problems, and to shorten the antennas. Hard-wired splits are an economical solution for facilities where power and grounding are well under control. When power and grounding are less well controlled, or when consoles with pin 1 problems will be used, or both, a split transformer with a Faraday shield per winding and a phantom power supply at the splitter provides the greatest protection from hum, buzz, and RF interference. The transformer must have one more winding than the number of outputs. Second best isolation is provided by a split transformer with the number of windings equal to the number of outputs and a Faraday shield per winding. Transformers with no Faraday shield or with only one Faraday shield offer only slightly more isolation than a hard-wired split, and are a waste of money. And if there is a passive mic splitter in a system, don't be surprised if a few mics don't work very well with it! *jb*