A PRIMER ON GROUNDING

by Greg Hanks

After alluding to the discussion of grounding in my last two Mix articles on studio installation (Aug., Sept.), it's finally time to give the straight poop about getting rid of the pops, buzzes and other grounding gremlins that recording studios are famous for. The first of the problems that we must face when discussing "grounding" is the relative flippancy with which we bandy terms about. Let me use the following example:

"It is never a good practice to ground any wire at more than one point. We should earth our common and shield lines at the point that is closest to zero potential."

The preceding sentence may or may not be true, depending on the definitions applied to the four terms that are generally used interchangeably to describe the same item. Therefore it is imperative that we start this dissertation with a few definitions, While it may appear that we are saying the same thing in four different ways, we are not. And this illustrates one of the difficulties in dealing with this topic.

Ground

Ground is the material composing that big ball of dirt on which we live. It is also the connection that the power company makes to the neutral line of the incoming AC service. This is a little confusing in that the NEC (National Electrical Code) only talks about "ground." Ground in the NEC handbook refers to: A) The earth; B) The electrode that is planted in "A"; C) The circuit that is formed by a connection to the electrode in "B".

What this means in a practical sense is that they are talking about the connection that is tied to all conduit and other electrical service metal enclosures. Conceptually, this is done to ensure that the maximum voltage that can exist at the electrical service is the voltage between any two conductors. We can live with that in this instance. Aw, what the heck, let's use this definition from this point forward to refer to the signal connection of the power company conduit, or safety bonding. This is the point that is most often available at the third pin of your standard receptacle.

Earth

Earth, when used in this text, will not refer to the circuit point described above, but to the "screening" or enclosure connection on the audio equipment that we are interconnecting. We will also use this term as "the earthing wire" to refer to the conductor used to bring the enclosure of a piece of equipment to the studio "zero reference," or "technical ground." Most consoles made have the chassis and the audio common brought together at one point. Earth is a good term for the circuit that is "other" than the audio common. This seems a little foolish, but please bear with me.

Shield

Shield is the term that describes the wire(s) that is tied to earth. The shield, in this writing, will refer to the wire enclosure, or the "drain." When we are referring to wiring, the shield is the conductive braid or foil that surrounds the signal conductors. When we are referring to theory, the shield is the electro-static barrier that is composed of the enclosure of the given piece of equipment, coupled with the screening provided by the conductive sheath of the cable.

Common

Common, or most often referred to as "the audio common" is the circuit point that is shared by both the input and the output of a circuit. This point is somewhat vague when dealing with the inside of an op-amp, because the op-amp inputs and output only share the power supply rails. But in application, it becomes very clear. In order to use this device, the positive input must refer to the point that is midway between the V+ and the V- connections. It is this point that establishes the quiescent output voltage. And the output must reference to this midpoint (or one of the rails). We do not often see circuitry wherein the output common connection is one of the rails, but even then, that common becomes the system common. When hooking up the power supplies, there are most often three wires, +, -, and 0 volts. Common refers to this 0 volt point. If good circuit layout and design are examined in depth, it is easy to show the direct correlation between system grounding method and good circuit board layout procedure. It is important to note that common and earth are not necessarily at the same potential. "Common" refers to the signal 0 volt connection.

Neutral

The neutral is the wire feeding your electrical outlets that is most commonly taken to "ground" at the electrical service entrance. Make no mistake about confusing this with "ground"! One of them is used to provide a return path for the AC power, and the other is used to provide for safety. The term "neutral" is used almost exclusively by the electrical trade, but is included here for completeness It is also necessary to understand that because the neutral is almost always taken to the same point as the ground, that all of the current that is used in any system is flowing through the neutral, thus imposing a mighty charge on the ground system unless it, in fact, is at the earth's "0" volt potential. (By the way, this is a near impossibility.)

Technical Ground

With any large recording system, there is one point chosen that will be the reference for all of the system earth references, and this point is the technical ground. I believe in single point ground systems, and the single point that we will be discussing throughout this article is the "technical ground."

Basic Theory

Now that we have defined the terms that we are going to be using throughout, we can move on to the other main area of confusion that exists when discussing "grounding." This is the difficulty that exists in drawing the equivalent circuit of a grounding system, with all of the operating parameters. The most often used representation of signal common is The most often used representation of an earth, or chassis connection is All too often the chassis connection (earth), and the signal common are both referred to with the "⏚" symbol, and where they are tied is almost never indicated. Well, what the hell, you say! A wire is a wire, is it not? Since they are tied together, you don't have to indicate how many times or where, do you? Well, that is why I am writing this. This type of misconception has brought many to tying down shields at both ends, not using ground lifts, and adding alligator clips between pieces of gear to eliminate problems. Life can be much simpler if some of the basics of grounding and shielding techniques are understood and carefully applied.

Charge

The first bit of physics that applies to this study is the understanding of the static charge (unit of charge = Q). (If any readers have a mathematical bent, the applicable formulae will appear in parenthesis.) Whenever an excess of electrons (6.28×10^{18} is equal to 1 Coulomb) exist on a body, that body is said to be negatively charged. If there is a lack of electrons, that body is said to be positively charged. Oppositely charged bodies attract each other, and equally charged bodies repel. When we have two oppositely charged bodies near one another, a force exists (force $= (Q1 \times Q2)/\text{distance}^2$). With one charged body, a force in fact exists, when the earth is taken into account. This force exists because the earth, for practical matters is considered an infinite source of charge, because it is at zero potential. The mathematical term is $-Q$. Because the earth is at zero potential, any charged body has a field that possesses force. This is an electric field. The field that radiates from a charged body produces electrostatic force. ($E = (Q / (\text{dielectric constant, "k"} \times \text{distance}^2))$). This force radiates from a charged body, and either terminates at infinity, or another charge. A conductor that has a charge on it, when surrounded by another conductor, radiates a field that terminates at the surrounding conductor. Any fields outside of this surrounding (shield) conductor also terminate at this conductor. The conductor(s) that is surrounded (the signal carrying conductor(s)) will not be affected by any charges outside of the shield conductor. Since the earth is at a zero potential, then a conduction path to the earth will bring the shield to zero potential. It should be understood that grounding the shielding conductor is not necessary for the shield to function. The potential that exists between two shielded conductors will remain unaffected by any fields outside of the shield, and the fields outside of the shield will not be modified by the potential(s) within it. The purpose of taking the shield to ground is to make the mutual capacitance of the conductors to the conductors outside of the shield zero, or so the classic theories state. What occurs in real world situations involves many conductors within shielding enclosures whose mutual capacitance is not zero. The mutual capacitance terms are defined by the geometry of the conductors and the shielding system itself.

Capacitance

Capacitance, in this discussion, is multi-influential. It is the self and mutual capacitance of shielding and shielded conductors that make electrostatic shielding work. When a potential is impressed upon a single insulated conductor, and that potential is varied, the charges that exist between that conductor and surrounding conductors varies. When a charge varies, current flows. This seems to defy the law that a circuit must be closed for current to flow. The capacitance that couples these systems provides the path for current flow. One of the sources of hum in our audio signal is the capacitive coupling of the power mains to our audio commons through the primary windings of the power transformers in the system.

Room Pickup

An electrostatic field at power frequencies exists in almost all inhabited areas. The sources of this field include lighting, power distribution, zip cords and other things that use electrical power, and are unshielded. The field originates on unshielded wiring and terminates on the various lower potential conductors. According to Morrison, (1) the room may be thought of as a large capacitor, with the signal carrying conductors as one plate, and the lowest potential conductors (earth, or ground), as the other. Therefore, a person standing in a room is standing in the middle of a big capacitor. Everything in a room will modify the coupling of the fields that exist, and this makes it almost impossible to map the field strength with any real accuracy. The induced reactive current flow of a typical room is about 100na per square foot at 60 Hz. This is the source of the buzz that occurs when you touch an amplifier input.

Ohm's Law

Everybody is familiar with the classic formulae, $E=IR$ and $P=IE$. Ohm's law is one of the fundamental concepts on which our understanding of electronics and its properties are based. Application to grounding theory and application is most profound when considering the voltage drop(s) that occurs over the finite resistance of our earthing conductors. If these wires did not possess a finite resistance, then all earthing connections could be made at any point, and there would be no problem. However, it doesn't work this way, and these finite resistances create small voltage drops that together create hum, buzz and noise. The above mentioned capacitive effects also reduce to resistance terms with the also classic formula of Xc (or 'R' for Ohm's law) $=1/(2 \times \text{pi} \times F \times C)$. Oh Lord, there I go again, rambling on without addressing the issue! OK, we'll try a little more direct approach—

Purpose

The reason that we are concerned with grounding in the first place is to eliminate unwanted signals from our system. This is accomplished through electrostatic shielding. The individual components accomplish this with the enclosure (hopefully!). As we interconnect the individual components of the system, we must bring all of the enclosures to the same potential. Minimizing current flow within this interconnection is the desired result, and making the audio signal see this shield charge as being the lowest potential is the way that this is accomplished. With almost any recording studio environment, the most desirable point to consider as the technical ground (the point of lowest potential) is the electrical point in the console that takes audio common to the console chassis. The reason that this point is most desirable is easily understood when you consider where most of the gain of the system is: the console. Summing busses, microphone pre-amplifiers and the like, as well as the location of the interconnection scheme of the patch bay make this the considered location of technical ground. When the system is thusly interconnected, chassis to chassis that is, the circuitry that is contained within the shielded enclosure(s) and the shielded wire that ties this stuff together are both "impervious to external fields." This is true for electrostatic effect. It is not so with magnetic fields, and this is cause for design concern (see previous article on control room installation design). The sources of interference that are most commonly encountered with studio installations have not to do with electrostatic coupling from external fields to the audio wiring, but coupling from the currents flowing within the shield(s) itself to the shielded conductors. Current flowing through the shield structure will not necessarily only be at AC power frequencies, but has a broad power spectrum response, and the system noise as a rule will suffer from current flowing in the shield(s). We will attempt in the following pages to show how to eliminate these currents and illustrate a time proven methodology for dealing with the hook-up vagaries that conspire to ruin our work.

Rather than end the article with a list of exceptions to the rules that we espouse, we will introduce some now. We just said that the point of choice for technical ground is physically located at the console. Not necessarily so, because it is possible to achieve other very good technical ground points. One of these involves the using of "hospital grounding method." This will be discussed in detail a little later. I think that this is a good time to discuss the "How To's" of system shielding, with a little of the theory that goes with it!

Rules

1) In order for a shielding system to work most effectively, the "system" audio common and the shielding system must be tied together at some point. The mutual capacitance of an unterminated shield leads to capacitive coupling of any interference fields that cut the shield into the signal conductors themselves.

2) For minimum hum, connect to technical ground at one point only.

The easiest way to think about shielding procedure is to consider it verboten to connect the chassis of a piece of equipment to technical ground with more than one path. Remember when we spoke of the rule that says that no current flows without a complete circuit? With multiple paths, the voltage drops that appear because of the leakage current(s) returning to their source create voltages that are amplified by any part of the system that reference to the path that the currents are flowing in.

3) Every signal line should have its own shield.

If signal lines appear within a common shield, then they will capacitively couple to each other. This leads to excessive cross-talk within the system. This effect is most noticeable at high frequencies, where the ratio of the Xc to the line impedance can become significant.

4) The shield wire should not be shorted to other shield wires at any point other than the signal source reference.

If shields are shorted together at some point other than that point described above, then they will share coupled signal currents through capacitive coupling, and this will cause a voltage drop in the shield through the finite resistance of the shield thus raising the shield potential above the signal reference zero point. This leads to high frequency cross-talk.

5) Never use a piece of equipment that does not provide true power transformer isolation from the chassis. An example of this type of equipment would be a television set, where the AC line goes to the signal common,

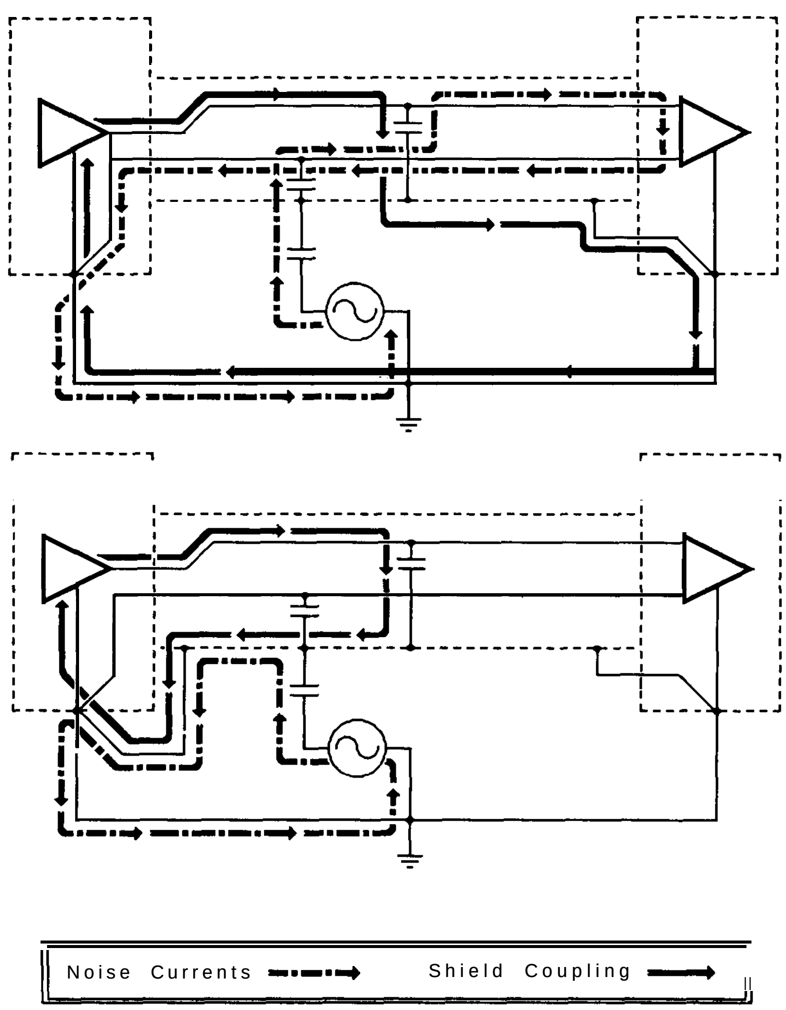
The reasons for this should be obvious, since the power mains would then be coupled into both the system technical ground, and therefore through the signal zero reference. There are leakage currents from all power transformers, and these will couple to the mains as a return path, therefore modulating the whole reference system at 50/60 Hz. Should it be necessary to use a piece of equipment of this type, then an isolation transformer must be used on the AC input. It would also be wise to transformer isolate the signal inputs and outputs to minimize the corruption of the technical ground.

6) Shields should connect at one end only, and the connection point should be at the signal source.

The shield wire is not sufficient in most instances as the method of return ing the earth connection of a piece of equipment to technical ground. It is not fortuitous for most installations to even consider such an action, in that the wiring termination point never goes through the physical area of the technical ground. Therefore the most expeditious practice is the utilization of an earthing wire that is either the third pin of the AC plug in a "hospital ground method' installation, or conversely a separate conductor that terminates at one end at the piece of equipment, and the other end at the technical ground.

Termination of the shield wire at the signal source end is desirable because any noise signals that are impressed upon the shield will capacitively couple to the signal that is also capacitively coupled to the shield. These currents must return to the signal source. If the shield were termi-

FIGURE ONE
Additional noise contribution created by coupling the shield to the input of the driven device



nated at the input of a driven device, then the noise signal would be amplified because the capacitive coupling of the signal to the shield would have to return to the source through the reference point of the driven device. The voltage drop that will occur because of the finite resistance of the earthing wire will cause currents to flow in the reference. These currents will be impressed upon the input stage of the driven device. See Figure 1 for an illustration of this phenomenon.

7) Never use the electrical conduit for technical ground.

The concept of a single point star ground is violated at the first contact with the conduit of the electrical system. Electricians allow the conduit to contact metal, other conduit, machinery, the building reinforcement beams or just about any damn thing that is convenient. Ground loops-where the earthing wire has more than one path to technical earth-are guaranteed if you allow this dastardly condition to occur.

I have stated that the single point star ground system is necessary. It is the only type of system that I have used that consistently works in audio applications. If you are wiring a video system, you don't care about 60, 120 and 180 Hz 40 dB below the signal. But in audio, with a dynamic range of 100 dB plus, it becomes a critical problem. A single point star system is one where the technical ground is the only point where all of the equipment comes together. There are basically two ways of going about implementing a star system. The first is that of using the "hospital ground method" that I mentioned earlier. The other is a separate earthing wire that is independently brought to technical ground.

REAL WORLD THEORY

AC System

The power system is the culprit. All we have to do to eliminate buzz and hum is turn everything off. Seriously folks, the power line is where most of our problems start. In an ideal world, the power coming in will provide a constant voltage, infinite current, have no noise on it and the neutral currents will always be zero. So much for the ideal world. Instead we face voltage fluctuations from 90 to 130 volts, Noise spikes that can exceed 1000 volts and lines that really sag when you want a hundred amps in a hurry. Neutral currents are often measured in the 10s of amps and this is our first concern.

Equipment manufacturers are in a bit of a bind when it comes to informing the buying public about how to correctly install their equipment. The reasons for this are legion. If, as a manufacturer, you recommend a particular course of action, especially in print, you assume liability for the execution of that action. This means that if someone mistakenly hooks up, say, a tape recorder, uses a ground lift (at your recommendation) and ties the chassis to 110VAC, then grabs both the tape recorder and a cold water pipe, you can be sued for any pain and suffering that results. Therefore all manufacturer statements will reflect the wisdom of covering thy behind, and will not necessarily reflect what is going to be the best action to take.

Building Codes

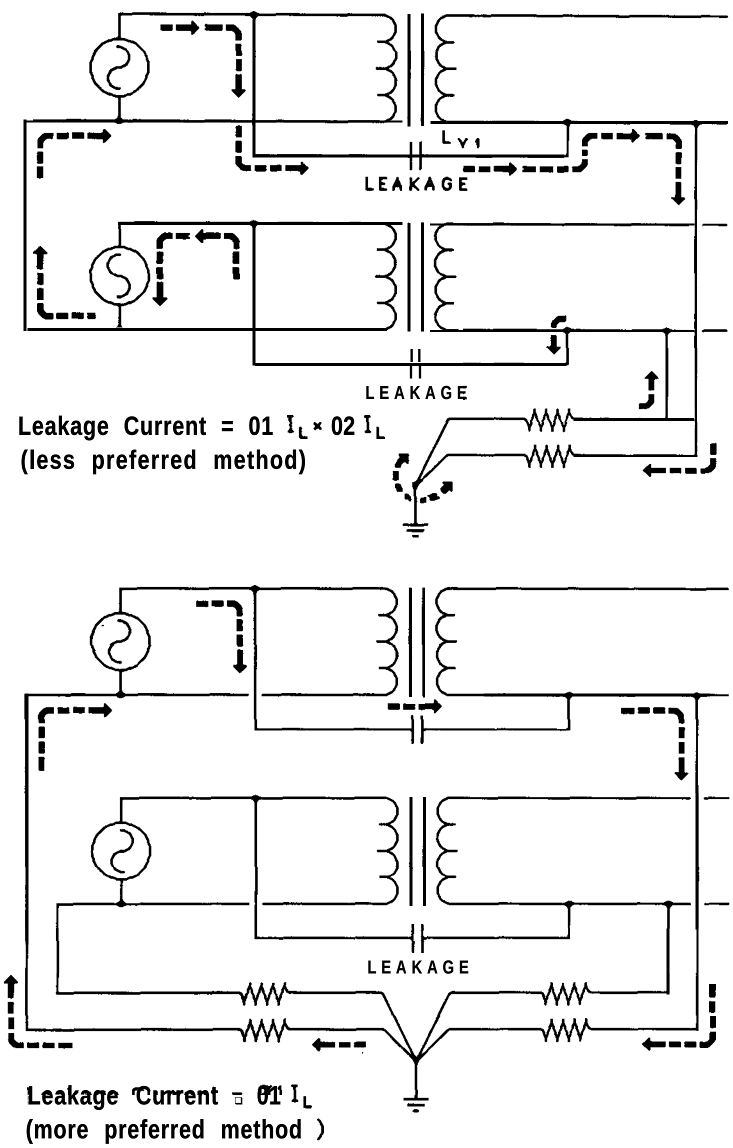
It's a funny thing, the National Electric Code (or NEC for short), tells us that all electrical service will have the neutral brought to earth either through a grounding rod, or a cold water pipe. All "ground" wires will also be bonded to the electrical conduit at the same physical point that the neutral is brought to ground. What's funny about this is that most municipal building codes require that there be no electrical connection between the water supply and the building. This brings to rise an interconnection system that kind-of gets to ground. There are ways around this of course, and these we will address.

Hospital Ground Method

The way this system works is through the use of the third pin on the electrical power cord. The outlets that are

FIGURE TWO

Two-phase wiring vs. single-phase wiring-how leakage current doubles when running on two separate phases



employed in the installation must have a separate earthing wire brought back to the technical ground. This technical ground is usually a large copper or brass bar located at the power distribution panel. The technical ground is kept isolated from the box and is brought to ground (power company ground!) at one point only, and this is accomplished through the use of a very heavy conductor. This methodology has the benefit of manufacturer approval, electrical building inspector approval, and overall safety improvement. The drawbacks come in the form of extreme expense, considerable difficulty in implementation and a lot of hassle with the electric company.

When implementing this type of system there are a number of rules that should be abided by. Most of these procedures are good practice, and you would be wise to follow them with whatever type of ground system that you employ.

1) The control room, and all equipment that is used therein should be kept on the same phase of the AC line.

When all of the equipment is on the same phase, the leakage currents due to capacitive coupling of the power transformer to the chassis are all in phase, and are not additive through the technical ground. (See Figure 2.)

2) Isolate the electrical feed from everything else. Keep the audio power separate from copiers, fluorescent lights, refrigerators and the like.

The simplest way of accomplishing the isolation required is to request a separate power transformer feed from the power company. This is not really practical in most urban areas, but it is worth a try anyway. Lacking this, an isolation transformer should be used. When implementing power isolation, power conditioning is desirable, thus cleaning up the noise, line drops and other forms of garbage that get into the power feed. An acceptable power conditioner will provide a Faraday shield that is connected to the secondary side of the transformer system ground. When considering isolation and power conditioning systems, look at the secondary impedance at RF frequencies. It must be low enough to act as a shunt impedance to radiated fields. Ideally, the transformer will provide for two or three phase input and single phase output. This output will then be taken as technical power. Keep it clean.

3) Shield all AC power lines.

As mentioned previously, unshielded power lines radiate a field that will terminate on your audio lines. It is ideal to use steel conduit because it provides not only electrostatic shielding but magnetic shielding as well. It should be noted here that steel conduit is desirable for the audio runs as well. The power and audio lines must never be run in the same conduit. Both magnetic and electrostatic coupling ***will*** occur.

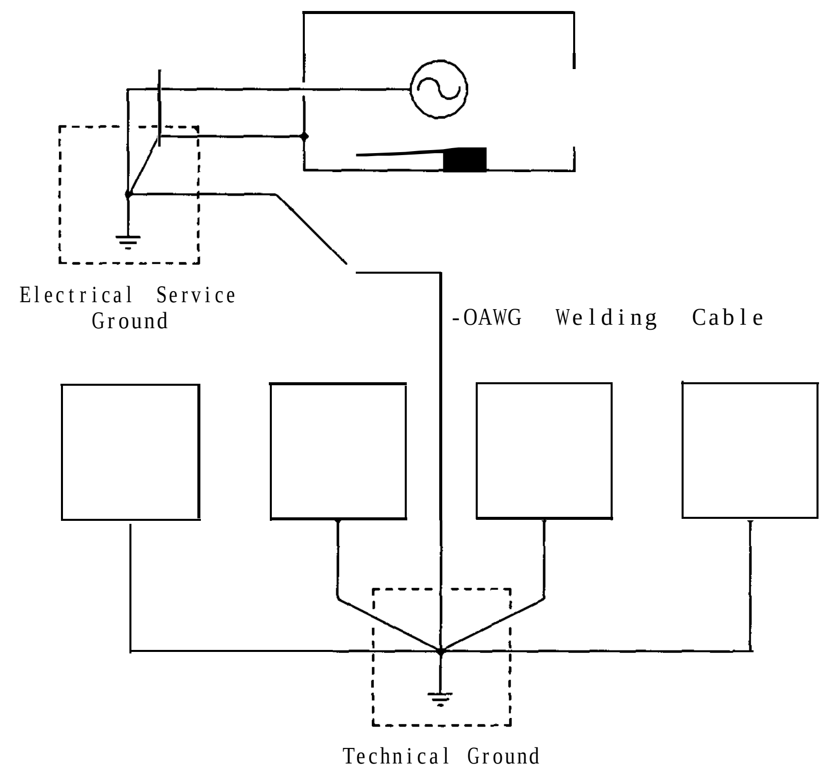
4) Bring the third pin of each outlet back to technical ground separately.

For a single point star ground to work, there must not be any serial ground connections. The leakage currents will add up and hum on the "downstream" equipment will result. The conductor should be at least the same size as the power carrying conductors and preferably larger. This means that only isolated ground receptacles may be used. These are identified by their distinctive orange color. This is an area of difficulty due to the large number of conductors that will be running back to technical ground. Conduit must be sized accordingly, and provision must be made at the power distribution panel for these wires to get to the technical ground, which is usually on one side of the panel. Multiple outlet distribution strips can only be used if the third pin connections are independent of their enclosure.

5) Never allow the third pin to contact the conduit.

The conduit, as mentioned earlier,

FIGURE THREE : GOOD GROUNDING PROCEDURES



will always introduce loops. The technical ground will contact the conduit at one point only, and that will be where the conduit is bonded to the earth. And the earth will be the only common connection point.

6) Take technical ground to the earth with only one very large conductor.

This connection is the one in which you take the system shield potential to -Q, or infinite negative charge. The size of the conductor is important because all voltage drops from leakage currents of different phases will return through this path. It is important that this connection be made at the point that the power company takes the neutral to earth. This is to ensure that the return path(s) of all leakage currents have minimal voltage drop. The importance of taking the system to "real" earth is illustrated in Figure 3. Examine this topology and trace the various leakage paths. It becomes obvious that the leakage is minimized by going back to earth at the same point that the power does. The previous statement is very difficult to achieve.

7) When utilizing relay racks for equipment, isolate the chassis of each piece that is not sharing an outlet with another rack-mounted chassis.

This is also a very difficult rule to implement. The chassis of each piece of equipment in the rack is in electrical contact with the third pin of its respective power cord. There are usually many more power cords than there are receptacles for power. When this occurs, the most expeditious means of installation that will meet acceptable criteria is to use a multiple outlet distribution strip that carries each third pin in a strip out to the master third pin. The chassis of the outlet strip must be isolated from the rack, but this is not difficult. The strip is then plugged into the wall outlet. If more than one strip is required, both strips are to be plugged into the same duplex receptacle. The equipment that plugs into each strip should be isolated from the equipment employing the other strip. This can be accomplished by having a break in the rack rails themselves-a real pain in the ass.

Separate Earthing Wire Method

The above described system topology is both difficult and expensive to employ. The less expensive alternative is to use a separate earthing wire attached to each piece of equipment that returns to the technical ground. In order for this method to properly function, it is imperative that the third pin connection of the AC cord is lifted. The technical ground is returned to earth with a very large conductor at one point only. The location of the technical ground in this type of system is much simpler to position and access. The technical ground should still be a large copper or brass bar. I prefer to tie this point down at the point on the console that is either the point that audio common and the enclosure make electrical contact, or a location near the cabling entrance to the console. When locating the technical ground bar in this manner, it becomes imperative that the bar is electrically isolated from everything, and is taken to the console commoning point with one large cable. We have often fastened the technical ground bar to the console leg by drilling and tapping the leg, and bolting it in place, running a braid to the console ground point. Theoretically this is not so good, but it has worked very well in most instances. I wish that all other console manufacturers would look at SSL's ground bar connection at the DL panel. It is the way to do it!

Implementations

One of the big advantages of using the separate wire method is the availability of using a larger conductor than is available at the power cord. With the 24-track, it is desirable to use a #8 or larger earthing wire. The power cord earthing wire is a #12 or smaller. Anyway, this is the implementation, so we won't futz around—

The General Idea

Using the separate earthing wire technique is much the same as the hospital method in that you:

1) Connect the shield of the interconnecting cables at one end only (preferably the source, or output)

2) Connect one earthing wire to the chassis of each piece of equipment interconnected, and the other end of each earthing wire to terminate at the technical ground bus.

3) Earthing wires all terminate at the technical ground bus and do not "daisy-chain" in a serial manner, to get to technical ground.

4) The technical ground should be located at either the power distribution panel or at the terminus of the audio cabling (99 percent of the time this will be at the console termination area).

5) The technical ground bus shall not touch any building conduit, except at the point that technical ground is taken to ground.

6) The third pin of each electrical power cord is to be lifted.

7) Shield wires are not to be shorted together at any point other than the chassis connection of the interconnected piece.

8) Keep all power distribution on the same phase.

9) Keep all audio power circuits

free and clear of office equipment, refrigerators, lighting and the like.

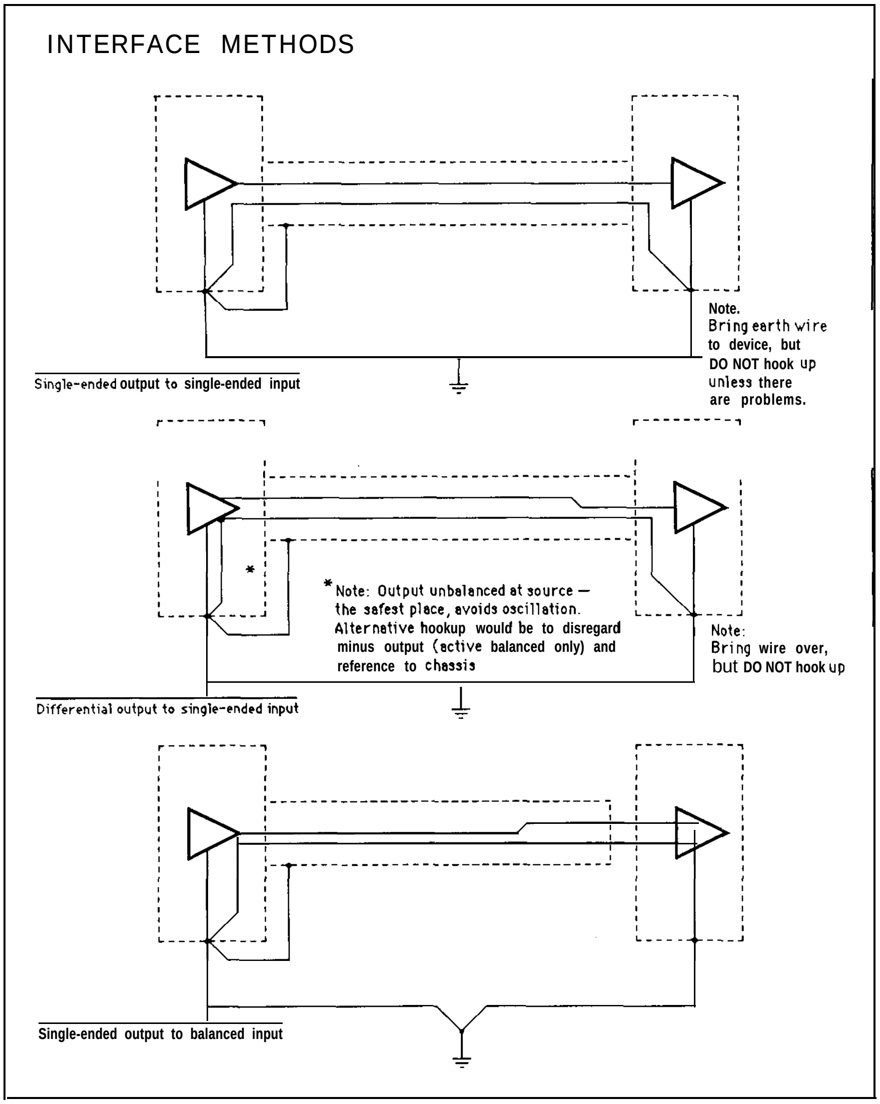
10) If the technical ground is to be taken to ground, then make sure that the ground, neutral to ground, conduit bond to ground, and technical ground to ground connections are all clean and tight.

Racks

Rather than having 20 to 30 earthing wires trailing out of a rack assembly, it makes a lot more sense to follow the *spirit* of the above rules rather than the strict letter. Attach a grounding bus in each rack, and treat it as a single piece of equipment. Bring each of the individual chassis to the grounding bus with an individual earthing wire, and then take the grounding bus to technical ground with a single, large conductor. We are treating each rack full of equipment in this manner as a single large piece of equipment. When the shield is properly terminated, this works very well in almost all instances. The time that you will find trouble is when equipment that has single ended inputs and outputs is mixed in the same rack as balanced equipment. When the console outputs, and/or driving source is single ended and it terminates in a single ended input, then there is a ground loop if the minus is tied to signal common, and an earthing wire is attached to it. The act of rack mounting such equipment with other earthed gear produces the aforementioned loop condition. Complete rack isolation is the only answer in this situation. The earthing wire attachment is not to be used here, rather the signal minus connection will bring the equipment shield to system technical ground potential. Power amplifiers in power supply racks are a common offender, and it is recommended that the inputs be converted to balanced, either via transformer or active balancing.

Microphone Panels and Boxes

Using the greatest care in establishing a proper earthing system, you get it all done and find that you have a multitude of points that get to power company ground unintentionally! Usually this is caused by the way that the microphone and cue boxes are installed. When running the mic wiring, use steel conduit. This provides both magnetic and electrostatic shielding for the cables. More often than not, the construction personnel are not as careful as you would like in maintaining the electrical and physical isolation from the metal of the building. Not a big deal you say. But what happens when you plug in your recently purchased, rented or borrowed microphone cable, and the system hums?



Well, most microphone cables out there in audio land have the connector body wired to pin 1 of the XLR. The shield is connected to the chassis of the console. The panel that the XLR connector is mounted on is almost always connected to building steel, usually through the conduit that ties to the box that the panel is mounted on. Because of the connection between the shell of the connector on the microphone cable, the power company ground, through the conduit connection, and the audio technical ground, through the shield of the microphone wiring to the console, are now tied together.

The shells of all of the mic level XLRs should at some point be referenced to technical ground. This is necessary for RF shielding. What must occur is that all of the microphone cables must have the pin 1 to shell connection made at the female end, and disconnected at the male end. Because of the previously mentioned rule that shields must not be shorted together at any point other than the chassis connection point at the wire termination, it is imperative that the panel mounted females connectors do not have the pin 1 to shell connection made. The best way to provide this shielding is to electrically isolate the box from the conduit that feeds it and from the building metal. Then take an earthing wire from technical ground to the box. This provides for shielding of the box, and because of the mechanical connection of the connector(s) to the panel and the panel to the box, the entire connection is shielded.

Multi-Track Dolby

Another source of consternation is the single-ended input of an M series Dolby frame. When driven with a single-ended console output, it is necessary to float the chassis and take the chassis connection back to the system technical ground. The console output(s) and the Dolby inputs will provide correct wiring if they are wired as balanced.

2-Track Single-Ended Machines

When interfacing cassette systems, G-track ¼-inch machines on the two mix bus with regular balanced +4 type machines, it is a good idea to isolate the unbalanced inputs with one of the commercially available interface boxes specifically designed for this purpose. What is necessary is to establish that the input of the adapter device is in fact balanced, and that the port on the console that the adaptor is driving is balanced, otherwise it will be necessary to again forego the advantage of a separate earthing wire and rely upon the signal minus to derive the shield connection.

The Final Steps

OK, you've followed all of the above advice and everything is wired neatly in place. It's getting to that time when you have to fire the system up and see if it all works! Whenever we construct a room, we don't terminate everything for the "fire up," but defer this to a more systematic approach.

It is necessary to isolate the various component parts of the control room so as to determine what is properly functioning and what isn't. This holds true for the earthing connections as well. With all of the earthing wires not terminated at the technical ground, there should be no ohmic connection between any two pieces of equipment (with the exception of single-ended equipment, and this should be disconnected for this test). Once it has been established that there are no loops present in the earthing system, terminate each piece and ensure that the earthing wire is the only path that takes the chassis to technical earth. Perform the above steps for each and every unit installed. It is now time to disconnect all of the signal wiring and check the console out. This is where the multi pin connector approach to console fabrication is an essential aid to the installer. The first thing that is hooked up is the console power supply system. It is best to ascertain at this time that the console itself is functioning properly. This is the time for basic testing, such as checking the power supply voltages, determining that signal gets to the two mix bus, and the like. Once it is established that the console basically works, terminate the monitor rack and hook up a set of control room monitors, The ears are great pieces of test equipment. With nothing other than the monitor system hooked up, listen for hum and buzz. If it is found, chances are that the monitor rack contains some single-ended inputs being driven by single-ended outputs. Also take care that the chassis connection isn't taken from, say, the power transformer core— lots of capacitive coupling to the technical ground will result. It may be necessary to experiment to determine the best place to terminate the earthing wire. Another little trap to avoid, if you are returning the cue system to the console, is to make sure that the audio '--' is isolated from the console chassis, otherwise some nasty things can happen. You should be able to turn the two mix master of the console all the way up, monitor this and turn up the control room monitor, and hear only hiss. Hum *in* the signal indicates a problem.

The next step is to terminate the signal wiring and earthing wires of the mix-down machines. This would include any noise reduction systems employed. Again, monitor the two mix, and the 2-track returns. Hiss is allowed, hum is not.

Following the two mix is the multitrack (again including noise reduction) and the above rules apply. Continue in this manner until everything is hooked up, tested, and correctly functioning. As you encounter problems in the just-mentioned procedure, remember the basic theories outlined here, and try to apply some of the physics principles learned to your mental models of what is really happening in your system. With a little thought, conscientious testing and application of wiring rigor, a quiet instalation will result. ■