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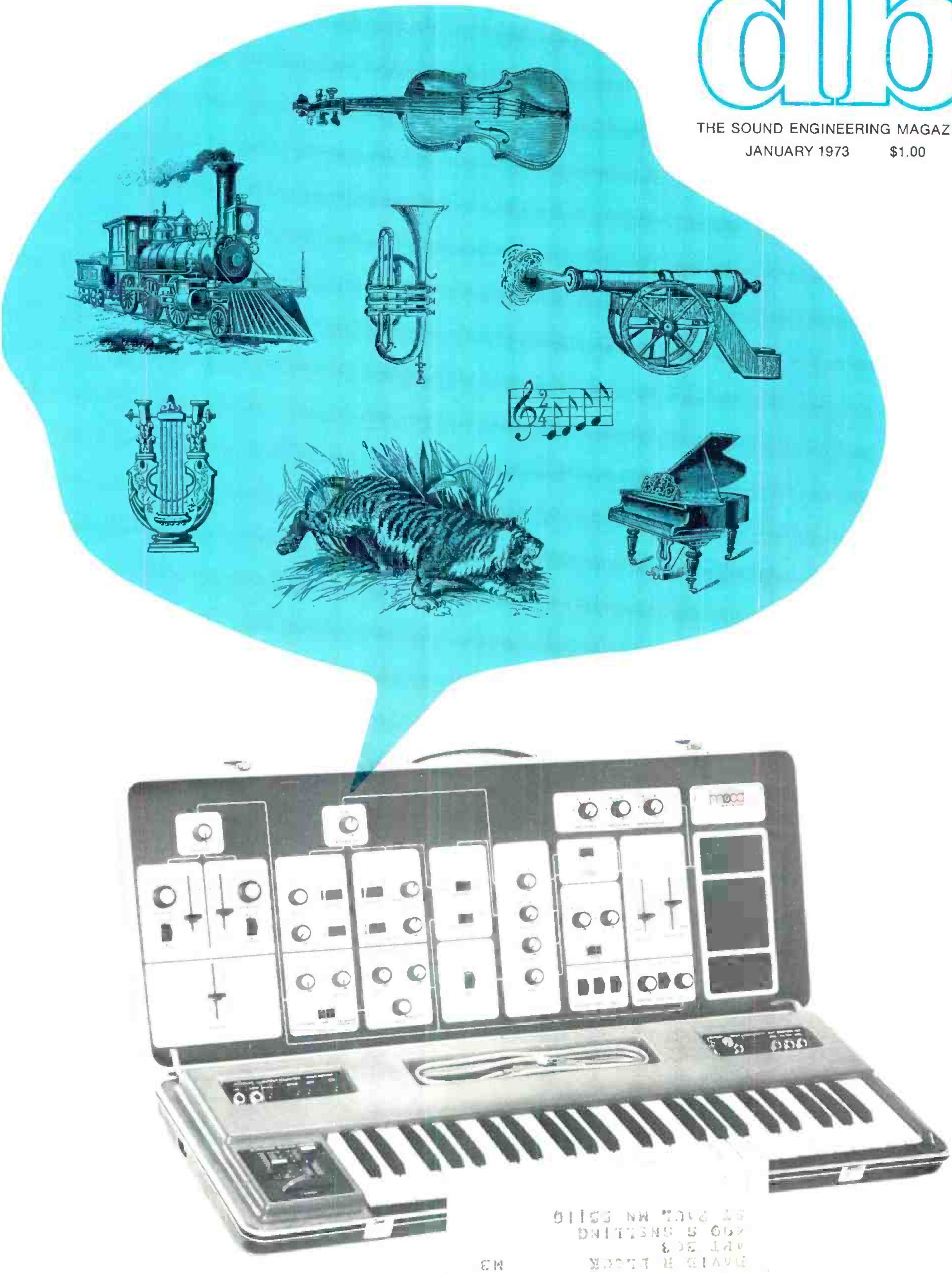
THE SOUND ENGINEERING MAGAZINE

JANUARY 1973 $1.00



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• Part one of special issues devoted to the problems of tape recording—machines, tapes, and the interfacing between these two components is next month.

Norman H. Crowhurst has prepared a look at where tape recording is today—from a manufacturer's view. He takes you quickly through the beginnings to the present, and peeks at the future.

Marvin Soloff of Maxell tape has come up with an interesting, useful, and sophisticated way to set up a professional machine so that it gets the best out of the modern tapes—anybody's—now in use.

And Steven Temmer has translated an article from the German, originally published in that country, that describes in detail the original thinking and execution that has gone into the A-80 multi-track Studers. There are lots of good closeup pictures.

And there will be our regular columnists: George Alexandrovich, Norman H. Crowhurst, Martin Dickstein, and John Woram. Coming in **db**, the Sound Engineering Magazine.

ABOUT THE COVER

• What could be more appropriate to Robert C. Ehle's ELECTRONIC MUSIC article beginning on page 22? It's a Moog.

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THE SOUND ENGINEERING MAGAZINE

JANUARY 1973 VOLUME 7, NUMBER 1

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letters

The Editor:

We are excited about what is going on in Indiana and we want everyone to know about it! In fact, there are three 1st class 16-track studios currently operating within a 50 mile radius and one of them even has a complete system of DBX/Dolby noise reduction as well as quadraphonic mixdown facilities. In short, for those of you who might have overlooked this territory in the past, the pro audio/recording scene is definitely on the move.

Yet there is another reason that prompts me to write this letter. For years I have had individuals call me and knock on the studio door wanting to know how they can become recording engineers or how to start a studio. For reasons that are related to the fantastic growth of the record business/communications industry, the current generation is really turned on to the "recording studio scene." Finally we offered a course last September in Recording Studio Techniques. Four days after I announced the plan we had a full house, all of whom were either students or instructors at Indiana University. Outsiders didn't even have a chance to enroll in the first seminar. Still the phone calls and letters have continued to come from many miles.

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Gilfoy Sound is currently undertaking a 2nd seminar. The "Studio Track" column in the September 13, 1973 issue of Billboard was very kind in giving us an accurate spread. Billboard pointed out that we had gotten considerable help and interest within the industry. Many individuals in the recording/audio business have realized that the current crop of students could well be the future studio musicians, producers and engineers as well as studio owners. Thus for the first seminar we were able to get brochures, catalogues, reprints and AV materials such as tapes, records, slide sets, films and even guest lectures from such as Ampex, Gotham Audio, Audio Distributors, JBL and ELPA Marketing.

Our current class has 30 students. Thus I will ask you to look around your office and see if you could spare 30 sets of anything that will be passed on to some bright young folks who are seriously interested in the workings of a recording studio, the equipment and the people who operate it. Can you think of a better way to get your message across to your future customers?

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George Alexandrovich

THE AUDIO ENGINEER'S HANDBOOK

Signal distribution methods

● The output of almost every audio system, be it a mixing console, tape machine, cart machine, turntable or telephone line inevitably winds up being fed into more than one channel. Console output usually feeds a program line monitor circuit patch bay, sometimes transmitter or telephone lines house a p.a. system and so on. Tape machines are quite often feeding or connected to several circuits at once—for example, a crossbar switcher. The same goes for cartridge machines and turntables. Telephone lines have to be treated somewhat differently because they are not simply loads for the signal source but signal can also be fed back through the same line—in this case the line is acting as a signal source. Interaction of the signal distributed and the signal coming back from the telephone line is an important point in a discussion about sound distribution.

There are many ways distribution of signal can be accomplished. The most simple and straightforward method using several separate amplifiers fed from the same source. This method offers excellent crosstalk isolation between the output channels and maximum reliability—but also is the most expensive.

The next simplest is the use of multiple taps of the single amplifier's output transformer for connecting several loads. Failure of the amplifier or a short circuit of a single line results in a shut down of the entire distribution circuit. In addition isolation between the lines is inadequate. This means that if impededance of one line changes for some reason (for instance, accidental double loading) then the output of the remaining lines will change too. In some cases, where only one 600 ohm line is being fed and the rest of the lines are bridging (10 k or higher) the effect of interaction between the lines is not so pronounced—but still exists. If the amplifier has no output transformer but is connected to the load through a decoupling capacitor, several loads can be connected across the output—providing the total load does not exceed the maximum permissible load for the amplifier. Additional isolation and safety can be achieved by providing isolation resistors in series with each feed. However, this produces side effects such as loss of level, change in line impedance, and possible loss of high frequencies.

However, lately we have become able to design into our systems transistorized amplifiers—some of them i.c. type operational amplifiers—which have an output impedance of several ohms, and in some cases fraction of an ohm. I have run into some engineers who were somewhat confused by this fact having worked all their lives with 600- or 150-ohm source impedances. The first thing that comes to their mind is how do I feed a 600-ohm line from the zero impedance source? In most cases you just

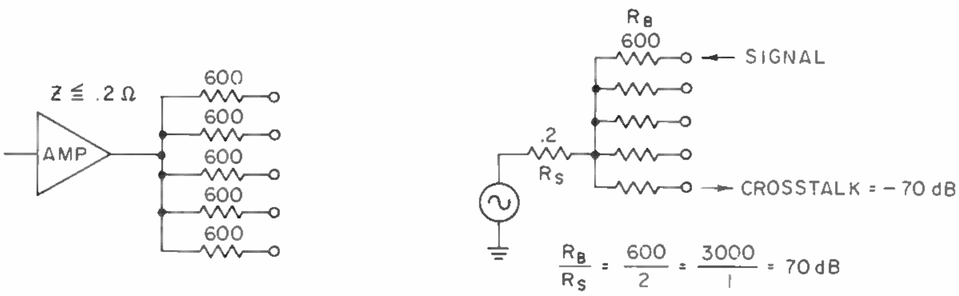

Figure 1. Signal distribution using the unbalanced output of a conventional class AB line amplifier.

connect it and forget about it. In some cases you have to think before you connect it. If the line can be fed from any source impedance—an amplifier, potentiometer, fader, or transformer—then interconnection is direct. If the load is a passive equalizer designed to work in a 600-ohm circuit then you have to provide impedance matching. This can be done simply by connecting a 600-ohm resistor between the amplifier and the equalizer. If you feed a telephone line (which is about 600 ohms) then a build-out resistor of 600 ohms is needed; and in the case of a dial line, d.c. decoupling because of voltage on the line.

Before we proceed, let us define required properties of the circuit to be used for signal distribution. First of all there should be adequate level at each output with enough headroom for peaks. Secondly, isolation between the lines must be such that if one line or several (or even all but one) are shorted the remaning line will continue functioning without affecting the level or the quality of the signal. Also, if signal is applied to any one of the lines it should not be detected in the remaining lines. With noise levels today being 70 or more dB below program level, it is desirable that crosstalk between the channels be as low as the noise level. Additional requirements are that all distribution channels have constant source impedance.

If someone is still thinking in terms of electron tubes this is a tall order, but if you are with it in transistors and operational amplifiers the outlined requirements are fairly simple to fulfill. Most of the class AB amplifier circuits with large amounts of negative feedback have output impedances of less than 1 ohm. This means that by using a build-out resistor of 600 ohms we are assured of at least 50 dB of isolation between channels. If source impedance is zero, then isolation will be infinite. In experimenting with the printed-circuit layouts I was able to produce not only zero source impedance but also negative impedance so that by connecting the load the output of the amplifier went up. Grounding of the different parts of the circuit produced this effect. By allowing different parts of the circuit to be grounded at different locations or moving the grounding point we can produce a practical zero source imdance.

But then a few other things may throw a monkey wrench into the gearworks. This can be the resistance of the output wire and the ohmic resistance of the contact (in the case of a plug-in p.c. board). We may adjust the amplifier impedance to be zero while the contact resistance may be 0.1 ohm. In order to achieve 70 dB of isolation, the common point resistance should be less than 0.2 ohms. FIGURE 1 and 2 show how a conventional amplifier and a combination of two such amplifiers can be arranged in a push-pull circuit producing balanced output without the use of transformers.

In the beginning we were talking

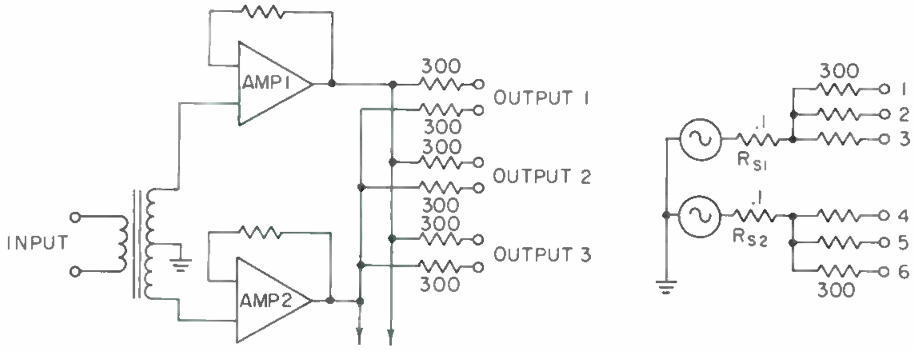

Figure. 2. A balanced output without transformers.

about the drawback of using a single amplifier and about the excessive crosstalk that one would get if the output impedance of the amplifier was anything but almost zero. In FIGURE 1, I am demonstrating the attenuation of the signal to be rejected in order to prevent the crosstalk. By combining two amplifiers a few things happen.

First we get balanced output. By adjusting the gains of each amplifier accurately we can achieve perfect a.c. balance. Secondly, output voltages of each amplifier add up, producing 6 dB higher output. This way amplifiers which individually produce about 20 dBm into 600 ohms, when combined add up to 26 dBm. This very nicely compensates for the 6 dB loss we encounter in the build-out resistors.

And, as a last bonus we increase the reliability of the system because even in the event of single amplifier failure the other can continue providing signal feed—although with 6 dB lower level.

It is suggested that amplifiers for such a distribution system should be small power amplifiers capable of sustaining loads of several ohms without losing output voltage. This sort of safety is nice to have to be able to supply many lines (total load of 8 ohms is equivalent to 150 six-hundred ohm lines) and as a safety feature. Sometimes in a large crossbar a switcher short may occur flipping all relays closed—or wrong patching can produce shorting of many lines.

The last consideration in the circuits of FIGURE 1 and 2 is use of transformers in addition to the build-out resistors. Sometimes, in order to provide d.c. isolation or change the output voltage, a transformer may be connected after the 600-ohms resistor. But the combined impedance of the windings and transformer losses may make it necessary to change the value of the build-out resistor until you read the impedance we were after across the secondary of the isolation transformer.

The circuits described offer several important advantages: distortion can be made extremely low (because no large power transformers are used), frequency response can be made extremely flat for the same reason, and the noise caused by magnetic fields is also minimized.

One of the most important things almost was forgotten—the whole distribution system can be packaged into space smaller than a pack of cigarettes. And most of the space will be occupied by capacitors, resistors, connectors, power supply, switches, controls—and not the amplifiers. ■

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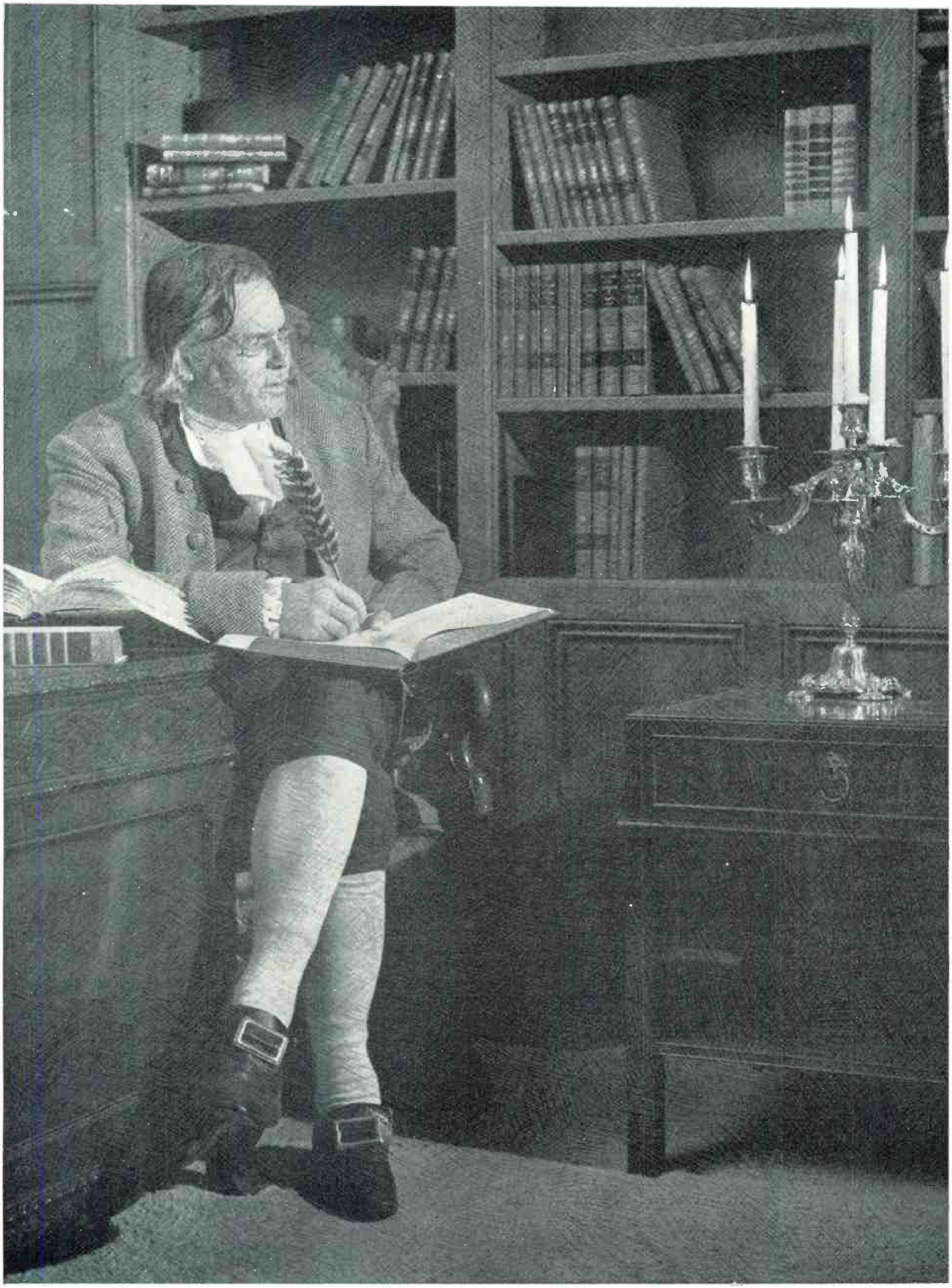

Mr. Webster enters a new word

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Norman H. Crowhurst

THEORY AND PRACTICE

• Technologically, we live in a rapidly changing world. This gets brought home to me when I get the periodic letter metaphorically out of the past, from someone who wants something explained about a piece of equipment made a few years ago. One such letter was from a man having problems with a tube-operated 'scope amplifier, the schematic for which is reproduced at FIGURE 1.

He wondered what function the triode using pins 6, 7, 8 of the 12AU7 served in the circuit. Fairly obviously, the 6, 7, 8 pins of the 12AX7 serve as a cathode follower (I almost wrote *emitter follower* from force of habit!) which serves the dual purpose of stepping up input impedance and ensuring that the input can handle wide swings before the control stage is reached.

But let's take a closer look. Did I say the cathode follower would raise the input impedance? As shown, that is fixed at 220 k. And as a 12AX7 has a grid base of about 3 volts or so, returning the 220 k to ground will "strangle" the tube, so it operates near cut-off. There were two good ways to operate the bias of a 12AX7. One would use a resistor of 5 to 10 meg from grid to cathode (FIGURE 2) relying on grid current biasing. The other would use a cathode bias resistor (FIGURE 3).

With either of the latter circuits, the cathode follower would provide a very high input impedance, and big swing handling capabilty. But, assuming the same cathode load and following gain control circuit of FIGURE 1 were used, just changing the bias arrangement, what is the working gain of the cathode follower, by which input impedance gets multiplied?

The plate load (connected in the cathode) will be 22 k in parallel with 13.5 k, which figures to about 9 k. Taking 80 k as an appropriate value of plate resistance, with an amplification factor of 100, this means the stage gain will be cut to about 10, multiplying the grid-to-cathode circuit resistance by about 10, to get the effective input impedance of the amplifier.

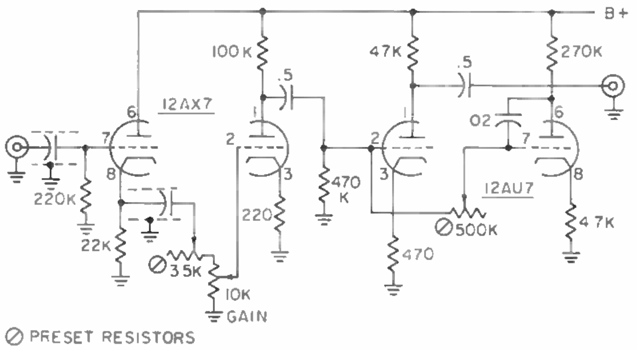
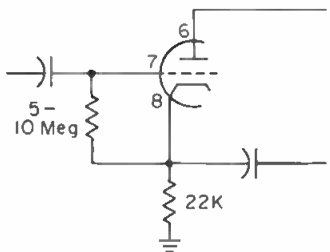


Figure 1. The schematic sent to me by a reader, of a 'scope amplifier.

A 12AX7 tube could provide a much higher gain and input impedance than that. However, it may be that values are kept low here, to maintain gain up into the megacycle region (in those days, no English-speaking designer had heard of mega*hertz*). What the 3.5 k preset was for is not exactly obvious, but it could have been a calibrate control, so the 10 k pot indicates some definite scale in volts/cm on the 'scope face.

Now we come to the reader's question. The 12AU7 triode, as anyone who has designed circuits to use it will know, is quite non-linear, although it

Figure 2. One way of biasing a 12AX7 input cathode follower.



New from Dolby

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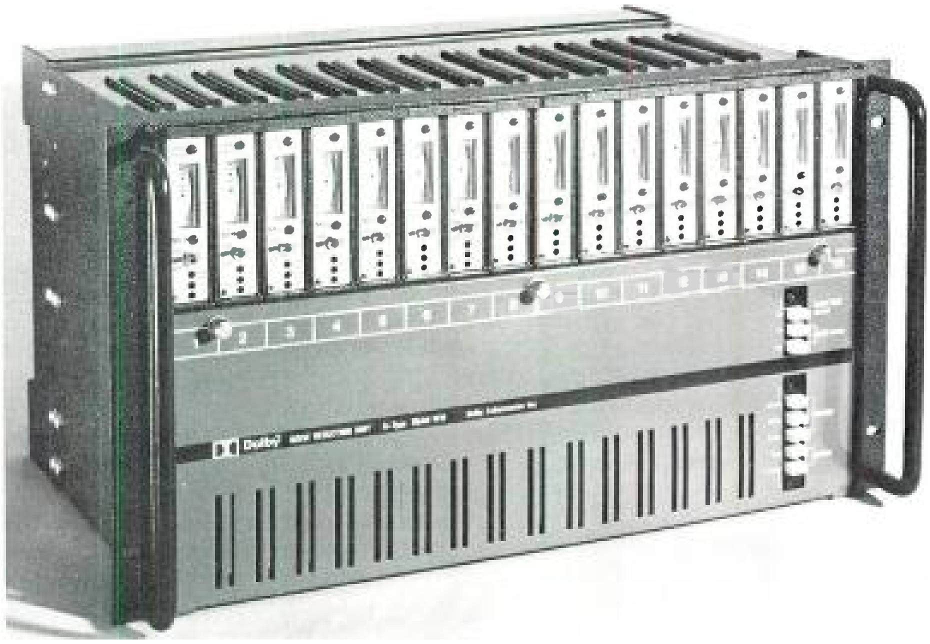

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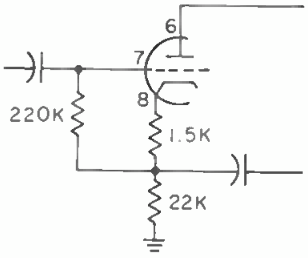


Figure 3. An alternative way of biasing the cathode follower.

handles the widest swing of any of that group of tubes. Better tubes came out later, but we will assume the designer was making best use of what was then available.

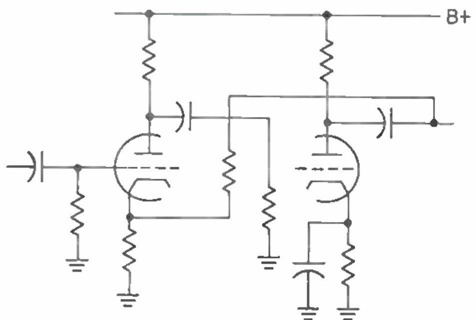
Here he is faced with a linearity problem. Of course, feedback, as a means of improving linearity had been known long before the 12AU7 tube was even designed. So why not use the two halves of the tube in cascade and use lashings of feedback (e.g. FIGURE 4)? If you struggle with design details, using a tube with as little stage gain as the 12AU7 has, you'll find out. Achieving stability, wide range frequency response, with enough feedback to produce satisfactory linearity is almost impossible.

So this designer evidently settled for using the gain of one half of the 12AU7 without feedback, and using the other half to correct the non-linearity of the first half. From my own design experience, I would imagine he could do better that way, and certainly without the stability problems.

Reverting to FIGURE 1, to explain how it works, the 12AU7 triode amplifies much more on positive-going grid signal than on negative-going. The linearizing part works by feeding back out-of-phase signal from its plate (pin 6) to its grid (pin 7). This has the effect of modifying the apparent value of the portion of the 500 k variable used, as a load at the grid (pin 2) of the amplifying stage. This loading modifies signal amplitude by virtue of the source impedance at the plate (pin 1) of the 12AX7.

The loading is also modified during the grid swing at pin 2 of the 12AU7,

Figure 4. A more obvious way of getting linearity, using two stages to get more gain, then applying negative feedback.



because of the similar swing delivered to pin 7 through the portion of the 500 k. When swing is positive, gain of the 6, 7, 8 portion increases, reducing the effective resistance value presented by the 500 k to pin 2, thus loading the signal more, when the gain increases. When the swing is negative, the reverse happens.

By adjusting the setting of the 500 k preset, quite good linearity can probably be obtained—better than likely by sacrificing an equivalent amount of gain in linear feedback.

Going over this turned my mind back to some work I did almost twenty years ago, but my memory of it was a bit vague, so I had to turn up the wording on that particular patent to remember just how it worked. The circuit, shown at FIGURE 5, was designed to be used as the output stage for a preamp.

In those days there were two camps: those who used matching transformers to match line impedance (usually 500 or 600 ohms) up to the plate load value required by the tube; and those who used cathode-follower outputs. Neither was altogether ideal. The transformer output had frequency response limited by the transformer, which could also change with loading, if the line impedance was not precisely 500 or 600 ohms, as specified. And the cathode follower, loaded with 500 or 600 ohms, which it matched, produced distortion.

The function of the circuit in FIGURE 5 was to offset the distortion produced by the cathode follower. The diode and resistor in series, shunting the grid-to-cathode resistor, did the same thing as the other triode (pins 6, 7, 8 of the 12AU7) in FIGURE 1. But it has a somewhat more complicated function.

If no matching load is connected, the cathode follower produces little distortion. Only when a 500 or 600 ohm load is connected does the stage distort seriously, and more the lower the load resistance value. The apparent impedance at the grid of the stage shown in FIGURE 5 is the impedance from grid to cathode, multiplied by the working gain of the stage.

This means that when the gain is high, because no matching load is connected, the impedance, of both the resistor from grid to cathode, and of the diode and resistor shunting it, is multiplied by a large number, and the shunting effect on the input source resistance (shown as a resistor in FIGURE 5, but the plate resistance of a previous stage in a practical circuit) is slight. Virtually no offsetting distortion occurs.

As the output is connected to a progressively lower load value, the work-

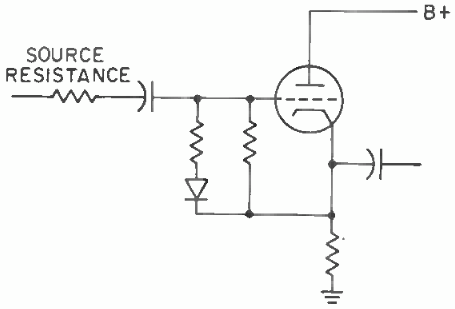


Figure 5. A revised form of cathode follower output stages, subject of an earlier patent by the author. This can keep distortion low over a wide range of output loading.

ing gain of the stage drops, so that the grid circuit values, as loads across the input source resistance, also drop. Thus the diode and its associated resistance produce more offsetting distortion, as the loading is changed so that more distortion occurs to be offset. By proper choice of values, distortion can be kept low over a wide range of load values.

Digging out that patent file brought back memories, as I thumbed through a whole bunch of documents, till I found the one I somewhat vaguely remembered. Each had its own little memory of solving a circuit problem. I had not realized there had been so many, because that part of the file had become a closed phase in my life. We left tubes behind when we moved into solid state.

And now we are moving quite a way from the early transistor circuits, as computer-designed integrated circuits take over more and more of the work. It's a changing world, indeed. The other side of my present activity combines with these memories to raise even larger problems.

In those days, we solved problems by applying our ingenuity directly to the physical phenomena and the mathematics that described them. Today, computers do all that, and more. Yet education, far from moving into step with these changed requirements, has the people who design math programs getting even further from reality than they were when I went through school. They seem to have a math world of their own, completely unconnected with the real world.

They are inventing all kinds of unrealistic things for kids to learn, that will never be of any use to them. And because those with practical minds, that could become the engineers and inventors of tomorrow, naturally shy away from these meaningless bits of garbage, they drop out, before ever they get far enough to think about meeting college entrance requirements. Where's it all going to end. ■

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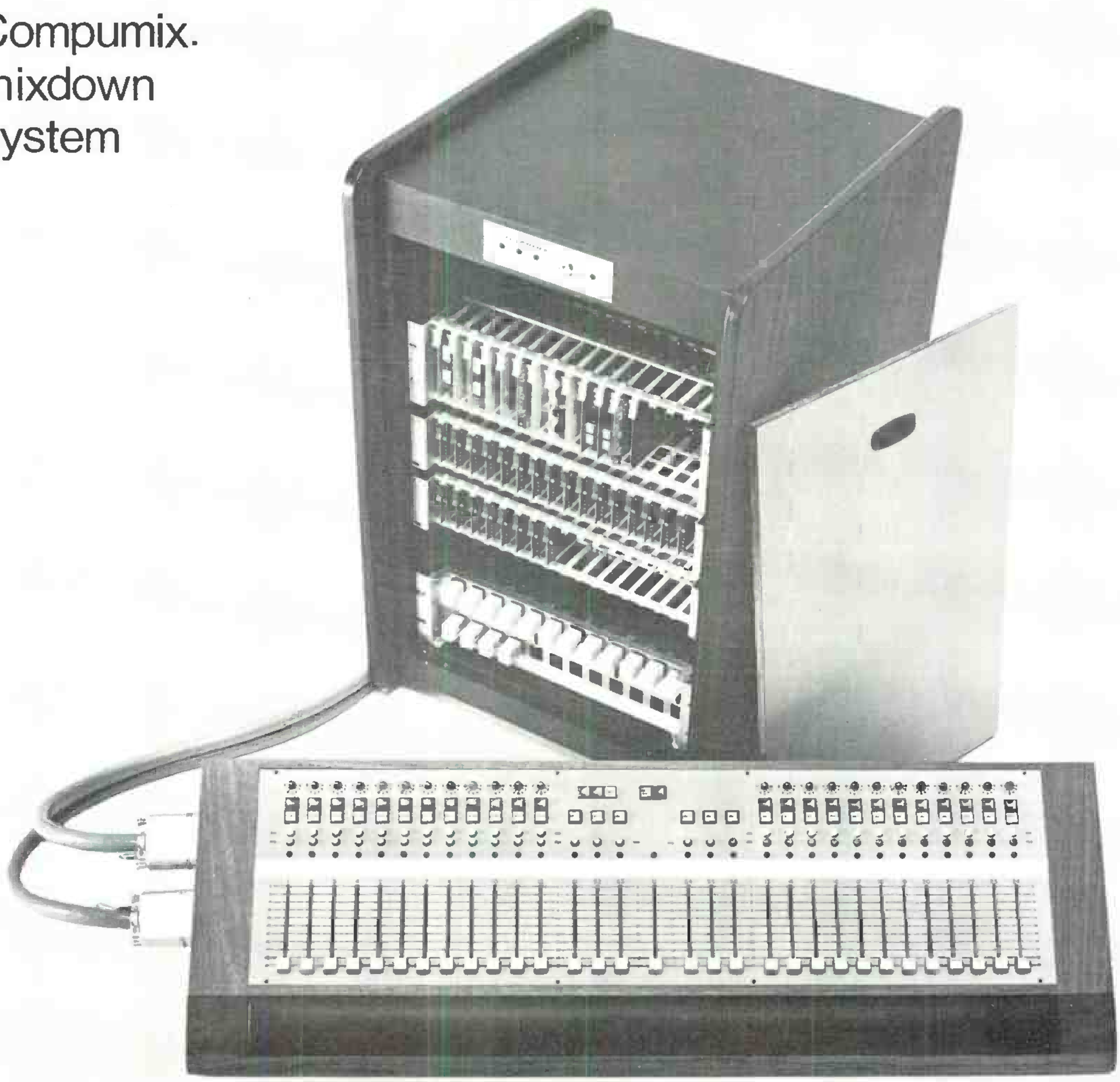

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Mfr: Crown International
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METAL REELS

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● The Stereo 400 is capable of delivering 200 watts continuous power per channel into an 8-ohm load, 300 watts per channel into 4 ohms, and 100 watts into 16 ohms. It can also be switched to provide a mono 600 watt output into 8 ohms, which can also directly drive a 70.7 volt distribution system. Safety circuits are built in with adjustable clamping of sustained overloads. There are switchable linear phase filters at 10 Hz and 15 kHz, a thermal cutout indicator lamp, individual input gain controls, heavy duty power switch, and individual load protection.
Mfr: Dynaco
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● Full side to side and front to back logic is employed in the SQD-2000 matrix decoder designed for SQ matrixed material. Complete audio control is offered, including movement of the quad field 180 degrees or front channel or rear channel reverse. Four meters indicate the audio level being monitored. Separate volume controls are provided for each channel as well as a master volume. Inputs and outputs are high level unbalanced, suitable for monitoring rooms or auditioning SQ quad encodings.
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● Announced as the first fully automatic portable flutter meter, the Model M-1 is also a sensitive audio voltmeter. A percentage demodulator permits extremely accurate measurements of flutter from carriers at any frequency between approximately 2 to 8 kHz. A 3 kHz oscillator is built in. There are no level or discriminator controls, filters are switchable, and there is built-in meter overload protection.
Mfr: Manko Instruments.
Price: $325
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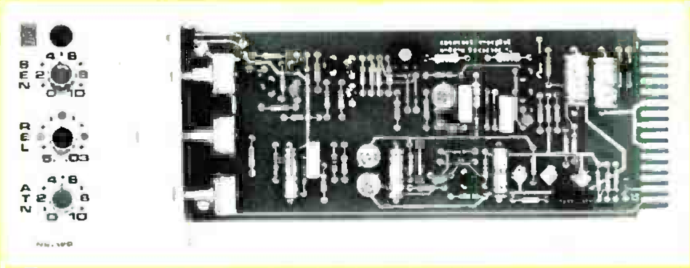

● Model NS-120 is a variable noise gate/suppressor designed for maximum flexibility in applications ranging from multi-track mixdown noise gating, to noise suppression for film dubbing and real-time background noise attenuation. A fast-acting all-electronic device uses no l.d.r units to achieve an attack time of less than 25 μsec. Release time is adjustable from 0.03 to 5 seconds and an attenuation range control permits a normal 0 dB to −50 range. A ±28 V d.c. bipolar power supply is recommended for maximum output of +24 dBm into 600 ohms. Sixteen channels can be mounted in one 3½ by 19 inch rack.

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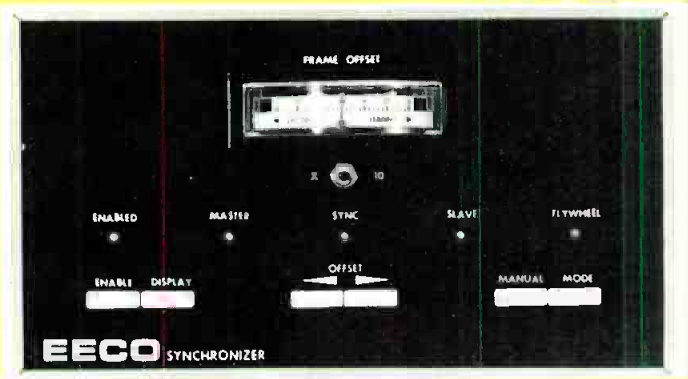

● Designed to syncronize an audio tape recorder to a quad or slant track video tape recorder—or to another audio tape recorder, the BE 450 keeps two mag tapes in frame to frame lock regardless of normal tape stretch or slippage. The unit compares identical SMPTE edit codes recorded on any two mag tapes, Providing the tapes are within 30 seconds of sync, the unit automatically adjusts control voltage to one of the recorders until tapes are in perfect sync. It then keeps the tapes in sync, or manually adjusted offset, in a frame to frame lock.

Mfr: EECO
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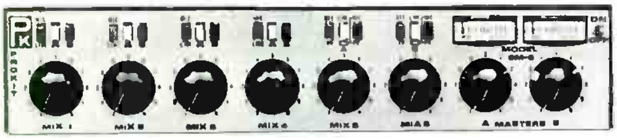

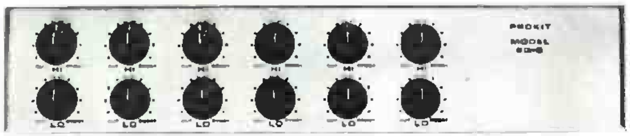

SLIDER POT

● A new conductive plastic linear motion attenuator has been designated the Series 220 Slideline. It has a 2¾ inch stroke, is completely interchangeable with earlier 200 series units, and most other attenuators of similar size. The conductive plastic element, called Resolon, is stated to be the same used in military precision pots and provides extended low noise life. It is offered in both single and dual channels having either linear or audio outputs. Housings and terminals are strengthened to withstand rough handling. Over-all dimensions are 4.25 by 1.15 inches.

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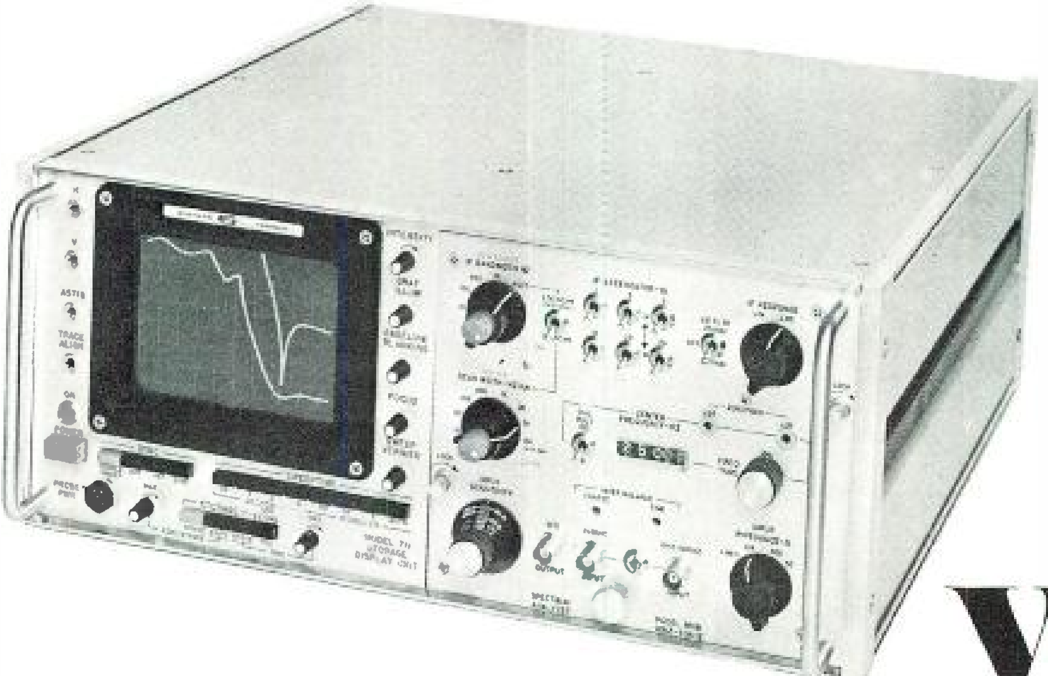

Display illustrated is the frequency response characteristic of a 20 Hz to 20 KHz filter from 10 Hz to 50 KHz over a 60 dB dynamic range. Waveform at right shows the resonance of the same filter with sensitivity increased 40 dB.

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ROBERT C. EHLE

What To Listen For in Electronic Music

If you have an occasion to work with electronic music but do not really understand composers or how they think, read this. It will help in communicating with the composer the next time electronic music must be devised to fit a commercial track.

. . . much new and unique apparatus has been devised for special purposes.

BROADLY SPEAKING, electronic music is any music involving electronics in its composition, performance or reproducton. Dedicated composers, however, mean anything but this general description by the term. They mean, specifically, that particular type of creative composition which they practice and which sounds idiomatically different from any music generated by non-electronic processes. Electronic music is, therefore, the modern example of a musical idiom resulting from technological progress.

THE ELECTRONIC IDIOM

In music theory we speak of certain periods in musical history as being primarily contrapuntal (e.g. the sixteenth century and the late Baroque periods), while others are homophonic or primarily chordally oriented (the Classical era and the Impressionistic periods). Some eras in musical history are characterized as modal (the Renaissance and the early twentieth century) while others are of a major-minor type in that they use the major and minor scales as the basis for musical composition (the Classical and Romantic periods are of this type). The music of some nations and ethnic groups is pentatonic, that is, based upon the five note scale equivalent to the black notes in one octave on the piano, while other nationalities employ six, eight or ten or more notes in their scales. All of these characteristics pertain to the idiom of a particular type of music.

Robert C. Ehle, PhD, is with the School of Music, University of Northern Colorado, Greeley, Colorado.

Serious composers have never failed to experiment with any new idioms coming to their notice, and so all the idioms originating in folk music have been explored in serious musical composition. A peculiar result of all this is that composers tend to develop trademarks. Scriabin had "his" mystic chord; Liszt liked augmented chords; Tchaikovsky used sequences. Bela Bartok developed the Hungarian folk idiom in his music while many American composers use jazz styles in their music. Each country has its own folk idiom composers and there are peculiar and distinctive characteristics in each national style. Throughout the history of music, composers have had their favorite chords, progressions or tricks which they made sufficiently famous so that anyone using them would be accused of plagiarism. Today, composers seeking new idioms will try anything to avoid this accusation. Thus we come to the style of electronic music.

So far, the idiom of electronic music seems to be going in the direction of new timbre generation and control. This is perhaps to be expected, since it is in this area that so much new territory exists. Conventional acoustical music is performed on instruments obeying natural acoustical laws. These laws, having never been broken, are the foundation of conventional music. Now electronic instruments have been designed which can violate acoustical laws and generate sounds never heard in nature. These sounds are usually unique in their timbre or overtone structure; it is probably for this reason that composers, seeking the new as they are inclined to do, have made electronic music an idiom of new timbres. A second aspect of electronic music is its control of time. This music may be constructed in such a way that it does not depend on a performer's sense of time. For this reason, extremely com-

Serious composers have never failed to experiment with any new idioms coming to their notice . . .

plex temporal patterns and rhythms may be generated electronically.

To sum up, the idiom of electronic music, as it is currently being practiced, is the exploitation of a wide variety of new timbres in an extremely elaborate time-sequencing arrangement. On the other hand, there is little harmony and melody and not a great deal of counterpoint (as one usually defines the term) in the majority of examples.

EXPRESSION AND INTERPRETATION

As there is normally no interpreter of an electronic composer's music this task falls on the composer himself. In fact, the music which originates in the composer's imagination undergoes interpretation as he attempts to generate it with his equipment. The power of his music depends both on the power of his imagination and his skill in generating what he wants from his equipment. This is not to say that he will not be open to suggestion from random or accidentally generated sounds but, if he is honest with himself, he will insist on digesting all such sounds mentally before designing the situation in which they might be used. The electronic music composer is confronted with a situation where he may control his music to a greater degree than any previous music.

In the matter of expression, each composer finds his own aesthetics and techniques. However, because of the idiom natural to electronic music, certain types of expression are common. In the first place, there are no necessarily discrete instruments in electronic music. Sounds of one color may gradually and continuously be transformed into any others with no audible breaks between them. As a result, expression in electronic music often is a result of a series of continuous, overlapping changes and the music resembles a mobile which rotates and changes gradually but which makes no sudden disruptions of its basic nature. With such a context, a sudden and abrupt halt or shift is a strong dramatic device usable occasionally as an element of surprise.

A second approach is just the opposite to that described above. Here change is abrupt and frequent. This is a style derived and extended from the serialists and the pointillists. If any sound should have any length or continuity to it, the effect is a contract to the normally short, fragmented texture. This technique is also characteristic of electronic music particularly because of the ease with which it may be assembled through tape splicing and editing techniques.

Electronic composers often seem to treat their material as if it were solid, having texture and substance. There is a definite relationship between electronic music and the various graphic arts which concern themselves with texture, shape, intensity, design, pattern, etc., as the primary elements, as is particularly true of abstract painting and decorative sculpture and design. In each case, the object presented for contemplation is not an easily recognizable object but a pattern of materials in which the relationship is all important. Electronic music, of course, has that same characteristic of all music—the temporal distribution of its elements. Music develops in time, just as do all human experiences; this is perhaps one reason why it is capable of carrying such emotional power. The patterns of music are able to mock the patterns of human emotion. Such musical terms as crescendo, diminuendo, recapitulation, development, sotto voce, pesante, etc., describe situations in life as well as in music. Electronic music is able to simulate human emotions in some new ways as well as those common to conventional music.

The musical collage is one result of a new way of duplicating human emotion. Here scraps and snippets of the most diverse aural materials are presented in juxtaposition in such a way as to make the listener aware of large scale relationships. The materials for such a work may be gathered by tape recorder and assembled through editing and splicing methods. In musical (or non-musical) material recorded live and then altered (often referred to as *music concrete*), the composer tries to show his virtuosity in manipulation and in the novel ways in which he arranges his material. It is important to note that the composer may seek and achieve negative (usually for the sake of social protest) effects. A listener, not in sympathy with such a protest, may object and question the validity of such work.

In summary, if the primary stylistic idiom of electronic music is the exploitation of new timbres and rhythmic patterns, the primary modes of expression derive either from continuously varying textures with occasional abrupt changes or from continuous change of the pointillistic type with interspersed moments of respite.

THE APPARATUS

Much of the apparatus used for electronic music is familiar audio equipment such as amplifiers, tape recorders, oscillators, speakers, and so forth. On the other hand, much new and unique apparatus has been devised for special purposes. One interesting observation is that nearly any electronic technique applied to the generation of audio signals may have strikingly fresh qualities. For example, electronic music has employed both frequency and amplitude modulation, waveform clipping, single-sideband suppressed-carrier techniques, resonant and non-resonant filtering, pulse-width modulation, and a host of others not so easily described. Some special audio equipment used includes variable-speed tape recorders, multi-channel amplifiers and speakers, and a great multitude of filters including very narrow-band types and tracking filters. The well-known but little-used theremin employs the principal of the beat-frequency-oscillator commonly found in communications receivers. Reverberation devices are much used and many techniques have been devised including the sheet-metal reverberator, the spring unit, and the new electrostatic reverberation unit. Multi-channel tape recorders, developed for telemetry applications have found use in systems of up to fourteen channels.

THE COMPLEX TONE

The concept of the complex tone is an interesting one and is truly a part of the electronic style. It must be understood to be distinctly different from the simple tones such as the sine, square, and triangular. It is also different in nature from the harmonic tones produced by conventional instruments and from combinations of harmonic tones (chords). The sine, square, sawtooth, and other fundamental tones have a fundamental and, in all cases except the sine, regular overtone structures; harmonic tones from conventional instruments have individual harmonic arrangements (or nearly harmonic, as in the case of the piano). The nearest thing to the complex tone in conventional music is the type of semi-pitched percussive tone produced by chimes, tympani, etc. These instruments, however, normally have attacks and short envelopes in standard practice. Electronically produced complex tone may be made to have any envelope.

Basically, the complex tone is a modulation product of two or more simple or harmonic tones. Therefore it con-

. . . electronic instruments have been designed which can violate acoustical laws . . .

. . . there is little harmony and melody and not a great deal of counterpoint . . .

tains them both and/or sums and differences of both. The variety of complex tones is extremely wide. No one has even begun to categorize the various types and the surface has only been scratched in their application in electronic music. Certain basic categories may be made according to the type of modulator employed in the generation process: unbalanced, balanced, ring, frequency, amplitude, phase, etc. Other categories may depend on the number of input tones and their individual complexities.

Although already used on occasion, there is, however, a dimension to the complex tone so far generally overlooked. This is its continuous variability. The electronically-generated complex tone is an array of mathematically related frequencies in which certain sets of frequencies may be varied at will. Thus, chameleon like, the complex tone may be made to shift its structure gradually. This yields the possibility of a continuous music without breaks or notes but simply a continually changing structure.

CONTROLS

Along with a discussion of the complex tone must go a discussion of the method available for controlling a musical instrument. Basically, there are four types of controls: the linear access switching array; the random access switching array; linear access linear controllers; and random access linear controllers.

Of the familiar instruments, the piano has a random access switching array (the keyboard) for frequency control; the trombone on the other hand is linear access linear controlled. Most woodwind instruments are random access switched and, in fact, this has been the most popular method for controlling a musical instrument's pitch or frequency with the linear control approach popular in string instruments. Linear access controls are those which must be operated in an incremental fashion; that is, the operator must pass through all intervening points when passing from one point to another. In a random access controller, the operator may move directly to any desired point without passing through other points. In the other aspect of the controller-type definitions, linear controllers have infinite resolution (analog) while switching arrays have predetermined steps (digital).

Although frequency is well controlled in conventional musical instruments, most of the other parameters of a musical tone are nearly uncontrollable. Here electronic music shines, for it has controls for every known parameter of a musical tone. These controls may be any of the above four types but, by far, the most popular is the linear access, linear controller better known as the potentiometer or *pot*. We have pots which vary attack time, decay time, all aspects of tone color, modulation levels, reverberation, and even frequency. This is a very important part of the current electronic music style simply because this very plentitude of pots for so many functions determines its basic characteristics.

And so the new electronic music composer must learn that he can vary many parameters; he must listen to the effects of such variation and decide what he can do with these new techniques. If he is left unaware of this area he will miss an important aspect of electronic music, and he won't gain this knowledge except from electronic music composers in the laboratory. This is one of the electronic music composition teacher's responsibilities.

It is quite possible to compose a piece of music with no abrupt breaks of any sort but only linearly varied parameters of the sort controllable with the potentiometer. Here is a style derived directly from the unique capabilities of electronic techniques.

. . . Electronic composers often seem to treat their material as if it were solid . . .

SCALES AND INTONATION

Ever since the dark ages, our western music has made use of portions of the twelve note chromatic scale or variations of it with regard to tuning procedures. It has served us well, for we have had ten plus centuries of music from it. However, is it really the only usable scale? Composers have often asked this question and some have gone to the extremes of building new instruments for experiments with other scales. Now, with electronic music, every music student may try the experiments for himself. Every serious contemporary composer should have the experience of sitting down at an instrument tuned in nineteen or thirty-one tone equal temperament, or perhaps a forty-three tone non-tempered scale. An hour of improvising at such an instrument may open his ears, so to speak, and so change the course of music. The interested theorist may want to refer to Joseph Yasser's *Theory of Evolving Tonality* or Harry Partch's *Genesis of a Music* for work involving new scales. There are many untried possibilities.

New scales and no scale, both are characteristics of the emerging electronic music style. Both need to be studied, listened to, practiced and taught.

AESTHETIC ORIENTATION OF ELECTRONIC MUSIC

Music in general may be thought of as a type of interaction between musicians, musical instruments, and listeners. As such, each of these elements will affect the style of the resulting music. So far, we have discussed the effects on style resulting from the first two of these. Finally the effect on the style of electronic music due to the listener must be taken into account. This means a discussion of the effects on style due to intended applications of music.

Part of the transition from conventional to electronic music has been, for many composers, the utilization of one or more compromises involving mixtures of techniques as previously described. On the other hand, pure and absolute music composed electronically, undeniably, is no compromise. It is, as we have discussed, unfettered by necessities common in conventional music (although it may introduce new necessities, peculiar to itself). Thus, due to its nature, it is more useful and acceptable in some forms than others. It seems to be most usable in those forms involving electronic distribution: radio, television, phonograph records and motion pictures. It is also at home where no visible performer is required to occupy the visual attention of the listeners as is the case in ballet, and theatrical productions. Eventually, we might have fully developed electronic concert instruments which overcome the many present limitations, thus allowing electronic concert music to become a reality.

Today, however, electronic music is a very abstract art; this is due to two facts: first the general absence of a visible performer, and second the newness and unfamiliar nature of much of it. Thus, electronic compositions are art objects, comprehensible either in themselves or through the words written about them but lacking much of the social conventions of traditional music. In this respect it has much in common with art and in particular the abstract art of the twentieth century. I think that composers sense this similarity and respond with a style of composition noticeably more abstract and complete in itself than they would employ for traditional music.

This means that electronic music, abstract as it is, must be more complete in itself than conventional music. It must be able to explain itself and complete itself. It can-

. . . the piano has a random access switching array . . . the trombone . . . is linear access linear controlled.

not depend on successive interpretations or bravura performances to compensate for intrinsic deficiencies. For this reason, composers must pay more attention to form and structure and many are doing so. As a result it may be more complex; remember, repeated hearings of the works intended and simple by electronic means (this has not always been the case). Also, electronic music should be expected to yield more on repeated hearings and to hold interest for a very long time as a result.

To sum up, electronic music is generally abstract and serious in style. It is probably intended more for individuals than for the masses and lends itself easily to economical distribution to interested individuals on a widespread basis.

SUMMARY

The style of electronic music is influenced by three factors: The capabilities of available instruments; the knowledge, skill and intentions of the composers; and the intended audience or application and the method of distribution.

Electronic music instruments are capable of a wide range of new tone colors, new scales, and rhythms. They are also capable of many new types of control over conventional instruments.

Electronic music composers are learning of the new freedoms as well as the new disciplines required of them by the medium; they are beginning to be aware of ways to teach these things to their students. Much remains to be done here.

Electronic music audiences are small but dedicated. They expect serious work and, thanks to the relative economics of electronic recording and broadcasting techniques, are able to get what they want. Probably ninety-nine per cent of the contact between listeners and electronic music is through phonograph records.

Electronic music is abstract and relatively "pure" as an art form. A comment by the noted conductor Antal Dorati on the subject is significant. Mr. Dorati suggested that electronic music may be part of "a new art of sound, still called music for want of a better term."

The significance of this remark is to emphasize the difference in all respects excect the use of sound between conventional and electronic music. Electronic music is not just a new technique but a new style, and even a new music.

Today, electronic music has become a satisfying mode of exploration and expression. Its effects are widespread in the educational institutions and many newcomers are added to its ranks each year for the reasons given previously. Although the popularity of electronic music as a listening entertainment is still low, this is compensated for by the large number of practitioners who are able to get a creative satisfaction from manipulation of both commercial and hand-made equipment. In addition, the research into the physics and psychology of music being done makes it a valuable addition to the realm of knowledge. Being only about as old as the tape recorder, it is already proving its significance and we can expect much in the future as greater skill is gained in its use. ■

WALTER JUNG

Optimizing Op-Amp Speed

ONE OF THE BIGGEST PROBLEMS associated with popular general purpose integrated circuit op amps such as the 709, 741, and the 301A has been their speed (or lack thereof). This may not be so obvious the first time you look over a data sheet, but will quickly hit you right in the face the first time you try to get a +20 dBm signal at 20 kHz through a 741. There are of course, readily measurable parameters which determine an op-amp's high frequency behaviour—in some cases these are under our control, in others they are not. But a sound understanding of the "whys" behind all of this is a prerequisite to achieving good high frequency performance from the attractively priced i.c. op amps. It can be done, so let's look into how we go about it.

There are two key parameters which directly affect the usable high-frequency response of an operational amplifier. They are its *slew rate* and *gain-bandwidth product.* Slew rate is the maximum rate of change of the output voltage under large signal conditions. Here large signal means a voltage swing at or near the i.c.'s specified maximum, generally 20 V p-p or more. It is commonly specified in *volts per microsecond.* Slew rate is directly related to the full power bandwidth according to the relationship

$$Sr = 2\pi Eo\ Fp$$

where
Sr=Slew rate
Eo=Maximum output before slew rate limiting (peak)
Fp=Full power bandwidth

Graphically, this may be understood by referring to FIGURE 1, which is a plot of large signal response versus frequency. Note that curve number 1 (which is typical for a 741 amplifier) begins to slew rate limit at 10 kHz, and at 20 kHz available output is reduced to half of the full power available at low frequencies. To deliver a 10 volt peak signal at 20 kHz we can compute the slew rate required as:

$$Sr = (6.28)\ (10)\ (2x10^4)$$
$$= (1.256x10^6)\ (volt)\ (hertz)\ or$$
$$= 1.256x10^6\ v/s = 1.256\ V/\mu s$$

This 1.256 volts per microsecond slew rate is a minimum requirement. In practice the circuit should have a working slew rate in excess of this figure to prevent rise of distortion at the onset of the rate limiting.

The second key parameter is the circuit's gain-bandwidth products—this is also called the *unity gain frequency.* This is the frequency at which the circuits natural open loop gain has fallen to 1, or 0 dB. For general purpose i.c. op amps (such as the 709, 741, and 301A) compensated for unity gain, this figure is approximately 1 MHz. The plot depicting this gain is shown by curve 1 of FIGURE 2. The corresponding amplifier connections which will display this response characteristic are shown in the inset. Although a complete discussion of frequency compensation techniques and stability criteria are beyond the aim of this article, the basic facts should be pointed out. In a feedback amplifier configuration a prerequisite for closed loop stability is the rate of rolloff of the response curve where it crosses the closed loop gain level. For a 20 dB per decade (6 dB per octave) rolloff as shown, the phase shift associated with this response is 90 degrees which cannot result in oscillation, even under the worst-case condition of unity gain. This necessary ingredient for closed-loop stability in operational amplifier circuitry is what led to the general purpose internally compensated i.c. op amps such as the 741. In a similar manner the 301A with a 30 pF compensation capacitor will yield identical results, as will the ubiquitous 709 with its three compensation components.

Now the above states what is necessary for stability under unity-gain closed-loop conditions. Does everyone operate 741's at unity gain? Hardly—and look what a penalty you pay in bandwidth and slew rate when you use a 741 or other op-amp compensated for unity gain at higher gains.

This curve we have been discussing is of course, the small signal response of the amplifier. At any closed loop gain you will get no more bandwidth than there is available from the device at the point where the closed loop gain intersects the open loop curve. Check a few examples from curve 1 of FIGURE 2 to appreciate this. At 20 dB gain, bandwidth is 100 kHz—fine. But look at the 40 dB gain situation. Here you have only 10 kHz of bandwidth, harly hi-fidelity response, and above 5 kHz you have very little feedback to lower distortion and output impedance. You will be operating essentially open loop at these frequencies, and in essence do not even have a feedback amplifier at all!

But back up a moment and consider what was said about the compensation necessary for a particular gain level. For stability the open loop rolloff should be 6 dB per octave where it crosses the closed-loop gain level. It does not matter if it undergoes another phase shift beyond this point, because the additional phase shift cannot cause an oscillation because of insufficient gain around the loop at this frequency. What does this mean? It means we can *lighten up* the compensation for the higher closed-loop gains and still have adequate stability. And the biggest thing it buys for us is additional bandwidth and an improved slew rate.

The bandwidth you may appreciate by regarding curve 2 of FIGURE 2. This is the open-loop response of a 301A or 709 compensated as shown in the corresponding inset. Now look at the 40 dB gain curve and where it intersects the open loop response—at 100 kHz rather than 10 kHz—a full decade more of frequency response and a 10 times improvement in distortion reduction from 100 Hz to 10 kHz. The point we are making here is that to take full advantage of an op-amp's capabilities you should compensate it to suit the particular application.

Compensation also directly affects slew rate, as you

Walter Jung is a frequent contributor to db.

may have already guessed. The slew-rate limiting is actually caused by the op-amp circuits inability to charge and discharge the compensation capacitance at high frequencies and high voltage swings. This leads to a "triangulation" effect where a sine-wave output gradually turns into triangular waveform as the amplifier crosses into its slew-rate limited region. The solution to this problem is to either reduce the compensation capacitance or increase the current(s) available to charge and discharge it—or, alternately, use some means to bypass the capacitance charging problem. All of these techniques work, and several practical circuits exploiting then will now be explored.

First, consider the case of general-purpose amps, the 709, 741, and the 301A. The 741 is inflexible as far as extending its h.f. performance goes, and cannot be considered for the applications we have been discussing. The situation is quite different with the 709 and 301A, however, and they can be quite useful in a variety of high-speed hookups. For instance in closed-loop gain configurations of 20 dB or more, both the 709 and 301A have slew rates approaching 3-5 volts per microsecond when compensated as per curve 2 of FIGURE 2. And at higher gains, slewing rate will improve proportionally as long as the minimum compensation necessary to stabilize the loop is used.

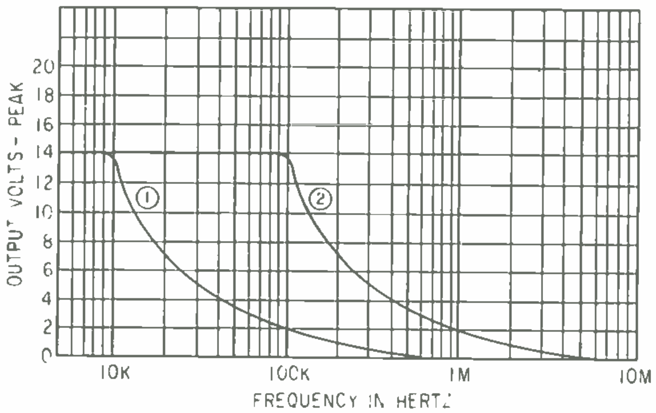


Figure 1. Large signal response of general purpose op amps with various compensation conditions. Curve 1 is typical for 741 and 301A compensated for unity gain. Curve 2 is typical for 301A compensated for 20 dB gain as in Figure 2, box B.

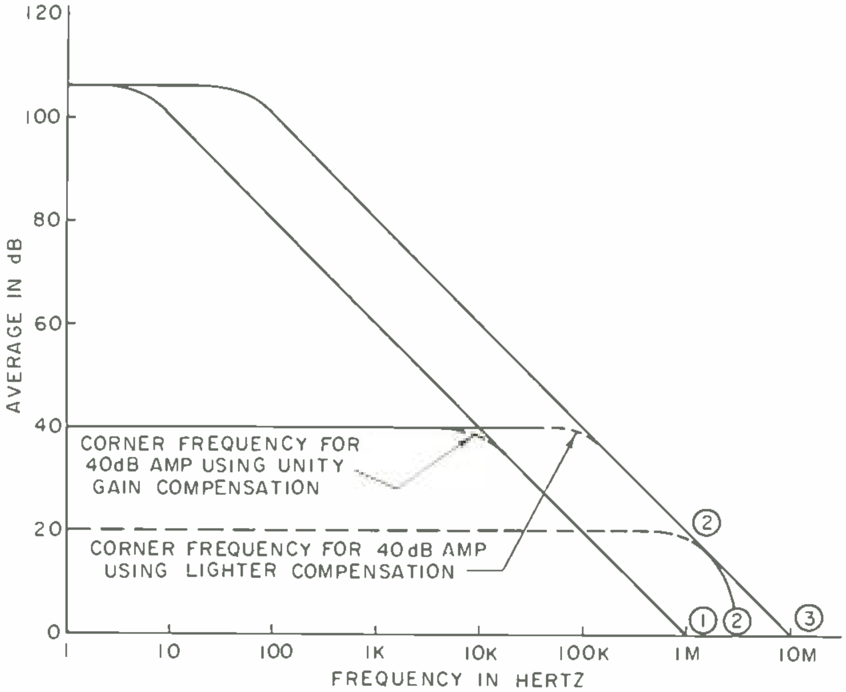
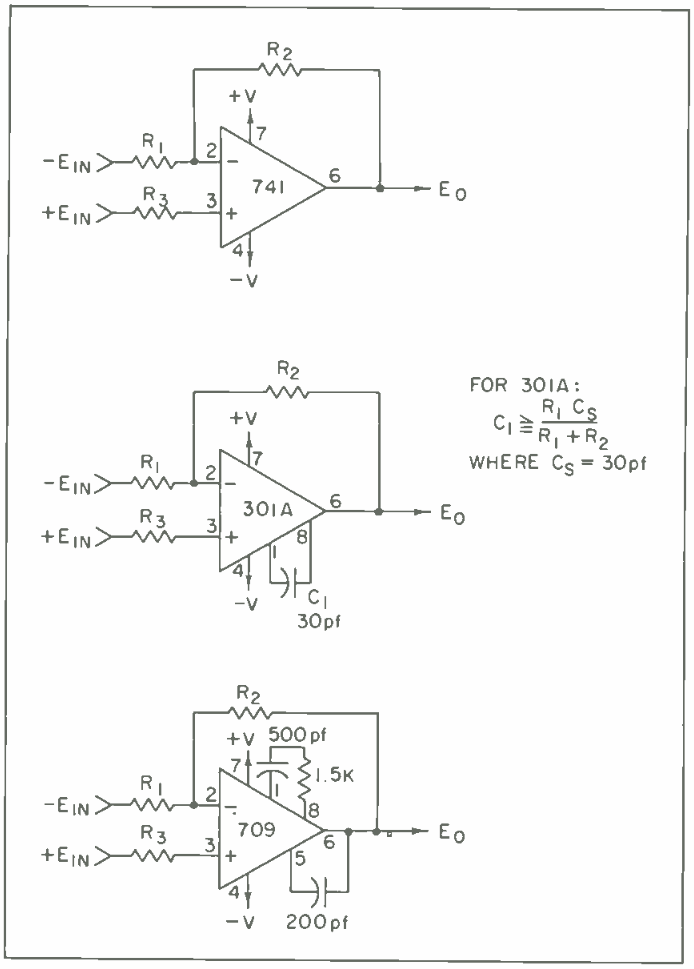
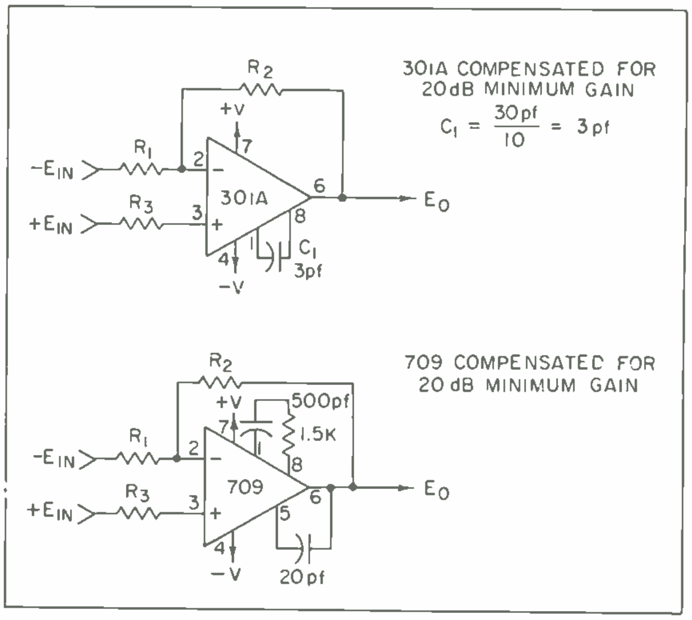


Figure 2. Unity gain frequency.



Box A. Standard unity gain compensation for general purpose op amps which results in open loop response as shown in curve number 1.

Box B. Externally compensated op amps. Compenated to produce the open loop response of curve number 2.



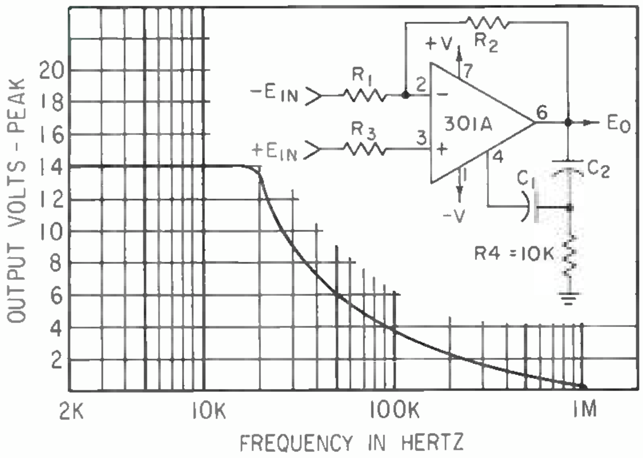


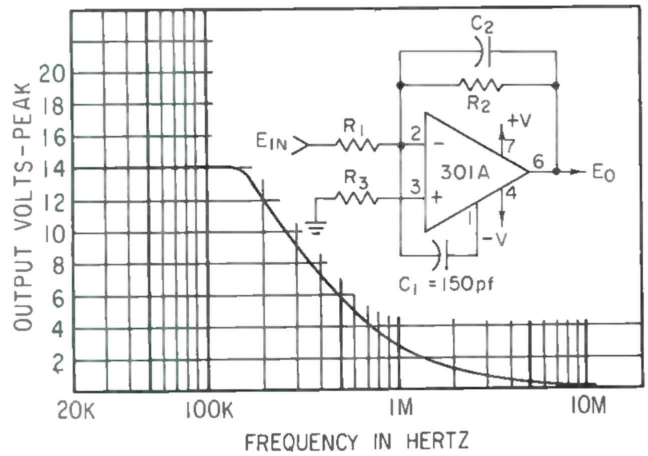
Figure 3. Large signal response of a 301A with fast compensation. (See reference 1.) $C1 \geq \frac{R1\ Cs}{R1+R2}$*;* $Cs=30$ *pF;* $C2=10\ C1$*. Typical values:* $C1=30$ *pF,* $C2=300$ *pF.*

There are other approaches to slew-rate improvement, perhaps more sophisticated in concept, but no more complicated in practice.

The first trick is a two-pole compensation[1] method used with the 301A to extend its power bandwidth by a factor of two or more. This circuit is shown in FIGURE 3 with the resultant power bandwidth. It should be noted that this is a general purpose circuit which can be used either differentially, as an inverter, or as a follower. It offers advantages at lower closed loop gains (between 1 and 10) where the additional compensation necessary normally limits slew rate. At gains beyond 10, the minimum standard compensation technique is both faster and more simple.

A big leap forward in slewing rate may be accomplished with the 301A by applying feed-forward compensation[2]. This technique, shown in FIGURE 4 with the resultant full power response, is the fastest of all the techniques applicable to the general purpose op-amps. It extends the unity gain bandwidth to 10 mHz and raises slew rate to 10V/μs. Its chief disadvantage is that it is limited to the inverting configuration as shown. As may be noted from the open-loop gain curve (number 3 of FIGURE 2), the circuits prime advantage is a dramatic increase in available high-frequency gain. Curve 3, the feed-forward response provides a bandwidth equivalent to the 20 dB compensation of curve 2, even though operating at unity gain. So where an inverting configuration is used and good high-frequency response is necessary the feed-forward technique is an excellent choice as it makes maximum use of available amplifier bandwidth, with only one additional component beyond the standard compensation hookup.

Figure 4. Large signal response of a 301A with feed-forward compensation as in Reference 2. $C2=\frac{1}{2\pi f_o\ R2}$ *where* $f_o=3$ *MHz. Typical values:* $R2=R1=30$ *k,* $C2=3$ *pF.*



It was mentioned that slew rate may also be extended by increasing the current available to charge and discharge the compensation capacitor. This is perhaps the most direct approach to the problem, and when properly executed, allows the large signal bandwidth to approach the small signal bandwidth. There was a drawback to the approach however, as it required a redesign of the basic op amp, as the bias current in both the 741 and 301A op amps is fixed by design. The i.c. which solved the slew rate problem by virtue of a new class B input stage is the Signetics 531[3,4] a fast slewing general purpose op-amp with small signal and d.c. characteristic similar to the 741. It also features the same pin arrangement and similar d.c. operating characteristics, thus making it an equivalent substitute in other senses. The 531 is capable of slew rates of 30/μsec in the worst-case unity-gain follower condition, and even faster response at higher gains with appropriately smaller compensation. An additional factor of importance in audio use is the improved output stage used which posses a minimum of distortion and a wide bandwidth, thus allowing lower distortion at the upper end of the audio band where crossover distortion often creeps up in earlier op-amp designs when they are loaded heavily.

An example of a circuit exploiting the 531's capability is the single ended to push-pull convertor of FIGURE 5. Here two 531's are cross-connected as a self-balancing combination gain stage and phase splitter. A1 is a high-input impedance follower with gain, suitable for bridging purposes. With the values shown it operates at a gain of 6 dB, by virtue of the 2 to 1 ratio of $\frac{R1+R2}{R1}$. R1, which would normally be directly grounded in a stage such as this, feeds the summing junction of A2. The virtual ground at A2 pin 2 serves the same purpose as a direct ground on R1 as far as A1 is concerned and at the same time also drives A2 as an inverting stage via the current flow in R1+R2. By making R3=R1+R2 the gain of A2 is fixed at —1, thus creating a mirror image of A1's signal at A2 (within the tolerance of the resistances, of course). The gain at both outputs may be adjusted simultaneously by varying the tap on R1 and R2 if desired or by making R1 and R2 a pot equal to R3.

This circuit configuration can be a very useful one, as it is a handy complement to the past **db** article, A DIFFERENTIAL BRIDGING AMPLIFIER[5]. Where the previous circuit converted double-ended signals to single-ended ones, this circuit performs the exact opposite; converting single-ended signals to double-ended ones.

The circuit shown provides a moderate amount of power (+14 dBm) with low distortion in the audio band. Up at 20 kHz the t.h.d. rises to 0.2 per cent at the +14

REFERENCES

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2. R. Dobkin, *Feedforward Compensation Speeds Op-Amp*, National Semiconductor Application Note LB-2, April 1969.
3. W. E. Hearn, *Fast Slewing Monolithic Operational Amplifier*, IEEE Journal of Solid State Circuits, Volume SC-6, no 1, pp 20-24, February 1971.
4. W. E. Hearn, *Application of the SE/NE531 Fast Slewing Operational Amplifier*, Signetics Corporation Application Memo 116, February 1971.
5. W. G. Jung, *A Differential Bridging Amplifier*, *db*, pp 21-27, July 1971.
6. W. G. Jung, *The Pitfalls of the General Purpose IC Operational Amplifier as Applied to Audio Signal Processing*, presented to the 43rd AES Convention in September, 1972. AES preprint #893 (contains a bibliography of twenty-nine references pertinent to i.c.'s in audio applications).

THE PROBLEM SOLVER

Say farewell to the grand old DC300, and welcome to THE PROBLEM SOLVER, the amp that is going to make your job easier and your customers happier. The original model DC300 was a great amp — the first super-power low distortion amp in the world, when Crown introduced it five years ago. Meanwhile, top sound systems designers have used it successfully in hundreds of demanding situations, and made some excellent recommendations for improvements. The response of the Crown design team was *not* an updated DC300, but a totally *new* and different amplifier, the DC300A. It is the *only* high power low distortion amp specifically *designed* for commercial sound applications. *(CAUTION: There are some large consumer-type amps attempting to sell in the commercial sound field without providing adequate continuous power for all load impedances.)*

Power You Can Count On

One of the DC300A's most outstanding features is that it has *double* the number of output transistors. This means effectively twice the muscle of the old DC300 — at the same price. Each channel has eight 150-watt devices for *1200 watts* of power dissipation *per channel*. The DC300A is rated at 150 watts per channel continuous into 8 ohms with both channels driven, 300 w/ch into 4 ohms or 500 w/ch into 2.5 ohms.

Two Amplifiers in One

As a dual-channel amplifier with separate level controls and circuitry for each channel, the DC300A is almost *two* amplifiers in one. This gives you additional flexibility in controlling your speaker load, as when driving separate front and back speaker systems in a large auditorium, or when bi-amping a system. For 600 watts continuous output at 8 ohms, the DC300A converts to a mono amp with two plug-in parts. This makes it possible to drive a 70-volt line directly without a matching transformer.

Superior Output Protection

The DC300A output protection circuitry is a radically new design which completely eliminates DC fuses and mode switches and further reduces service problems to the negligible level. It is superior in every way to the old VI-limiting circuit pioneered by Crown and now used by most other high power amplifiers, since it introduces *no* flyback pulses, spikes or thumps into the output signal, whether operating as a single-or dual-channel amp.

Gone too is the need to baby the amp by carefully juggling load configurations. The Problem Solver can drive *any* speaker load — resistive or even totally reactive — with *no* protection spikes! Parallel speakers with no deterioration of sound quality, since changing the load impedance only affects the maximum power available, not the ability of the amp to keep on producing clean sound.

Lowest Distortion and Noise

Also new is the DC300A's IC front end, which sets new world's records for low distortion and noise. At the 8-ohm rated output, IM and harmonic distortion is less than 0.05% full spectrum; hum and noise is 110db below. Servicing — if ever necessary — is a snap, since removing the front panel accesses the entire circuitry.

Although it is a completely redesigned model, the DC300A has inherited some characteristics from its predecessor:

PRICE - $685, the same as the 1968 introductory price, incredibly. As two amps in one, it will probably give you or your customers a welcome cost-break when you design your next multiple-amp system.

WARRANTY - three years, covering all costs of parts, labor and round-trip shipping.

COOLING - excellent heat dissipation provided by massive cooling fins and the entire chassis itself.

DEPENDABILITY - stringent pre- and post-inspection and testing proves every electronic component, every circuit module and every finished unit, to bring you one step closer to install-and-forget field dependability.

PEOPLE - the same innovative design team and careful craftsmen who made the DC300 such a sound success. And the same knowledgeable customer-service men ready to discuss your special application and send you detailed technical data. Phone 219 + 294-5571 or write Crown International, Box 1000, Elkhart, Indiana 46514.

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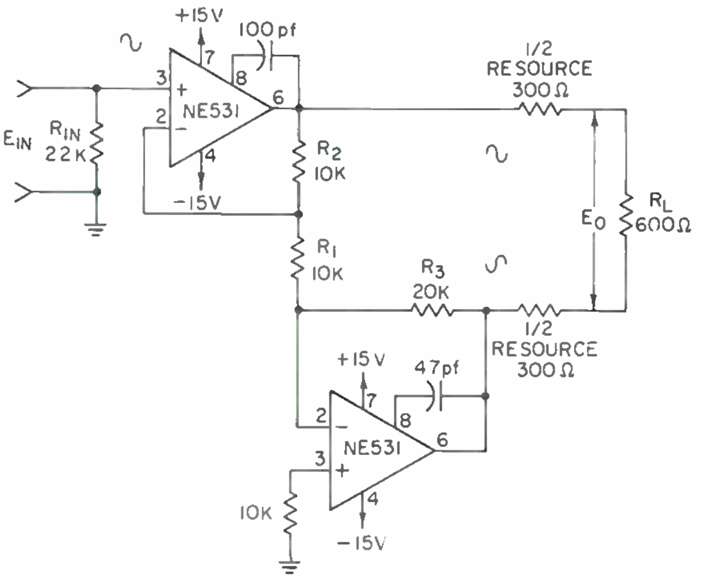


Figure 5. A single-ended to double-ended line driver.

dBm level, but at 0 or +4 levels the distortion is less than 0.05 per cent at any audio frequency. If higher power op-amps are used, the circuit can of course deliver proportionally more power.

What we have tried to accomplish in this article is to illustrate the basic problems which limit high frequency performance in popular i.c. op-amps. To a large degree these problems can be circumvented by careful consideration of the reasons that cause them and selection of optimum components for the particular application. ■

Corrections to Walter Jung's previous Automating the Audio Control Function series.

Part 3 (August/September). Errors exist on schematic of Figure 5 (B), on page 50.

Pins 2 and 3 of A4 should be interchanged.
R26 and C3 should be connected.
Unmarked connection from the DPS to +15V is pin 9.
R18 should be 470 ohms not 470 k.
In Figure 2 on page 47, C6 connects between pins 2 and 1 of op-amp 301A.

In part 4 as it appeared in November the following errors or omissions occurred.

In Figure 2 the 10 k and 0 source resistances curves are interchanged. The curves were not reproduced accurately. We can supply an accurate curve to any one requesting it.

Table 2 at (2) input bias current should be 50 nanoamps not milliamps. In the caption for this table HA-240S should be correctly HA-2405. And finally, in Figure 6, the truth table is wrong. Gains should be 0, —6, —12, —18, not 0, +6, +12, +18.

We regret any difficulties these may have caused.

ROBERT C. EHLE

Collecting Old Radios

ANYONE OVER THIRTY can certainly remember the pre-t.v. days and the family gathered around a big console a.m. radio in the living room listening to the old radio shows. The a.m. console radio in those days was a truly impressive piece of equipment: it had a minimum of three bands and often as many as eight or nine. The range covered was often from 150 kHz to 16 MHz or higher. Fancy dials had planetary drive for different tuning speeds and some radios had motor-driven tuning.

What happened to all of these old instruments? Some were retired to attics while others were traded in on the early t.v. sets. As a youngster I used to collect these radios, usually to dismantle for parts but the most impressive specimens were reserved for use and experimentation. In my youth I had, at one time or other, two Grunow "All Wave" sets, one Silvertone with motor-drive tuning, one GE also with motor-drive tuning, and two Zenith sets with 6L6 output tubes (high power for their time). I also had an assortment of less impressive sets including several early record players and changers. These usually became parts rather quickly.

One day a neighborhood friend, we were about twelve years old, suggested that we get some old radios and build a p.a. system from the parts. We went door-to-door for several blocks and collected no less than two-dozen sets from people's attics which they didn't want. Many of them did not work.

Among the sets we collected was an Atwater Kent with the familiar domed top. There was a set with inductive tuning (I can't recall the brand). There were many other very old types with the nonoctal tubes and with special unmarked parts designed by the manufacturer (no standard resistors or capacitors).

I had already seen some very old sets. I had inherited an RCA Radiola-26 which ran from a large battery pack. I never got it to work. I had a friend with a somewhat newer RCA set with large blue tubes that looked like lightbulbs, and it did work.

At any rate, I was impressed by the variety and by the elaborateness of some of these old sets. They have very pretty coil work in the r.f. section and those with many bands can have some elaborate turret type band switches, and I never could get over the fact that they could be obtained very cheaply and sometimes free. Like old automobiles, all this impressive machinery was devised for a purpose better served by newer models and most units were apparently worthless. However, like old cars, I suspected that there might be a movement to collect some of the rarer or more impressive specimens. So far, this collectors hobby has not gone very far. But the time seems to be ripe for it to get going.

There is one primary reason why the collecting of old radios is not as big as the collecting of old automobiles: radios did not suffer the nearly complete destruction during the war that automobiles suffered. Thus they are still plentiful and any visit to an antique store will turn up one or two. Perhaps old radio collecting is a hobby which will catch on at some future time. If so, now is the time to get started, before the prices on prime units skyrocket.

This article is a suggestion to the audio fan and electronics experimenter that he ought to think about the possibility of some of these old sets becoming collectors items and to consider obtaining a few for his own personal collection. I would like to offer some suggestions as to what might constitute a valaublе find or a real rarity.

In the first place, age is a real factor in the value of a set. Any set with octal tubes is almost modern (after all, octal tubes are still being manufactured). A set with non-octal tubes that works can be considered to have some significance. The type of tube in use immediately before the octal tube was a set of tubes having as many pins as the tube had elements. These pins were sized so as to permit orientation. The number of pins was from four to seven on top. A receiver with this type of tube dates from the nineteen thirties or earlier.

Tubes used in sets before the type mentioned above were not standardized to any great extent. These tubes were usually manufactured by a particular company for use in its own products and were not interchangeable with another manufacturer's product. A distinguishing feature of tubes from this era (pre-nineteen twenties) is the lightbulb shape of the glass envelope and often a blue-colored glass. This is probably the earliest type one is likely to encounter and a working set with such tubes is a rarity. The real enthusiast might want to rework tubes which no longer work in order to restore such a set.

Very often, old sets were not built to work from 110 volt power sources. These often did not exist and there was less standardization as to voltage, frequency, or even a.c. or d.c. Commonly, battery packs were used. These were chests which had to hold three sets of batteries, the A, B and C voltages. The A voltage was a bias supply, the B voltage has become our familiar B+ while the C supply was for the filaments. Batteries used in these battery packs resembled those in our automobiles more than anything else. Size and weight were impressive as the battery pack was usually larger than the radio (which also was large).

The collector who is able to find one of the old battery-powered sets (such as the RCA Radiola 26) should be able to build a modern power supply for it to replace the battery pack. The radio receiver itself could be restored in exact original condition.

If the very old sets we have been discussing are the real antiques in the radio world, some of the sets built in the nineteen thirties must certainly be classic units by any standards. In this era, eminence must be decided on the basis of extras, refinements and a certain over-design. Here, such features as noise-limiter circuits, motor-driven tuning, many bands, many tubes, tuning meters or eyes, *afc*, signal-seeking tuning, and so forth, can be considered as outstanding qualities. What we are seeking is the radio equivalent of the Dusenberg or the Rolls Royce of the same era. There was an extraordinary extravagence in some of the sets marketed during the twenties and thirties (and some daring engineering as well). Such factors should make certain models greatly sought after.

The folklore of the old radios is certainly apropos. The story has been told of one manufacturer (suspecting that people bought those sets with the most tubes) who installed several unnecessary tubes in each set and connected only the filaments (so they would light up). Old timers also like to tell about the early days of radio broadcasting when there were no FCC limitations on power and when the band was not crowded. In these days, reception up to half a continent away was a common occurrence on the a.m. band. Distance reception seems to have been a favorite pastime. Many fancy long-wire dipoles were manufactured with matching transformers in large tin cans that could be strung up between poles or trees. After the a.m. band reached its state of saturation, interest in distance reception switched to the short-wave bands. It seems that this mode of entertainment was not restricted to the hams of the era but that at one time most radio listeners enjoyed listening to long-distance reception on the short-wave bands.

Anyone interested in the technology of electronic equipment will find it interesting to explore the circuits used in some of these old sets. Today, there are certain techniques which have become so common that they are considered standard. In the days the old sets were manufactured these standards did not exist and engineers tried any possible method to achieve results. I've already mentioned inductive tuning which became common in automobile radios and some military sets but which eventually was replaced by capacitance tuning in console radios. One who explores these old sets will discover all sorts of novelties such as peculiar tuning indicators, unusual tubes and applications, different types of bias, etc. If some of these circuits do not work, the modern technician can be quite confused trying to figure out what they were supposed to do, not to mention how they work.

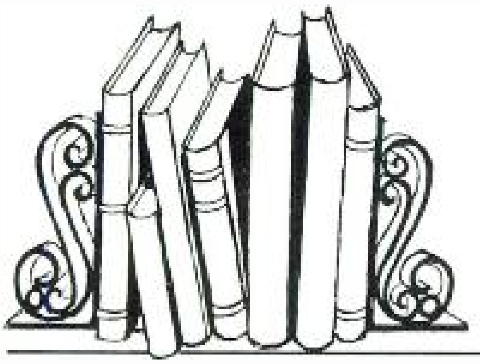
Another item of interest is the early attempts to improve sound quality. The term *high fidelity* is not as new as some of us might think. Some manufacturers (RCA in particular) were using the term to describe their products in the thirties (in particular, institutional equipment such as classroom phonographs). Some of the more elaborate console radios of the thirties had large transformers and high-power amplifiers. Some even used special noise limiters and so forth. One of the more daring moves must have been to put a solid wooden back on the traditionally open-backed cabinet and, perhaps, install a bass reflex vent or some other sort of resonator plumbing. A few manufacturers actually did such things, but they were definitely in the minority.

So, there is a large amount of novelty in the old radios. There is also a certain peculiarity. The aesthetics of the design of the cases and of the dials is definitely quite different from that of modern sets. After all, the *really* old sets are actually Victorian furniture with all the ornamental frillwork of the period.

Peculiarities in the use of lights is also fascinating. Often sets would have as many as a half-dozen bulbs, each with a different colored filter. The bulbs would be switched by the bandswitch so that a color would correspond to a particular band. Other manufacturers used bulbs to indicate various things such as tuning (the intensity of the bulb corresponded to the intensity of the signal) or for settings of various controls (intensity of a bulb indicated the setting of the volume control or of a tone control).

This is only a brief listing of the features and peculiarities to be found in certain of the older sets. The collector is certain to discover many more novelties for himself as each set has some. These things were the edge one manufacturer had over his competitor and each one tried to capture the public imagination by engineering gimmicks as well as number of tubes and sensitivity.

Today, when the vacuum tube itself is a dying thing, old radios have a particular attractiveness as representatives of the past of electronics—an earlier era of our business hobby. ■



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28. Environmental Acoustics. *Leslie L. Doelle.* Applied acoustics for those in environmental noise control who lack specialized acoustical training. Basic information in comprehensible and practical form for solving straightforward problems. Explains fundamental concepts; pure theory minimized. Practical applications stressed, acoustical properties of materials and construction listed, actual installations with photos and drawings. Appendixes illustrate details of 53 wall types and 32 floor plans and other useful data. 246 pgs. **$18.50**

21. Acoustics—Room Design and Noise Control. *Michael Rettinger. 1968.* The enormous problems and hazards presented by noise are dealt within an orderly and practical manner. With many charts, graphs, and practical examples, the text covers the physics of sound, room acoustics, and design, noise and noise reduction. 392 pages. **$17.50**

22. Acoustics of Studios and Auditoria. *V.S. Mankovsky.* Basic theory plus a mass of design data covers the field with special reference to studios and places of public performance. For acoustical designers and specialists in sound transmission in cinema and broadcasting. Features exhaustive treatment of studio acoustics by the statistical, geometric and wave methods in parallel. 416 pgs. **$15.00**

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FOR SALE

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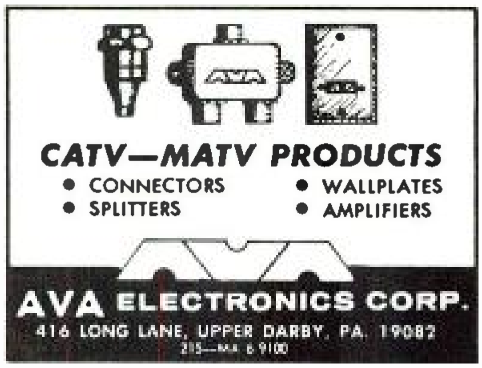

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MAINTENANCE ENGINEER. Large three studio operation (24-track) with high-speed duplication facilities. Full knowledge of Scully and Ampex recorders, console systems and audio electronics required. Good pay. Great people. Send complete resume including personal information to W. Craig Kenney, **Flite Three Recordings Inc., 1130 East Coldspring Lane, Baltimore, Md. 21239. (301) 532-7500.**

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FOR SALE

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PEOPLE, PLACES, HAPPENINGS

● The seventh annual **Midwest Acoustics Conference** is scheduled for April 7th at Northwestern University in Evanston, Illinois. Loudspeaker experts will square off for what is expected to be a battle royal. Presenting various subjective evaluation techniques are **C. G. McProud** and **Julian D. Hirsch,** and presenting opposite but differing views on objective measurement are such advocates as **Dan Queen** and **Paul Klipsch.** To balance the technical presentations, academic viewpoints will be presented by prominent faculty members from two universities, including a session on psychoacoustics by Dr. Carhart of Northwestern University. A panel of these experts will discuss how subjective and objective measurements can be correlated. There will also be a meet-the-experts noontime session. Advance registration fee is $3.00. Write **Midwest Acoustics Conference, c/o D. Burkhard, Industrial Research Products, Inc., 321 Bond Street, Elk Grove Village, Ill. 60007. Phone (312) 439-3600.**

Bubbers

● **Acoustic Research** president Victor **Amador** has announced the appointment of **John J. Bubbers** to the position of director of engineering. He replaces **Roy Allison** who is leaving to continue his research work in the field of room acoustics. John Bubbers previously had a long association with **Stanton Magnetics, Inc.** where he was vice president of field engineering and professional products manager. Prior experience includes ownership of **B&C Recording** where he was instrumental in the introduction of stereo recording and the manufacture of stereo records. He also is presently executive vice president of the AES and holds a Fellowship in that organization.

● **Cetec Inc.,** a recently formed subsidiary of **Computer Equipment Corp.,** El Monte, California, is now producing **the Electrodyne Gauss** and **Langevin** lines of professional audio consoles, tape duplicating equipment and instrument loudspeakers at its plant in North Hollywood. The lines were acquired by Cetec from **MCA Technology Inc.** under a purchase agreement conclued October 1, 1972. **Phillip L. Gundy,** executive vice president of Computer Equipment Corp. has been elected to serve also as president of Cetec Inc. **M. Ned Padwa** is vice president and general manager. **Keith O. Johnson** and **Don McLaughlin,** founders of the original Gauss and Electrodyne Corporations, have joined Cetec Inc. as vice presidents of advanced development and product planning, respectively.

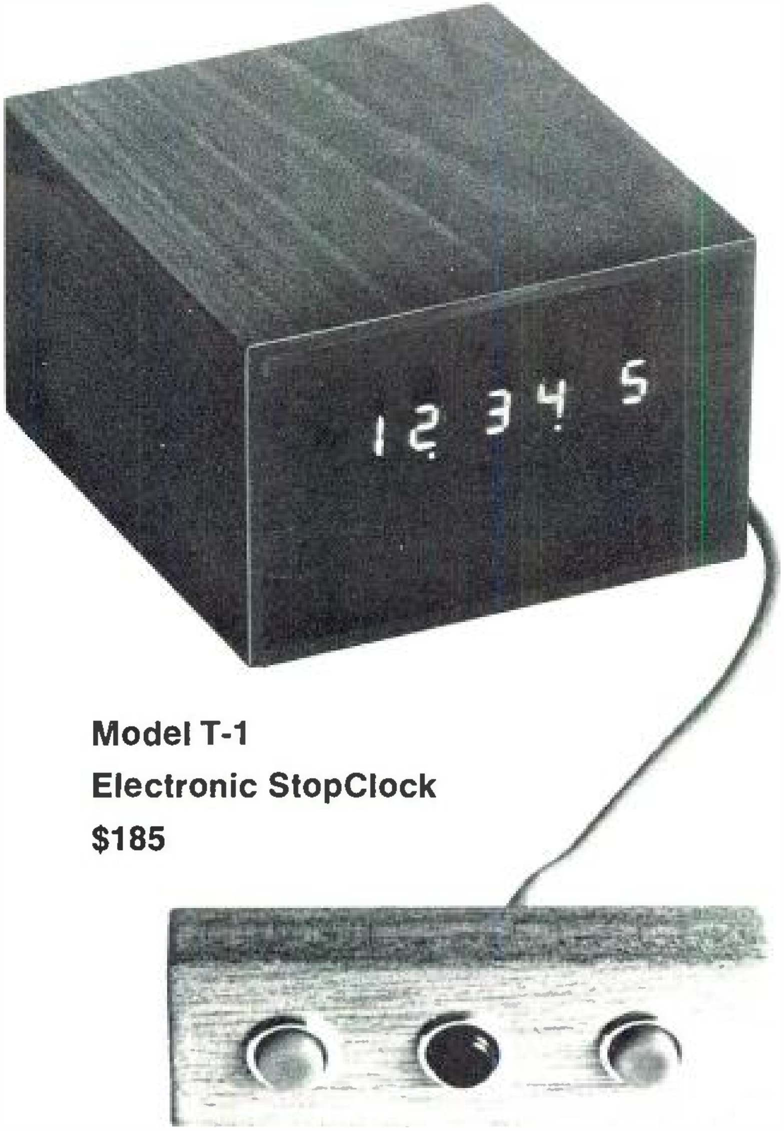
● **Recording Engineers Institute** announced its March classes beginning Monday, March 19th. A 10 week course in all facets of recording engineering ranging from the operation of studio consoles to the use of automated mixdown computors is offered. The classes are being held in **Echo Sound Studios, 2686 Hempstead Turnpike, Levittown, L.I., New York.**

Berliner and Kahn

● Labelled a **Bundle for Britain,** we see **Dolby Labs./USA** manager **Morley Kahn** on the right accepting the 1972 "Maker of the Microphone Award" on behalf of **Ray Dolby** for the latter's development of the noise reduction system for magnetic recording that bears his name. Making the award is **Oliver Berliner,** grandson of **Emile Berliner,** inventor of the microphone and the disc record.

StopClock

A New, Accurate, Digital Timing Instrument for Recording Studios, Broadcasters, and Other Demanding Applications



Model T-1
Electronic StopClock
$185

Timekeeper is proud to introduce a new inexpensive *Electronic* StopClock—a compact instrument featuring an easily-read visual display.

Only 5⅛″ wide x 3¼″ high x 5½″ deep, it uses modern digital circuitry to provide accuracy of a very high order with exceptional long term stability. The large ⅜″ high, seven-segment numerals can easily be read from a distance of more than 15 feet. Maximum count is one hour (59:59:9).

Three remote-mounted push buttons are used for manual control: START, STOP, and RESET. These buttons may be placed in a console, operating desk or any convenient location. The clock may be remotely located in the equipment, or on a desk or table. (A mounting flange is provided.)

Operation is similar to any conventional stopwatch. The green button starts the clock; the red button stops it. The black button resets it to zero. These may be depressed in any order, or all at once, without damage to the clock. If it is desired to start the clock by releasing a button rather than depressing one, the green and black button are pressed simultaneously. When the black button is released, the clock will start automatically.

The accessory plug on the rear panel may be used for all remote operations. All BCD information is available at this plug for accessory units such as digital printers, slave units, etc.

The Model T-1 is supplied for 120 volt 60 Hz operation, in an attractive simulated walnut grained enclosure with a red lucite face. However, 120-volt 50 Hz operation is available at no extra charge if so specified at the time you place your order.

The Model T-1 is priced at $185.00. As with all Timekeeper products, it is fully guaranteed to meet with your complete satisfaction, or your money will be promptly refunded. It is guaranteed for one year against any defects in manufacturing.

The Timekeeper Electronic StopClock is a must. More than a high quality timer—it provides the added convenience of full visual display, high accuracy and stability plus operational flexibility. Order one soon. You will be delighted with it.

TIMEKEEPER

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Plus three new drivers, full-range horn loading, and a computer-aided design that led to more efficiency and higher power handling than any of the standard monitors.

You can read about SENTRY IV design in an AES convention preprint we'll send you. It was written by our Ray Newman (left) the man behind the SENTRY IV. We can also show you curves and specs that make impressive reading. And even better listening.

But we know you won't be truly convinced until you hear the SENTRY IV. That's why we're scheduling studio demonstrations now all across the country. You can arrange an audition through your E-V sound specialist. Or write us today. But be prepared to accept a new standard in sound. The Electro-Voice SENTRY IV monitor speaker system.

Sentry IV Professional Monitor and Sound Reinforcement Loud Speaker

Response: 50 — 18,000 Hz. Dispersion: 60° x 120° from 600 to 15,000 Hz. Sound Pressure Level: 117 dB at 4′ on axis, with 50 watt input. Dimensions: 27-3/4″ w. x 20-5/8″ d. x 50-3/4″ h. as shown. Weight: 148 lbs. $501.00 suggested professional retail net.

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