The Audio Engineer's Handbook

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● Last month we looked at the construction, electrical characteristics, and commonly-used circuits in which switches are normally used. We also covered noise suppression in power switching.

In *audio* switching the variety of levels and circuits may create special problems when the goal is noiseless audio transfer. It may be helpful, therefore, to classify switches for audio according to the function they must perform. In sound-mixing consoles we would distinguish the following types of switches:

microphone level switches
channel selector switches
monitor selector switches
talkback switching systems
patchbays.

There are other types of special switches, of course, but the above categories cover most of the normally encountered types.

The noise and click suppression methods described last month do not apply to audio circuits. In *audio* the sequence of switching is the most important condition, while in *power* circuits short-circuiting of the power pulse transient is the objective.

However, the origin of transients is basically the same in both types of circuit. Current flow has been suddenly interrupted or resumed. All the reactive components in the circuit (the capacitors and inductors) are storing or dissipating energy—creating the transient.

From this statement you might assume that the elimination of reactive elements from the circuit would remove the danger of switching noise. But there is always the possibility that the circuit to be opened or closed has d.c. bias (possibly due to faulty design or component failure; but also possibly purposeful as when d.c. bias is carried for condenser mics). Interruption of this established current flow produces a step function causing a click even though there might be no reactive components present.

Basic good-engineering practice calls for several rules to be followed when switches are called for.

1. Analyze the circuit before deciding what kind of switching can and should be used.

2. Determine if the impedance of the circuits in question must be kept constant and what effects impedance change may have on associated circuitry.

3. If the signal to be switched is at mic level and the circuit is a balanced one, be sure to select a switch with adequate shielding and enough contacts to provide switching in of a dummy load when the source is disconnected.

In the last rule above it is important that the dummy load be switched in *before* the source is disconnected. Conversely, the source must be re-connected before the dummy load is removed. Switches designed to do this job have make-before-break contacts. If the input of an amplifier is switched to different sources it is feasible to use a

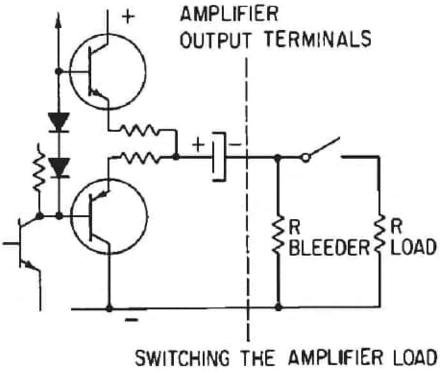

Figure 1. Switching the amplifier load.

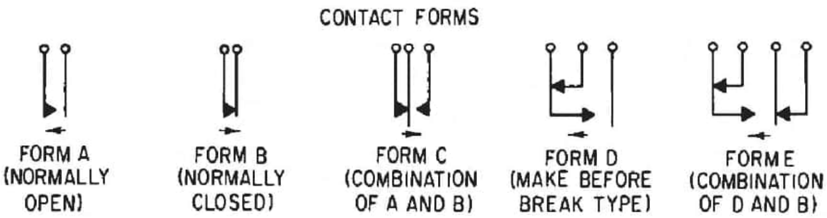

Figure 2. The various contact forms found in switches and relays.

permanent dummy load across the input to the amplifier—providing the sources require load resistors anyway. In this way, the input to the amplifier is never left hanging—picking up noises and hum.

In a modern directly-coupled amplifier, the output is available through an electrolytic capacitor. The amplifier side of the capacitor faces a certain d.c. potential. If the amplifier's output is left unterminated the charge on the capacitor will slowly fade away. Reconnecting the load produces a renewed charging of the capacitor, drawing excessive current and producing an audible click.

In order to eliminate this click a bleeder resistor should be put across the output as a permanent load. In this way, even when there is no regular load connected, the bleeder resistor keeps the capacitor charged. This is shown in Figure 1. (Take this as a hint in servicing. Leaky electrolytics can cause switching clicks. If you have a stepped or carbon attenuator as a load, d.c. will cause crackling noises when the fader wiper is moved.)

In many systems, where it is important to keep input circuits free of extraneous noises, each microphone is connected to its own preamplifier without any intervening switches. This brings the level of the input up to easier-to-manage line level.

MIXING BUSSES

There is much to be said about mixing busses when the technology of audio mixing deals with problems of multichannel mixing consoles and tape machines. It's only been fairly recent that we have become so interested in maintaining channel separation. The tools for achievement have followed classic forms with lengthy formulae and matching impedance loads and sources.

The advent of operational amplifiers and transistorized circuits have given audio engineers the opportunity to generate new approaches to old problems. There is no need for having every component in the system available on the patch bay. The packaging of consoles and the attendant reliability of present-day circuits are such that balanced lines needed to patch around failed components are all but forgotten. Only with long mic cables and output lines will they still be found.

The compactness of packaging affects the choice of the circuits being used. Because of the extensive use of transistors and the consequent elimination of balanced lines, transformers have been used mostly as a means of isolation from mic and output lines. Normally, transformers contribute to noise-free switching by keeping d.c. away from switches. Without transformers, switching, wiring, and grounding circuits become more involved; they will be discussed in detail in future installments. And since mixing normally is a subject in itself, it too will be treated separately in the future.

TALKBACK SYSTEMS

One of the most difficult switching problems to be found in a recording console is the complete talkback system. Switching must be noise-free and it must be sequentially correct.

Basically, a talkback facility allows the engineer or producer located in the control room to communicate with the performers in the studio. Since studio microphones are feeding signal to the console and control room (CR) monitor speakers, one-sided communication already exists. Reversing the direction of signal flow requires that the mics be turned off in the studio (to prevent acoustic feedback) while a mic in the CR that is tied to speakers in the studio is turned on. This complicated switching sequence is begun by depressing the talkback button (TB) on the console. (This sequence is shown in Figure 3.)

A most important condition for TB switching is the sequence with which the circuits close and open in order to get smooth switching. Since many of the circuits to be affected are physically scattered in different parts of the system, relays are the most common solution to this problem. (Since a relay is nothing more than an electrified switch, we will treat it as a switch.)

Relays, just as manual switches, can be purchased with a variety of contact configurations. The most common type, however, is form C as shown in Figure 2.

The TB sequence of switching is as follows: first, the monitor speakers in the CR have to be disconnected; Then the studio microphones are cut; next the TB mic is connected; and finally the studio monitors are switched in. This completes the switching sequence in one direction.

When returning to normal console operation, the switching sequence is reversed. First the studio monitors are shut off; then the TB mic; followed by connection of studio mics; and last by the control-room speakers. In order to appreciate the potential complexity, realize that an eight-channel console would have at least sixteen relays. There may be short cuts that allow you to achieve the same results with less relays. but you may well end up buying extra wiring and crosstalk problems instead.

There are a number of ways in which the correct switching sequence can be achieved. In smaller installations, manual switches with form E contacts or several switch-operated relays having sets of adjustable contacts—each set closing or opening just a little later or sooner than the other contacts—can be used. In this way a selection of the proper sequence of contact closing will properly activate the remote relays.

Another way to achieve the same results, but at higher expense, is by connecting the relays through series resistors and placing a capacitor across the relay coil. Thus, the time required to charge the capacitor to the voltage at which the relay kicks in becomes controllable. Larger capacitors take longer to charge and also longer to discharge. Therefore, in order to make this type of circuit work for us both ways, a diode should be inserted between the capacitor and the coil. This will prevent discharge of the capacitors through the coil; also preventing a prolongation of the turn-off time. A fairly large resistor should be placed across the capacitor to help it loose its charge for the next switching cycle. This is a complicated circuit, to be sure, but it does offer one particular advantage. Switching delays are fixed regardless of the speed with which the talkback switch is operated.

It is recommended that the selection of relays for switching using capacitive-delay circuits be in favor of higher-voltage, more-sensitive d.c. relays. These require less power to operate and smaller capacitors to do the job. A circuit configuration is detailed in Figure 4.

Adjustment of the capacitors is dependent on the relays used. and on voltages and series resistors. The higher the voltage, the larger the series resistor, must be, and the smaller the capacitor required. However, it is recommended that the total time delay be kept to less that 0.5 seconds in one direction. Any-

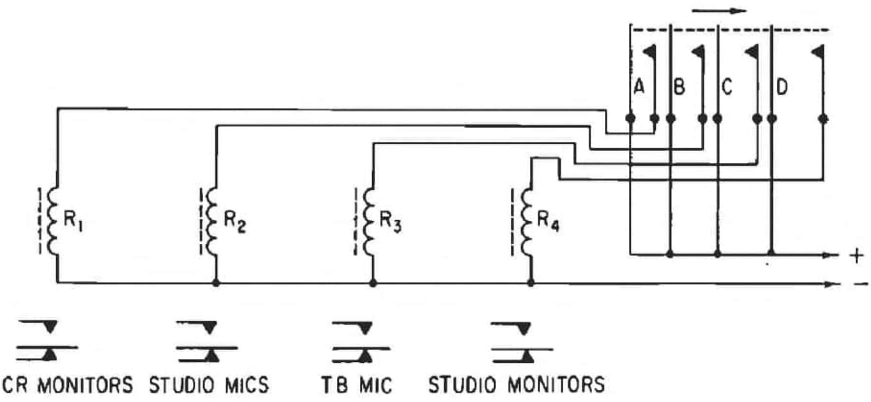

Figure 3. The sequencing of relays in a studio talkback system. In the illustration, note that the contact distances in sections A,B,C, and D are different, producing a switching sequence. Most lever keys can be so adjusted.

thing longer is likely to be objectionable because of sluggish response.

AMPLIFIER LOAD SWITCHING

Since talkback switching involves the selection of different monitor speakers in the control room or studio, special power switching will be required if economy dictates the use of one set of power amplifiers. Under this condition the amplifier outputs are being switched into different loads. It is important to remember that tube-type amplifiers must have a load across the output at all times when signal is present. Failure to do so may cause burnout of the output tubes and transformer.

The story is quite different with transistor amplifiers. Transistors are basically current amplifiers, not voltage drivers as tubes. Thus when we talk about loading properly as it relates to a transistor amplifier, we are not considering impedance matching. We *are* considering the power transfer to different impedances. The source impedance of a transistor may be on the order of hundredths of an ohm; however, best power transfer is achieved into impedances much higher than the source impedance. We may look upon the loading of a transistor amplifier as a bridging of the load across the output. Output voltage across the amplifier doesn't change. If there is no load, current just doesn't flow through the output transistors.

Obviously, this means that it is simpler and safer to switch transistor amplifier output loads than it is with tube amplifiers. With a tube amplifier we must use dummy loads, or switch with make-before-break contacts. The opposite is true for transistor amplifiers. Caution should be exercised to ensure that a transistor amplifier is not shorted or overloaded (even though most amplifiers are protected against damage from such conditions).

In the end the most desirable type of power circuit switching involves switching the *inputs* to the power amplifiers—something possible only in systems with separate monitor amplifier systems for control room and studio.

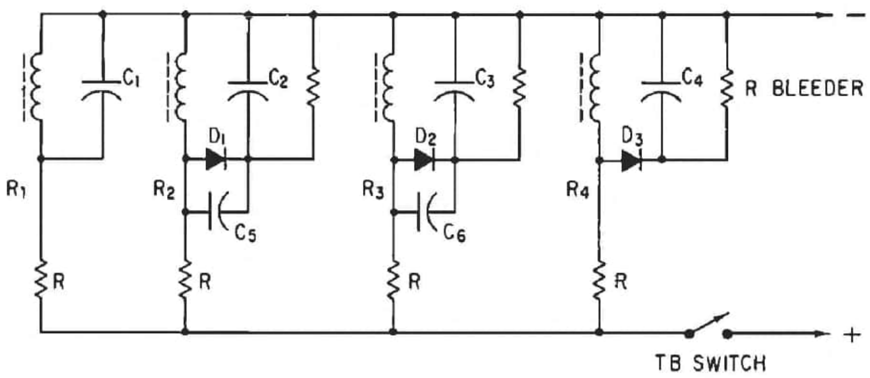

Figure 4. A relay-operating capacitive-delay circuit. In the circuit, R is the same in all cases, C_1 is the smallest and C_4 is the largest. The turn-on sequence is R_1, R_2, R_3, R_4. D_1, D_2, and D_3 prevent discharge through the coils of R_2, R_3, and R_4, but C_5 and C_6 delay turn-off enough to reverse the sequence with the same time constants: $C_1 < C_2 < C_3 < C_4$ $C_5 < C_6$.