

NOTE 102

Professional Audio Products



ANALOG I/O STANDARDS

- 3-PIN CONNECTOR WIRING
- BALANCED INPUTS & OUTPUTS
- FLOATING UNBALANCED OUTPUTS
- RFI & EMI PROTECTION
- GROUNDING
- PASSIVE BYPASS

INTRODUCTION

Quality engineering necessitates standards. Recognizing this, Rane has adopted an input/output (I/O) convention for all of its products which parallels international standards where applicable and accepted practices elsewhere. This Note describes and discusses each of these so the user of our equipment will never be in the dark regarding polarities, grounding or connector wiring. In general, we are a left-to-right, front-to-back, top-to-bottom society—which has absolutely nothing to do with this Note. It's just interesting.

Dennis Bohn
V.P. Research & Development

Although written in 1982, Rane customers continue to request this Note. They refer to it often for its basic information and background on connectors, circuit and wiring conventions. Indeed, the derivation given for the differential-mode and common-mode input impedance of the everyday difference amplifier continues to be referenced by other authors. While some of it may seem dated (and *is*) we continue to keep it among our current Rane Notes for its historical perspective and general usefulness. Please read it with its origin date in mind. Seeded throughout the text are a few parenthetical *Update Notes*. These aid in making certain important concepts current. For exact detailed specifics on any current Rane product, contact our Technical Service Department.

CONNECTOR CONVENTION

The single biggest source of wiring confusion in the pro audio industry is 3-pin connectors. Even their name is a source of confusion. Most commonly called “XLR” jacks, they are also known as “Cannon plugs”, “3-pin connectors”, “XLR-type” jacks, and “circular connectors”. The name confusion makes sense since this type of jack has never been given a generic title. Other audio connectors are commonly referred to as “phono” (originally called RCA jacks), or “phone” (1/4" jacks, after headphones and telephones—their original usage), or “DIN” plugs (Deutsch Industry Norm) a German standards organization and European standard.

Nothing comparable has caught on for 3-pin connectors, so they have become known by the original manufacturer’s model number. The original manufacturer was ITT-Cannon and the model number was “XLR”. Today, “XLR” is a registered trademark of ITT-Cannon and cannot legally be used to describe any other manufacturer’s version of this connector. And since very few use ITT-Cannon XLR connectors, violation of their trademarked name is commonplace. Until something better comes along, Rane will refer to this type of jack as a “3-pin connector”.

3-PIN CONNECTORS

Much to many people’s surprise there is a standard for wiring 3-pin connectors—not *two*, as commonly believed. The conflicting so-called “European” and “American” standards are myths. There is one standard. It is *IEC 268¹* issued in 1975 and signed by 17 countries, including the UK and USA. In addition, the same convention was adopted separately in the UK as *BS 5428²*. And finally, has been made an American National Standard. ANSI PH7.102-1983. There *should* be no conflict in connectors. There obviously is, and that is a sorry reflection of how badly informed are many manufacturers of pro audio equipment. (*Update Note: In 1992, the Audio Engineering Society finally issued it’s Standard AES14.1992 agreeing with the above standards.*)

Rane wires its 3 and 5-pin connectors per IEC 268 as follows:

3-Pin Connectors

- Pin 1 Ground (Shield, screen, etc.)**
- Pin 2 Positive (Signal, Hot, etc.)**
- Pin 3 Negative (Return, Common, etc.)**

5-Pin Connectors

- Pin 1 Ground**
- Pin 2 Left Positive**
- Pin 3 Left Negative**
- Pin 4 Right Positive**
- Pin 5 Right Negative**

1/4" PHONE JACKS

On Rane equipment outfitted with input/output phone jacks, the wiring convention for standard tip-ring-sleeve (TRS) connectors is:

TRS 1/4" Jacks

- Tip = Positive**
- Ring = Negative**
- Sleeve = Ground**

TS 1/4" Jacks

- Tip = Positive**
- Sleeve = Ground**

For 1/4" TRS output jacks designed exclusively for headphone use, the standard is:

Headphone Jacks

- Tip = Left Positive**
- Ring = Right Positive**
- Sleeve = Common Ground**

TRANSFORMERLESS BALANCED INPUTS

Rane incorporates automatic balanced-unbalanced inputs on all of its pro audio products. Balanced inputs are a thing of beauty. They take two signal lines and amplify only the difference between them while rejecting anything that is common. The common stuff is all the garbage induced in the lines as they dutifully connect two pieces of equipment. Hum, noise, AM radio stations, police, fire and ambulance radio signals, radar, fluorescent lights—even life itself—all competing to violate the pure signal as it tries heroically to traverse from one piece of gear to another.

Many solutions exist to accommodate balanced inputs. Transformers are the most common. And the most expensive. And the most troublesome.

So much for transformers.

Rane uses the best active balanced input design that fits the application and budget for each particular unit. These range from the true instrumentation amplifier designs used in Flex (and other) units (see the *Flex Users Guide* for details), to the very popular and successful difference amplifier found throughout the pro-audio industry.

A difference amplifier, like its name implies, is one that amplifies only the *difference* between two input signals. For instance, two inputs of +1 volt and -1 volt respectively result in an output of +2 volts for unity gain designs, i.e., a *difference* of +2 volts. Or, two signals equal in value, say, +1 volt each, result in 0 volts output (their difference). Two equal signals are called *common*, and the amplifier is said to be operating *common mode* (as opposed to *differential mode*). For real-world audio input signals the amplifier operates in both modes simultaneously—it amplifies anything that is different (signal) and rejects anything that is common (garbage).

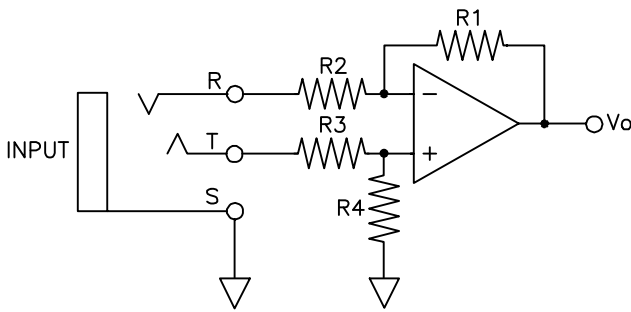


Figure 1. TRANSFORMERLESS BALANCED INPUT STAGE

With a single op-amp difference amplifier, you can have *either* equal common mode input impedance or equal differential mode input impedance, but not both (see sidebar box on back page for details). Of the two the most important is common mode impedance; it must be equal for the minimization of hum and RFI pick up.

With equal common mode impedance, you get unequal differential impedance. For some designs (where all resistors are equal), the mismatch can be as much as three to one, with the positive input impedance being three times the negative input impedance. This sounds like a big problem, when in fact, it is not. All it means is that the load impedance seen by the positive and negative line drivers are not equal, so the negative driver has to deliver more current. But, as long as the impedances are within reason (at least 5k ohms or greater), you really do not have a problem.

AUTOMATIC BALANCED-UNBALANCED OPERATION

Figure 1 shows a balanced stage with a TRS 1/4" phone jack input. There is a bit of cleverness going on here that comes for free. Using a stereo phone plug into the stereo jack gives you the balanced line input. Not so obvious is that by using a mono phone plug the circuit automatically switches to unbalanced single line operation. Nice, huh? What happens is that the ring of the jack gets shorted to ground by the mono plug and turns the difference amp into a non-inverting stage with a gain of two (assuming all resistors equal), but there is a 6dB pad (a loss of 1/2) hung on its positive input, so the net result is a unity gain unbalanced input. The stage becomes universal now, being either balanced or unbalanced, depending on whether the input plug is stereo or mono.

TRANSFORMERLESS BALANCED OUTPUTS

Balanced outputs have evolved in similar fashion to balanced inputs, starting out with everything using transformers and gradually moving toward transformerless solutions. The most commonly seen solid-state circuit involves two op amps as shown in Figure 2 (or some variation of this configuration). There is one problem and one myth that must be overcome

before this circuit can be used. The problem is one op-amp gets shorted to ground if an unbalanced (mono) plug is used for interconnect. If allowed to happen this can cause possible damage to the op amp, along with possible distortion interaction with the other op-amp if they are part of the same IC package. Rane solves both of these problems very simply by adding resistors in series with each output (isolation of reactive output loads require these anyway), and by ensuring that separate op-amp packages are used. These things, along with using IC's capable of driving lines, guarantee that shorting either of the outputs does not damage the op-amp or induce any distortion products into the other side.

The myth involves a mistaken belief that the cross-coupled output stage developed by Thomas Hay at MCI (AES preprint no. 1723) retains the 6dB headroom advantage of balanced lines when used in an unbalanced fashion. Hay's circuit does two nice things when either side is shorted: [1] The shorted op amp's output is forced to zero volts. It does not drive the output resistor at all, so no stress is put on the output stage. [2] It doubles the *gain* of the unshorted op amp. This way, the output still delivers the same level for the same input either balanced or unbalanced. For example, a 1 volt input produces either ± 1 volt output balanced, or 2 volts unbalanced. On the surface, this suggests the 6dB headroom improvement offered by all balanced output stages is preserved when used unbalanced. *This is not true at all.* Since the *gain* of the output stage is doubled then it will run out of headroom 6dB earlier than when operated balanced. The op amp can only swing so many volts. When only one op amp is driving the line there will be a 6dB loss of headroom—period. It does not matter how cleverly the op amp is configured.

Since a discretely implemented cross-coupled output design requires many carefully trimmed precise parts, without producing any real advantages. Rane does not use it. Where appropriate. Rane does use a special laser-trimmed integrated circuit developed for this purpose. This design exhibits the same 6dB loss of headroom when used unbalanced, but otherwise is an excellent balanced line driver in a small package. (See note 124 for additional details.)

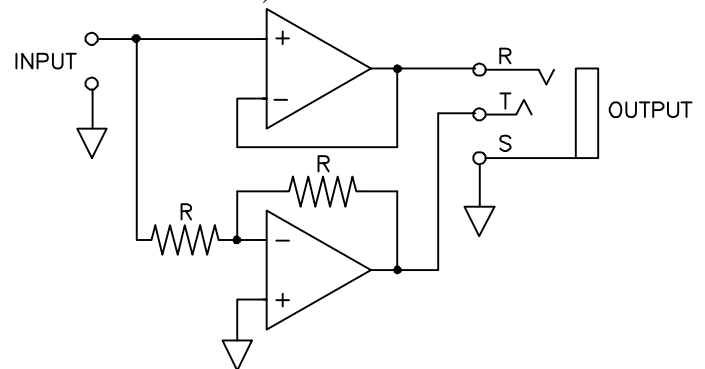


Figure 2. BALANCED OUTPUT STAGE

FLOATING UNBALANCED 1/4" OUTPUTS

On many Rane products fitted with 1/4" outputs, a floating unbalanced drive circuit is used. What is required is an output scheme compatible with balanced or unbalanced inputs that allows signal ground and shield (chassis) grounds to be isolated.

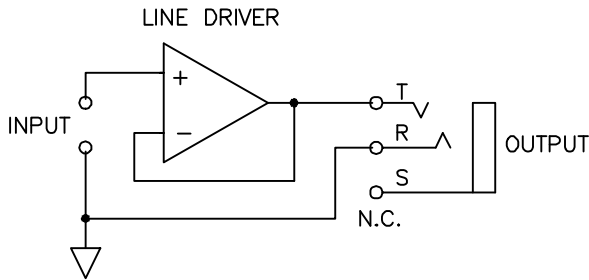


Figure 3. FLOATING UNBALANCED 1/4" TRS OUTPUT

The best solution, as is so often true, is the simplest. It is no more complex than Figure 3. By taking a regular single-ended (unbalanced) line driver and floating its ground you create a compatible system for driving differential (balanced) inputs that is trouble free. Figure 4 shows the interface between the two systems. Note that while the chassis of each unit may be at the same potential, their signal grounds are allowed to be at different potentials. This is very important in keeping hum common mode, and not differential. Any difference of potential existing between the two grounds is seen as a common mode signal and is rejected. This problem is particularly acute where units of various manufacturers

are bolted together in the same rack. All of Rane's products may be intermixed with other brands with minimal hum problems.

Like the balanced input stage of Figure 1, the floating output stage of Figure 3 automatically switches to a conventional unbalanced output stage if a mono phone jack is used for interconnection. The ring of the jack gets shorted to the sleeve, thus grounding the sleeve as you would in a normal unbalanced system.

CHASSIS GROUND

Signal ground is tied to chassis ground by a network consisting of a 10 ohm resistor and a .01 microfarad capacitor in parallel. (Update Note: the resistor has been replaced by a Ground Lift switch on most products.) The small resistor allows the signal ground and the chassis ground to be at different potentials for all audio frequencies; while the capacitor shorts the two grounds together for high radio frequencies. The actual chassis is carefully tied to the chassis ground path at only one point. This is critical if proper chassis shielding is to be realized.

SIGNAL POLARITY THROUGH RANE PRODUCTS

While not wishing to engage in the controversy that rages on in the audio world regarding whether or not signal inversion is audible, it is Rane's policy to not invert signals through its products. Our position is very simple—overall signal inversion is not necessary, so why do it?

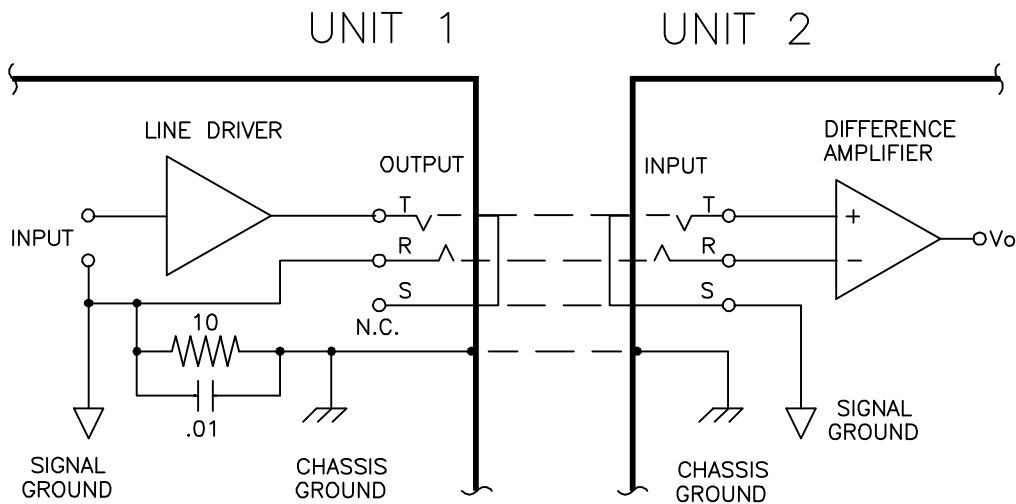


Figure 4. INTERCONNECTION

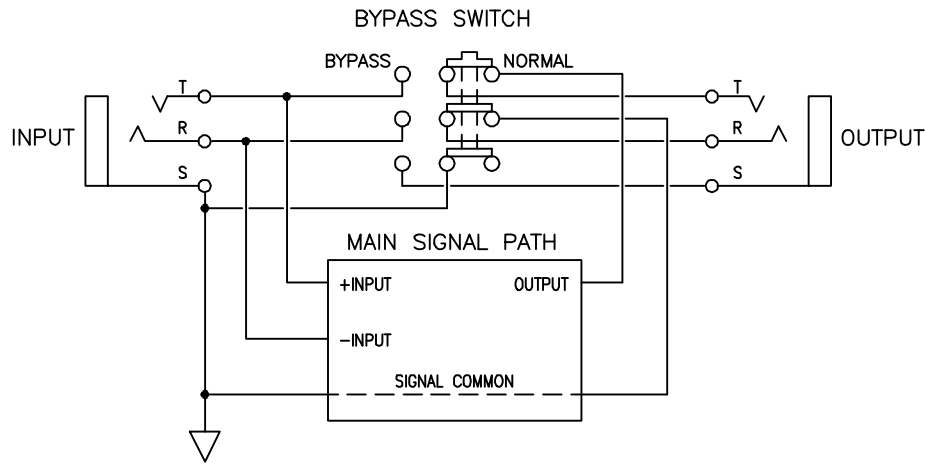


Figure 5. PASSIVE BYPASS WIRING

PASSIVE BYPASS

It is Rane's philosophy that Bypass switches should not require power to operate. For this reason all bypass circuitry is totally passive as shown in Figure 5. (*Update Note: Some digitally controlled products violate this rule, while others use relays to accomplish the same function. Technically not passive, but they work in a fail-safe mode so that bypassing is automatic with power failure.*) With the Bypass switch engaged, all signal connections are rerouted directly to the output (including ground) thus turning the unit into a rather expensive 3-wire patch cord. (Note that the floating output ground reverts to a straight through balanced ground connection in bypass condition.) If at any time, power is lost to a Rane product, simply pressing the Bypass switch completely restores the signal path. Some Rane products use relays to automatically restore signal path upon power loss. Check data sheets.

RFI & EMI PROTECTION

Radio frequency interference (RFI) is one of the most annoying problems that plagues any piece of equipment featuring high gain (e.g. mic preamp stages in mixers). It normally enters as a common mode signal induced into the mic input cables, although it also gets in via the line cord, or in extremely bad areas directly onto the output lines.

The use of balanced inputs and outputs on Rane products greatly reduces their susceptibility to RFI pick up. In addition, RFI filter traps are featured on all high gain inputs. The single point chassis ground concept discussed earlier further helps in reducing RFI problems. Praying doesn't hurt either.

Electro-magnetic interference (EMI) can also be very troublesome if proper steps are not taken during product design. EMI is primarily due to one piece of equipment inducing 50Hz or 60Hz hum into another piece of equipment. For example, power amplifiers with their large transformers and associated magnetic fields may easily induce hum into low level signal processors having high gain. Rule: Thou shalt not mount thy amplifier upon thine mixer.

Proper shielding is essential in reducing any piece of equipment's susceptibility to EMI. All Rane products utilize steel chassis and front panels to help shield against stray field pick up. Balanced inputs further help in rejecting EMI since it is nearly always a common mode signal. And, again, the single point chassis ground is another important safeguard.

INPUT IMPEDANCE OF DIFFERENCE AMPLIFIERS

Differential Or Common Mode Positive Input Impedance

Figure 1 shows a standard difference amplifier. On the surface it looks simple enough, but close examination of the available literature and text books covering difference amplifiers reveals a subtle complexity that causes great confusion. It all revolves around the fact that the negative input impedance is *dynamic* while the positive input impedance is *static*. That is, the positive impedance is unrelated to the type of input signal or feedback resistor. It is always equal to equation (1), whether the input signal is differential or common mode.

$$R_{in (+)} = R3 + R4 \quad (1)$$

This is not true for the negative impedance: the negative impedance is *different* depending on the nature of the input signal. This is due to the dynamic servo loop nature of the feedback circuitry, which is always working to keep the voltage at the negative input to the op amp equal to the voltage at the positive input (the virtual short concept).

Differential Mode Negative Input Impedance

The negative differential input impedance is not equal to resistor R2 as popularly believed. It is equal to equation (2):

$$R_{in (-)} = \frac{R3 + R4}{2R4 + R3} R2 \quad (2)$$

For the most common design where all four resistors are equal, R_{in} equals $2/3 R2$.

An example may be the best way to understand why the impedance is $2/3 R2$. Assume there is +1 volt at the tip and -1 volt at the ring of the input jack and that all resistors are equal. There is therefore, $+1/2$ volt at the

plus input port of the op amp—and the minus port (virtual short). The ring input current equals the voltage across resistor R2, divided by R2. The voltage equals $+1/2V$ —(-1V), or $3/2$ volts. The current is then $3/2 R2$. The ring input impedance is, by definition, the input voltage (-1V) divided by the input current ($-3/2R2$), (the minus sign indicates current is flowing *out* of the circuit) giving an answer of $2/3 R2$.

Common Mode Negative Input Impedance

The negative common mode input impedance is found from equation (3):

$$R_{in (-)} = \frac{R3 + R4}{R3} R2 \quad (3)$$

For the case where all four resistors are equal, R_{in} equals $2 R2$.

Again, an example may be the best way to illustrate equation (3). For common mode input signals, the op amp works to reject them such that the output will be zero. If the output is zero and the input currents to the op amp may be ignored (a reasonable assumption with modern IC's) then the negative input impedance is simply $R1 + R2$. Equation (3) is the general equation found by writing the input current equation as before, and dividing it into the negative input voltage. It serves to illustrate the negative input bootstrap effect caused by the feedback.

Comment

For further confusion (clarification?) it is necessary to reiterate that both cases occur simultaneously. That is, the negative input impedance is lower than R2 for all differential input signals and higher than R2 for all common mode signals—*at the same time*. Audio input signals are almost always a mixture of signal (differential input) and interference (common mode input).

REFERENCES

1. International Electrotechnical Commission Standard No. 268. Part 12, titled. "Circular Connectors for Broadcast and Similar Use", 1975. Signers were Australia, Belgium, Canada, Denmark, Egypt, Hungary, Israel, Japan, Netherlands, Norway, Romania, South Africa, Sweden, Switzerland, Turkey, the UK, and USA.

2. British Standards Institution No. BS 5428. Part 5. Sec. 3, 1980/81.