THE PA BIBLE

ADDITION NUMBER THREE
MICROPHONE TYPES

In our prior P. A. Bible material we have dealt with acoustic transducers that convert electrical energy into sound (loudspeakers). Another type of acoustic transducer is the microphone. The microphone is similar to the loudspeaker, but its function is to convert sound into electrical energy.

The following discussion will describe the various types of microphones in terms of four factors that help define them. In addition, some information will be given that should help in selecting a microphone type and a few important operating tips will be mentioned. It is not our intent to go deeply into applications in this supplement. We intend to reserve that complex topic for a later issue.

MICROPHONE TYPES AND OPERATION

All microphones have two basic components: the diaphragm, and the generating element. The diaphragm is a membrane which vibrates in accordance with the pressure variations of sound. The generating element converts the diaphragm vibrations into electrical voltage. This generating element is one of four factors which determine the type of microphone. The kinds of generating elements vary greatly in expense, fidelity, complexity, ruggedness, and longevity.

Ceramic and Crystal Generating Elements. The diaphragm of a crystal or ceramic microphone is attached to a special material which produces an electric output voltage when it is moved. Such materials are termed "piezoelectric." A typical ceramic microphone is diagrammed in Figure 1. Such microphones generally provide insufficient fidelity and ruggedness, even for the most modest requirements of the professional and serious amateur.

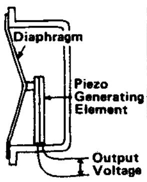


FIGURE 1– Ceramic/Crystal Generating Element

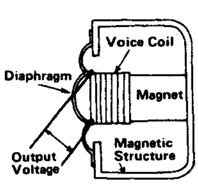


FIGURE 2–Dynamic Generating Element

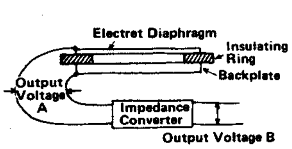


FIGURE 2A–Condenser Generating Element

Ribbon (or "Velocity") Generating Elements. Ribbon microphones are similar to dynamics, except that a very thin metal-foil ribbon serves as both diaphragm and voice coil. In order to obtain adequate frequency response and output level, the thin ribbon must be exceedingly light. Older ribbon microphones could easily be destroyed by mechanical shock or a suddent blast of air which would stretch and destroy the fragile ribbon. However, the best current designs have been improved for satisfactory durability.

Dynamic Generating Elements. The diaphragm of a dynamic microphone is attached directly to a coil of wire (voice coil) located close to a magnet. When the voice coil vibrates, a voltage is produced. A dynamic microphone is shown in Figure 2.

The dynamic microphone is a proven tool for the public address and instrumental miking requirements of the professional performer. It provides excellent fidelity, extremely stable performance characteristics, and a high degree of ruggedness – all at a reasonable price. These same characteristics are ideal for conventional sound reinforcement and recording, as well. In addition, the diaphragm of a well-designed dynamic microphone is able to withstand the close miking and high sound levels often employed by musicians; all without damaging the microphone or distorting its output. The many desirable features inherent in the dynamic microphone make it a good choice for most applications.

Condenser Generating Elements. The diaphragm of a condenser microphone is a movable plate of a condenser (capacitor), a common component in electrical circuits (Figure 2A). When polarized by applying a direct current voltage, motion of a diaphragm in relation to a fixed backplate produces an output voltage. The extremely high impedance of the condenser generating element is matched to typical inputs by an impedance converter in the microphone. Condenser microphones, many of which are capable of very wide frequency response, have been widely used in recording studios for years. For the performer, due to their relatively high output level, condensers may produce input overload distortion (distortion caused by too great an input signal to a mixer) unless appropriate precautions are taken.

Modern day electret type condenser microphones can offer ruggedness comparable to dynamic microphones. The electret microphone can often yield superior performance at the frequency extremes (high and low) when compared to dynamic types. Because electrets utilize an impedance converter to match the diaphragm signal to the mixer input, they require either a battery or phantom power for operation. Phantom power is a means by which power is supplied to the microphone from either a mixer or power supply by way of the microphone cable. Phantom power eliminates the need for batteries and the problem of replacing dead batteries. Even though electret microphones are more complex in construction, their performance advantages are making them an increasingly attractive choice for exacting applications.

MICROPHONE PICKUP PATTERNS

A microphone's pickup pattern is three dimensional in character and shows how the microphone responds to sound from different directions. Omnidirectional microphones pick up sound from all directions. Unidirectional microphones reject or reduce sound from their sides or rear. The pickup pattern is the second of four factors which determine the type of microphone.

Omnidirectional Pickup Pattern. The pickup pattern of an omnidirectional microphone may be represented as an inflated balloon with the microphone at the center, as shown in Figure 3. Usually a polar pattern is used to represent the pickup pattern, illustrated in Figure 4. The polar pattern shows the loss in output (in dB) experienced as a constant-output sound source moves 360° around a fixed microphone at a fixed distance from the microphone.

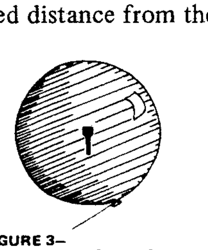


FIGURE 3– Omnidirectional Pickup Pattern

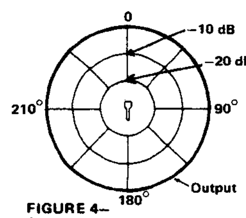


FIGURE 4– Omnidirectional Polar Pattern

How does an Omnidirectional Microphone Work? The case of the microphone shown in Figure 5 is totally sealed, so that sound pressure can strike only the front of the diaphragm.

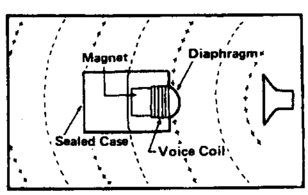


FIGURE 5–Omnidirectional Microphone

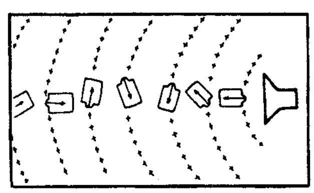


FIGURE 6–Omnidirectional Microphone at Various Angles

Pressure variations passing over the diaphragm move it no matter how the unit is oriented with respect to the sound source! This phenomenon is shown in Figure 6. Thus, microphone output is constant regardless of orientation.

Why an Omnidirectional Microphone? In systems where extremely close working distances are employed, say touching the lips to six inches, the omnidirectional microphone, if it can be used, has several advantages in its favor:

1. For a given price, an omnidirectional microphone generally has a smoother frequency response than its cardioid counterpart. Such smoothness of response is important because any roughness invites feedback.
2. An omnidirectional microphone is significantly less susceptible to breath pops than its cardioid counterpart.
3. An omnidirectional microphone is significantly less sensitive to mechanical shock than its cardioid counterpart.
4. An omnidirectional microphone is often more rugged than its cardioid counterpart.

Unidirectional Pickup Pattern. The most common unidirectional microphone is called a cardioid. Cardioid is a mathematically descriptive term that denotes the geometric form of the pickup pattern. The pattern happens to be crudely heartshaped (hence the term "cardioid"). Side pickup is moderately reduced in a cardioid microphone and rear pickup is dramatically reduced. The polar pattern of a cardioid microphone is shown in Figure 7. The apple shown in Figure 8 would be a good three-dimensional model of the cardioid pattern with the stem representing the microphone.

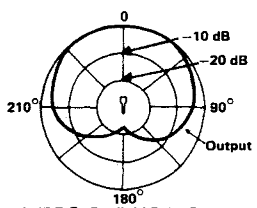


FIGURE 7—Cardioid Polar Pattern

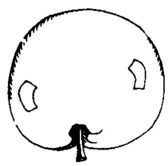


FIGURE 8—Cardioid Pickup Pattern

How does a Unidirectional Microphone Work? In a cardioid unidirectional microphone, the case is not sealed. The sound pressure is permitted to contact the diaphragm from the rear as well as the front. The rear contact occurs through a port which is precisely located in the microphone case.

A simple cardioid microphone is shown in Figure 9 with the sound source at its rear. With sound originating from the rear of the microphone, diaphragm motion is neutralized by equal, in phase sound pressures arriving at each side of the diaphragm, resulting in zero net force acting on the diaphragm. (Note the "plus" sound pressures on both sides of the diaphragm.) However, with sound originating from the front as shown in Figure 10, a delay in the sound pressure reaching the rear of the diaphragm due to the increased distance (that is, distance to the rear opening plus the distance back to the diaphragm) permits motion of the diaphragm. Microphone output results. (Note the "plus" sound pressure on the diaphragm's front, and the "minus" pressure at the rear.)

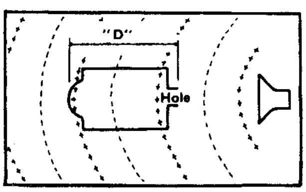


FIGURE 9—"Single-D" Cardioid Microphone with source at rear

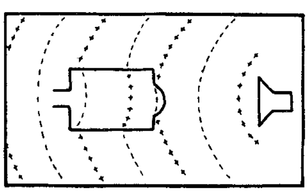


FIGURE 10—"Single-D" Cardioid Microphone with source at front

Why a Cardioid Microphone? The pickup pattern of a cardioid microphone – relatively dead at the sides and rear – tends to increase the working distance (the distance between the sound source and the microphone). The limiting factor is when the distance becomes so great that amplifier gain must be increased until:

1. The sound becomes over-reverberant due to room reflections.
2. The pickup of random background noise becomes excessive.
3. Sound system feedback results from P.A. or monitor speakers.

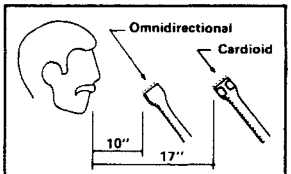


FIGURE 11—
Working Distance Comparison

This increase in working distance is theoretically 1.7 to 1, as shown in Figure 11. For instance, if the maximum effective working distance of an omnidirectional microphone is ten inches, then theoretically a cardioid mic can be used at seventeen inches with the same effectiveness!

The feedback-reducing characteristics of cardioid microphones would seem to make a clear-cut case for the use of a cardioid microphone by professional performers. In marginal feedback situations, the cardioid will produce a higher level in the room before feedback occurs. This situation is often encountered in portable P.A. systems and other systems employing high-level stage monitors, where high levels of direct speaker sound reaches the microphone from the sides or rear. Usually in such instances, the loudspeakers are closer to the microphones than would be desirable from a sound-system design standpoint, and care must be taken to maintain proper gain without feedback.

Two vastly Different Types of Cardioid Microphones. A 'Single-D" cardioid gives big bass. The simple cardioid microphone described previously (the one with a single port located in the case) has a frequency response which varies strongly with working distance! As shown in Figure 12, at one-quarter inch, the bass response is boosted fifteen dB over the response at 24 inches and beyond! In engineering terms, this type of cardioid is called a "Single-D", named for the single distance between the rear sound entrance and the diaphragm.

The close-up emphasis of bass tones of the Single-D cardioid, called "proximity effect", provides a big, no-mistake-about-it bass sound – and for certain vocal applications, this is a popular sound. The Single-D sound, however, may not provide the super-clarity often desired by today's performer.

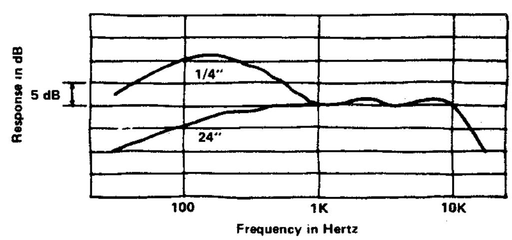


FIGURE 12—"Single-D" Proximity Effect

A "Variable-D®" cardioid emphasizes clarity. In order to reduce bass-boosting proximity effect, Electro-Voice developed and patented the "Variable-D" microphone. In a Variable-D, multiple ports are used with high frequencies entering the port closest to the diaphragm, mid frequencies entering midway along the length of the microphone case, and low frequencies entering the port farthest from the diaphragm. A Variable-D microphone is shown in Figure 13.

The virtual elimination of proximity effect of a Variable-D microphone is shown in Figure 14 in comparison to the strong bass boost of the Single-D cardioid microphone.

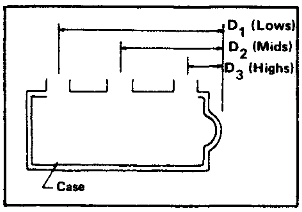


FIGURE 13– "Variable-D" Cardioid Microphone

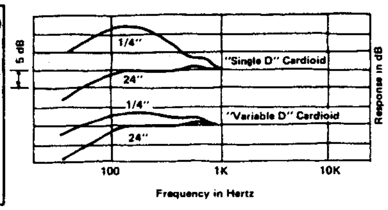


FIGURE 14– Proximity Effect Comparison

Latest Electro-Voice designs employ a variation called "Continuously Variable-D" where the mid- and low-frequency ports are replaced by a long, slotted entrance which has a continuously varying frequency acceptance along its length, with the lowest frequencies entering at the farthest point from the diaphragm. The frequency discrimination of Variable-D or Continuously Variable-D microphone ports can be effectively demonstrated by speaking, with lips touching, into the front, then mid, then rear openings. The change in vocal character will be readily apparent, with the sound very "bassy" at the rear port of the microphone and with much more "treble" evident toward the front port. A Continuously Variable-D microphone is shown in Figure 15.

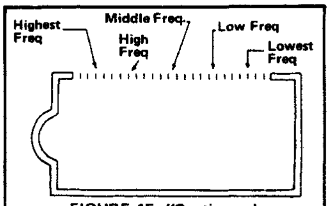


FIGURE 15–"Continuously Variable-D" Microphone

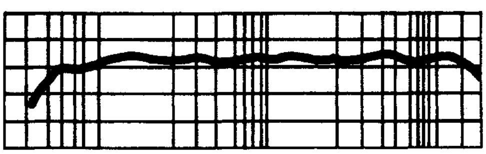
In addition to reduction of the Single-D's proximity effect, Variable-D and Continuously Variable-D cardioids have reduced breath popping and shock sensitivity. Thus, the popularity of the Variable-D microphone is due to its combining of the omnidirectional's clarity and inherent pop and shock resistance with the cardioid's feedback reduction and working distance advantages.

Variable-D and Continuously Variable-D (CV-D) are registered trademarks of Electro-Voice, Inc.

MICROPHONE FREQUENCY RESPONSE

The third factor which determines microphone type is frequency response. Response information for each microphone will help you select for special results. For instance, a microphone with "rising" response will emphasize the brightness of a trumpet or other brass instrument; one with proximity effect (single "D" cardioid) will add bass boost to a close working "thin voiced" singer. Communications microphones almost always have rising response or a "presence peak" to add intelligibility to voice transmission. A flat response, for most accurate sound reproduction as shown in Figure 16, would be typical for studio recording under ideal room and low noise conditions.

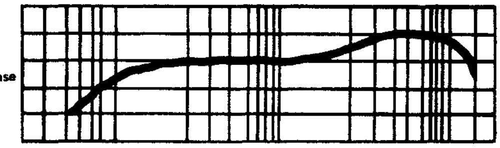
FIGURE 16 – Nominally Flat Response



Choose an appropriately shaped response (an example is shown in Figure 17) for special requirements: rolling-off frequencies of unwanted background noise (such as in a vehicle or plant machinery) and room reverberation; boosting bass; brightening high frequencies or increasing intelligibility.

When choosing a microphone, be certain its frequency response is wide enough to reproduce the sounds you need to reproduce with no perceptible change in quality. It should be pointed out that the response curves shown in Figures 16 and 17 (as well as curves shown on data sheets) were produced with the microphone at a sufficient distance so as to be in the "free field." When microphones are measured at very close distances, changes in the response curve can occur from microphone characteristics, such as proximity effect, which we described earlier. The chart shown in Figure 18 shows the frequency ranges of various instruments as well as the human voice, and it should be of some help when selecting an appropriate microphone with respect to frequency response.

FIGURE 17 – Typical Shaped Response



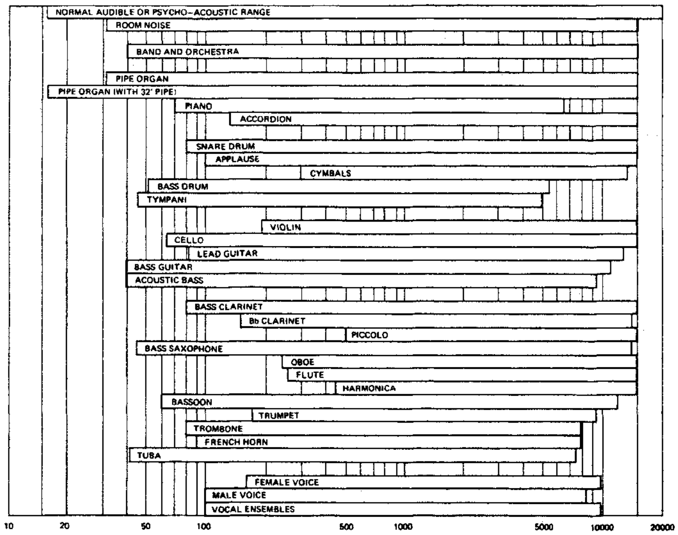


FIGURE 18 – Range of Sounds

MICROPHONE IMPEDANCE

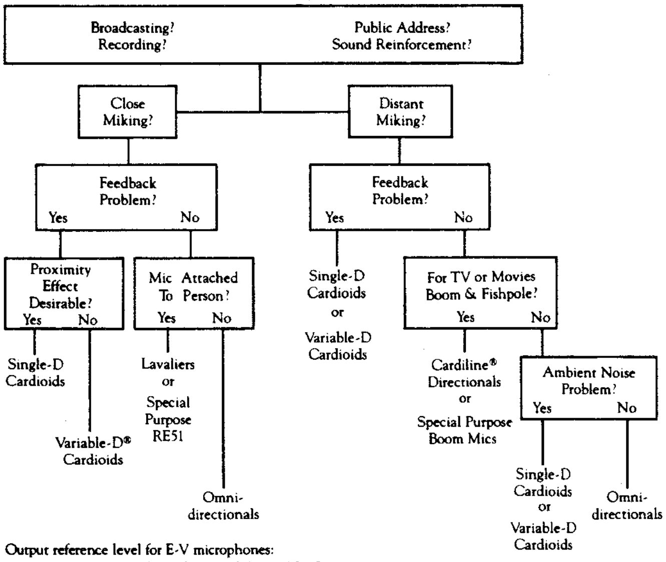
Choosing Between Low-Z and High-Z Microphones. Microphone impedance is the fourth factor that determines microphone type. High impedance microphones have higher output than low impedance types (about 20 dB). However, low-Z microphones permit the use of longer cables without high-frequency rolloff. Therefore, if microphone cables will be longer than fifteen or twenty feet, only low-Z microphones should be used if the maximum clarity of extended high-frequency response is desired! Low impedance microphones have become the industry standard due to their versatility and the availability of equipment which accept low impedance inputs.

HOW TO CHOOSE THE RIGHT MICROPHONE

Knowing how microphones operate and taking into consideration frequencies of sound, pickup patterns, impedance, ana proximity effect, you should now be able to choose an appropriate microphone. To accomplish this use the chart shown in Figure 19. It will allow you to pick the microphone that fits the application. Start at the top of the chart and work your way down. Answer the questions in each box and the chart will indicate the type of microphone recommended for your application.

OPERATING TIPS

Since we are dealing with the subject of microphones, a few tips on applications should be of interest. As mentioned earlier, we intend to devote a future supplement totally to applications, but we would like to include a few of the more important topics right now.



Output reference level for E-V microphones:
Hi-Z & Transistorized 0 dB = 1 Volt/Dyne/CM²
Lo-Z 0 dB = 1 Milliwatt/10 Dynes/CM²

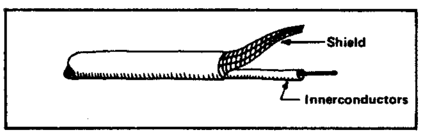
FIGURE 19 – Microphone Application/Recommendation Chart

Impedance Matching for Dynamic Microphones. In usual practice, high-Z microphones operate properly when connected to high-Z mixer inputs only. Connection to a low-Z input results in drastic low-frequency attenuation. Low-Z microphones are designed to operate through low-Z inputs. However, they will usually operate in high-Z inputs when the sound system has sufficient gain, and the microphone output level is large. This technique, incidently, is often used to control input overload since a voltage drop of approximately 20 dB usually results when a low-Z microphone is moved from the mixer's low-Z input to its high-Z input.

Connecting the Microphone to the Mixer Input.

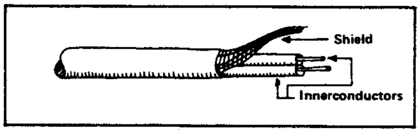
Hi-Z Cable. High impedance microphone cables are single conductor shielded, as shown in Figure 20. The output of a dynamic microphone voice coil is carried by the inner conductor and the shield, which also acts as ground to prevent hum. High impedance mixer inputs have two connections, with the shield going to the mixer's ground. Because one of the microphone voice-coil leads is connected to ground in such hook ups, the inputs are called unbalanced.

FIGURE 20 – Single Conductor Shielded Cable



Lo-Z Cable and Inputs. Low impedance microphone cables have two inner conductors and a shield, as shown in Figure 21. In such low impedance cables, the voice coil signal is carried on the two inner conductors, while the shield acts only as a hum and noise protector. This configuration is termed balanced line since neither voice coil wire is connected to ground. The balanced line arrangement provides hum and noise protection superior to the unbalanced lines used with high-impedance microphones. Low impedance microphone mixer inputs generally have three connections, with the shield going to ground.

FIGURE 21 – 2- Conductor Shielded Cable



Occasionally, mixer inputs for low-impedance microphones will have two connections like typical high-impedance inputs. Such low-impedance inputs are unbalanced similar to their high-impedance counterparts. In order to use an unbalanced input with a standard low-impedance microphone cable, one inner conductor must be connected to ground before the system will work. This must be done by connecting either one of the inner conductors to the shield at the mixer input.

Avoiding Multiple-Microphone Interference. Voids which can occur in frequency response when the outputs of two microphones are combined can be avoided if the microphones are at least three times as far apart as either is from the user. The 3-to-1 ration is illustrated in Figure 22. The ratio is frequently violated in stage microphone placement and is often the culprit for strangely inadequate sound-system performance. Some illustration of "good" and "bad" multiple-microphone placements are shown in Figures 24, 25, and 26. The "bad" placements can ruin the performance of an otherwise excellent sound system!

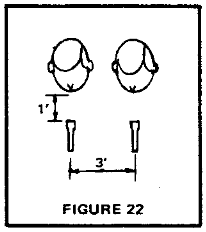


FIGURE 22

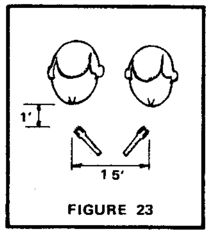


FIGURE 23

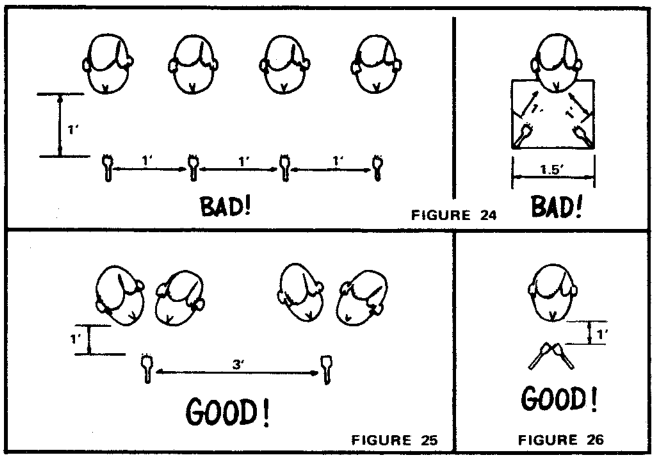


FIGURE 24

FIGURE 25

FIGURE 26

When two microphones must be used close together, multiple interference can be avoided by placing the heads directly together. (See Figure 26)

When cardioid microphones are used, the 3-to-1 ratio can be reduced somewhat by angling the microphones away from each other as shown in Figure 23.

The 3-to-1 ratio studies were first performed by Lou Burroughs, and are described in Lou's book, MICROPHONES: DESIGN AND APPLICATION. This is an excellent text for the microphone user. The book is published by Sagamore Publishing Co., Inc. (1120 Old Country Road, Plainview, N. Y. 11803).

We intend to expand on microphone uses in later issues of the P. A. Bible, as well as covering other subjects of interest to P.A. practitioners. We would appreciate receiving your comments about the first issues of the P. A. Bible and would welcome suggestions regarding future issues. Send your comments to P. A. Bible, Electro-Voice, Inc., 600 Cecil Street, Buchanan, Michigan 49107.

Electro-Voice®
600 Cecil Street, Buchanan, Michigan 49107
8234 Doe Avenue, Visalia, California 93277
Electro-Voice Div , 345 Herbert Street, Gananoque, Ontario • Electro-Voice, S.A., Romerstrasse 3, 2560 Nidau, Switzerland