THE PA BIBLE

ADDITION NUMBER EIGHTEEN
CONTROLLED SYSTEMS

What are Controlled Systems?

In a sense all loudspeaker systems are electronically controlled. They cannot function without an amplifier and this amplifier has control functions implicit to its operation. Such functions can be as simple as integral subsonic filters or even a single level adjustment knob. Control is a natural operating condition for all loudspeakers. The matter of significance is the degree and detail of control and the consequences associated with a given concept in controlled systems.

Historically, the earliest forms of explicit control may have been fuses and certain automatic devices intended to protect the more delicate components of a loudspeaker system. Such devices permit the system to be pushed closer to ultimate acoustic output capabilities with less damage risk than before.

During the last 10 or 15 years, the concept of controlled systems has been expanded and a number of manufacturers have offered their versions of this idea. These versions differ in various details of philosophy and execution. Figures 1 and 2 show a block diagram of a controlled system and a photograph of a typical system format.

What is the purpose? The intent of this concept is quite direct and simple. It is to permit maximum usable output to be achieved from a system with minimum risk of damage and minimal alteration of important sonic characteristics.

Note that once an electronic circuit becomes a part of a loudspeaker system, a number of possibilities beyond the core purpose become possible. As an example, it becomes relatively simple to incorporate circuitry to create systems such as Thiele's higher-order, assisted, vented box designs [Ref. 1] that require electronics for their realization. Electronic delays for loudspeaker acoustic alignment can also be included. However, it is best to separate out such possible additional functions from the basic concept to avoid clouding the main issue.

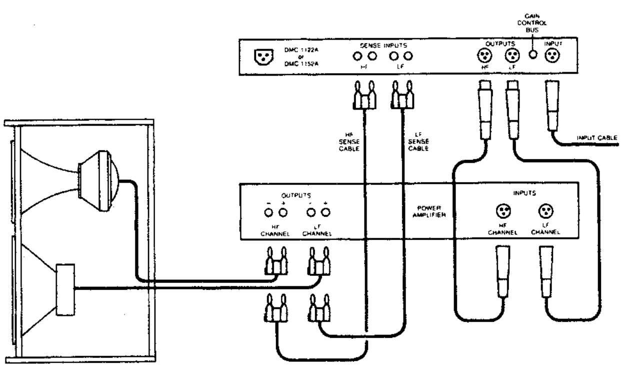

FIGURE 1 — A block diagram of a controlled speaker system.

Why Are Such Systems of Interest and Where Do They Apply?

Such systems are of interest because of the useful nature of maximum output from a given package with minimized risk of damage. This statement has been made previously, but it is important to keep in mind. This does not mean to suggest that all classes of loudspeaker products are appropriate for the full application of this concept.

It should be stressed that this technique is not a substitute for good fundamental loudspeaker system design. The additional expense required to do a system of this type should not be secured by skimping on the acoustic components and then attempting to make the result more survivable. The intent should be to make pieces of fine machinery even more valuable when the circumstances warrant. The words "expense" and "value" should perhaps be expanded upon as their implications are not necessarily obvious.

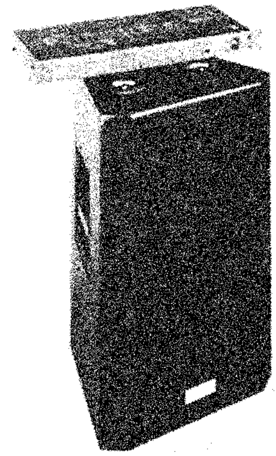

FIGURE 2 — DML-1122A speaker system with companion controller.

A high-quality system incorporating a controller will cost more than a similar system not involving one. However, the value of such a system can be enhanced considerably. This is especially true when the system is pushed to near-ultimate output and cannot be overseen by human "controllers" who are intimately familiar with its characteristics under high-output conditions. The value of a system is substantially reduced when audible distortion intrudes on a performance. Its value is reduced to zero when failure occurs.

It might be argued that all systems should be moving in the direction of controlled protection. In fact this appears to be happening, although with various degrees of sophistication in the nature of the mechanics of control. Methods of control are being incorporated into many products, beginning with relatively simple devices such as fuses and relays that protect tweeters and ending with relatively elaborate multi-protection-mode devices with individual sections tailored to each loudspeaker in the system. As the degree of complexity increases, so does the degree to which the system can be pushed toward ultimate output with safety.

Are there arguments against controlled systems? Beyond the matter of additional expense associated with elaborate control methods (but recall earlier comments regarding the concept of value), arguments mainly fall into three categories. The first of these involves undesirable alterations in the sound of the system when the protection methods begin to kick in. To an appreciable degree this depends on the particulars of a given protection system. The next section will discuss this somewhat complicated topic and give some perspective to the situation. The second argument involves the loss of much human control since, to a substantial extent, the system is on "auto pilot" at high outputs. To a degree this is related to the first matter as the presumption is that skilled human control will result in audibly better results than those achievable under "auto pilot." The last argument involves the particular nature of controlled systems. This is that they are of a set, coordinated format that is unalterable. A given sophisticated controller cannot be switched to another loudspeaker system and function in an acceptable or even safe manner. Total systems are packages that are unalterable from their set format.

What is Being Controlled and What Are the Consequences?

A discussion of loudspeaker protection is typically divided into thermal and excursion considerations [Ref. 2 and 3]. The actual operating situation is made more complex by the interactions between these two conditions. A third category, not so commonly described, involves the consequences of exceeding strength of materials bounds. This matter also interacts with the prior ones to provide yet more complexity to the situation. One example will be given below to illustrate the nature of interactions.

This example involves a strong continuous music signal raising the temperature of a loudspeaker and reducing the strength of an adhesive joint near the voice coil. A sudden high-excursion producing explosive input signal (say a drum rim shot) accelerates the coil. The various conditions cited cause very high sudden stresses in a weakened joint resulting in complete or partial failure. This example is meant to illustrate the complexity in combined failure mechanisms which must be dealt with.

The matter of what is being controlled to ensure safe system performance differs from manufacturer to manufacturer [Ref. 4]. The main functions that are typically chosen for control are discussed below.

1. **Amplifier gain.** The gain of the amplifier can be reduced as maximum system output is approached. This can affect the various system channels (typically two) independently or together.

2. **Peak limiting.** The peaks of short-term transient output can be limited in various fashions when they exceed safe limits. This is usually a protection from over-excursion and avoids stress and damage to the moving system.

3. **Dynamic frequency response tailoring.** When used, this measure typically rolls off output at the frequency extremes to conserve available amplifier power for the middle registers. At low frequencies, over-excursion protection is again provided. At high frequencies thermal protection can be provided by reducing the normally provided amplifier boost used to equalize the upper two octaves of constant directivity horn designs.

4. **Crossover frequency shifting.** At high input levels the crossover frequency can be shifted upward, taking program away from the more delicate high-frequency driver and directing it toward the usually more robust woofer.

The control methods that cause the greatest concern are those which alter the spectral balance, or frequency response, of the system. At some point, enough of an alteration will be audible to a degree that most listeners would notice and judge undesirable. This can be imagined from the circumstance of going to a home music system and rolling off bass and high frequencies. It might also be imagined that a scheme that involved altering the general level of the woofer and high frequency section in a non-unison fashion could also prove unpleasant if done to any appreciable degree.

The condition of shifting a crossover frequency to a value more conducive to greater protection is a rather complex situation to definitively comment upon. In order to be effective, a shift of a half octave (a factor of 1.41) or more would be required. A number of loudspeaker behaviors would need to be well enough controlled in order to not be audibly objectionable. This would include:

a. smooth response over the alteration range;
b. sufficiently behaved phase characteristics to allow summing the net response well;
c. off-axis response (i.e. "polar" patterns) that don't change too abruptly over the desired alteration range.

Adequately good behavior of all these matters would normally be difficult to achieve over an appreciable frequency range and would make this protection method a chancy one at best.

The most workable protection methods are the ones that involve carefully done overall compression (uniformly applied to the whole system to avoid low-high spectral imbalance) and peak limiting done in the most audibly graceful manner achievable. It is felt that these "bread-and-butter" approaches, when done in a sophisticated and audibility-conscious manner, offer a legitimate means of providing a high degree of protection without undue compromise.

The Future of This Technique

In the future there is little doubt that controlled systems will become both more widespread and sophisticated. However, certain complicating and restrictive matters will be favorably modified or eliminated. Creative thinking and creeping Darwinism* are bound to exert their influence to elevate the general usefulness of this class of system.

In virtually all cases, current approaches presume a "model" for the behavior of components set into a specific system. Based on this model the controller exerts programmed input voltage alterations based upon determined ultimate output capabilities. This model is essentially built into the control electronics which then keeps track of the loudspeaker's input voltage and frequency. It then adjusts them in a programmed manner designed to keep the loudspeaker out of dangerous territory. This entire process is very

*Left alone, solutions to acoustic problems will eventually be resolved by a creeping Darwinian process: better solutions will occur in use until they eventually become the norm.

interconnected and is typically applied to a particular set of parts used in a well defined manner. Some of the specific matters that can determine the nature of the loudspeaker system model are as follows. (Note that these statements presume a two-way vented-box-format system. This is the most common type encountered.)

1. **Box characteristics**
   a. volume;
   b. tuning frequency;
   c. thermal insulating properties;

2. **Woofer characteristics**
   a. Thiele and Small (operational) parameters;
   b. excursion (cone travel) limitations;
   c. thermal input power capacity;
   d. changes in characteristics at elevated inputs;
   e. strength-of-materials limits;
   f. crossover frequency;

3. **High frequency section characteristics**
   a. excursion limitations;
   b. thermal input power capacity;
   c. changes in characteristics at elevated inputs;
   d. strength-of-materials limits;
   e. crossover frequency;
   f. acoustic impedance nature of the specific horn.

Two observations that come from this complex set of characteristics are that extensive and detailed testing is needed to arrive at the best controller dynamics and that the controller is intimately connected (dedicated) to the exact nature of the loudspeaker system. These observations should suggest some possible future directions. A third observation is that what is being dealt with is a combination of subsystems. The box and woofer, when treated together form one subsystem. The high-frequency section is a second subsystem usually contained within the low-frequency subsystem. Together these two sub systems, each requiring individualized but coordinated control, form the total system.

Although a starting point for determining appropriate controller operating dynamics are the "generic" power ratings of the components involved, a considerable amount of testing is required to reflect the influence of system details and the complex interactions that take place under actual use. "Actual use" is a complication within itself as the nature of an input signal can be very diverse and difficult to categorize because music and sonic events are by their very nature diverse and changing.

The generic power ratings used on components and systems (typically assessed using band-limited noise inputs) are useful for making comparisons but they are not sufficiently detailed and diverse enough for the highly sophisticated task of controlled system design. As a result, extensive testing using varied music signals is or should be used to set proper steady-state and transient controller characteristics. With time and perspective, it is suspected that improved ways of gathering endurance information will be developed. Perhaps data will be able to be gathered in a way which distills the number of variables to a more fundamental and accessible set.

Improved loudspeaker data gathering, as used to define the loudspeaker model, can only contribute to increased growth in the application of the technique. This should lead to greater diversity in the combinations of subsystems that can be chained together to form total systems.

Controlled systems are currently in a constantly evolving condition with new entries periodically appearing. This is a result driven by the basic merit behind the idea. In a sense, the concept began decades ago with simple mechanical relays and fuses. It has progressed to specialized systems with dedicated controllers whose control functions and general philosophy vary between manufacturers. The persistence of a good idea will cause continued refinement in the mechanisms of control. It is also expected that more sophisticated ways of assessing loudspeaker characteristics will result in a greater variety of systems suited to ever more general use.

References

1. A.N. Thiele, "Loudspeakers in Vented Boxes: Parts I and II." **Journal Audio Engineering Society,** Volume 19, PP. 382-392, (1971 May); PP. 471-483 (1971 June).

2. Clifford A. Henrickson, "Heat Transfer Mechanisms in Loudspeakers; Analysis, Measurement and Design." **Journal Audio Engineering Society,** presented at the 80th Convention (1986 March).

3. R.J. Newman, "Do You Have a Sufficient Quantity of Acoustical Benzin? — Aspects Related to the Significance of Diaphragm Excursion." **Journal Audio Engineering Society,** presented at the 80th Convention (1986 March).

4. M.T. Miles, "An Electronic Loudspeaker Enhancement and Protection Device."Journal Audio Engineering Society, presented at the 84th Convention (1988 March).

SPECIAL NOTE TO THE READER

The EV "PA Bible" and this addition have been prepared to help you solve your PA problems. Let us know if you have any other areas in mind for us to tackle. If you don't have a copy of the "Bible" and would like to,

You may call, write or E-mail any comments to:

E-V "PA Bible"
Electro-Voice, Inc.
600 Cecil Street
Buchanan, Michigan 49107

Outside the USA: 616/695-6831
Fax: 616/695-1304
E-Mail: www site: http://www.eviaudio.com

ELECTRO-VOICE, INC., 600 Cecil Street, Buchanan, Michigan 49107
MANUFACTURING PLANTS AT ■ BUCHANAN, MI ■ NEWPORT, TN ■ SEVIERVILLE, TN ■ OKLAHOMA CITY, OK ■ GANANOQUE, ONT

■ Litho in U S.A
Form 3211