Guide to

ELF

Systems

A New Era in Bass Reproduction

VERSION 1.3

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FORWARD

The problems encountered by anyone who has tried to reproduce tight, clean, realistic sound in the bass range are not trivial. The bass range presents the most difficult performance requirements for a sound reproducing system. One reason why the bass range is so important is that it contributes more to the sense of loudness than any other part of the sound spectrum. It provides the foundation upon which the total quality of the sound rests. When the bass is solid and realistic the resultant sound is usually perceived as being very good to excellent: when it is weak and ill-defined, the perceived quality suffers, even if the rest of the audio range is reproduced with great clarity and definition.

Edward M. Long

Theory to characterize ported loudspeaker systems and optimization utilizing high order alignments have led to the availability of designs which have significantly improved low frequency response. Unfortunately the cost has been deterioration of the phase response and the consequent smearing of the arrival times of these now audible low frequency sound components. With the ELF technique we do not degrade the phase response while extending the frequency response.

Ronald J. Wickersham

ELF is a fundamentally new approach to an old problem of accurately reproducing bass frequencies. This guide is intended to explain and share with you some of the work done in this technology to date.

The measurements in this guide were performed with a TEF-20 in a reasonably controlled environment and a great effort has been made to make the most meaningful measurements possible within the scope of the instrument’s ability. The fundamental reality of how and why an ELF system sounds correct to the ear is extraordinarily difficult to measure and express with total precision. The very concept of the different measuring techniques and underlying mathematical formulas of the instrumentation itself, used to perform the measurements, is not universally agreed upon, and work in these areas continues by the most advanced minds of today. The simple measurements found in this guide do however highlight some basic differences inherent in the ELF approach and we do draw conclusions based upon the measurements, the theory behind ELF, and our listening experiences. We continue to work in this area and invite review, comments, and suggestions in our pursuit of meaningful ELF measurements and explaining the benefits of the ELF approach ever more precisely.

James P. Wischmeyer

SECTION 1

INTRODUCTION

Although ELF has, at first, found its way into many large and highly visible applications, the basic ELF technology applies to "all" types of audio systems. We have designed this guide with the hopes of addressing this wide variety of applications and interest levels ranging from the audio professional to the home enthusiast.

ELF systems are currently in use in a number of performing arts centers, portable concert reinforcement systems, musical instrument systems, professional recording studios and homes.

THE INVENTORS

The ELF inventors, Ron Wickersham and Ed Long, well known in the audio field, are responsible for some of the most significant audio breakthroughs of the past several decades, including Time Align® Loudspeakers, Near Field Monitors™ and PZM® Microphones.

WHAT IS ELF

ELF is an acronym for "Extended Low Frequencies". It is a fundamentally different approach to reproducing bass frequencies from a loudspeaker by extending the low frequency range farther down and with greater accuracy than has ever been done before. In the larger historical view of audio developments, the ELF technology represents as significant a contribution to low frequency sound reproduction as the introduction of the acoustic suspension principle over 40 years ago by Edgar Villchur in 1953.

WHAT IS A SUBWOOFER

A subwoofer is a term given to a loudspeaker that is made to operate in the lowest audio range, typically from 80 or 100 Hertz down as far as the design will allow. Response to 20 Hertz is often the ambitious goal of the larger conventional subwoofers, but is seldom realized. Recently there is more and more interest in adding subwoofers to audio systems because adding these subwoofer low frequency capabilities to a system adds a feeling of power and quality to the system. ELF type subwoofers offer realism and musical richness as well as the feeling of power, even when the music, instrument, or voice is not thought to have significant content in the range of the subwoofer.

BASIC ELF SYSTEM CONNECTIONS

The ELF technology, when applied to a low frequency loudspeaker system, is referred to as a subwoofer system. It requires a separate power amplifier channel dedicated to powering the ELF loudspeaker. An ELF electronic unit is required to drive the power amplifier input. This electronic unit may have various features but at its heart is the "integrator", the circuit that makes it uniquely ELF.

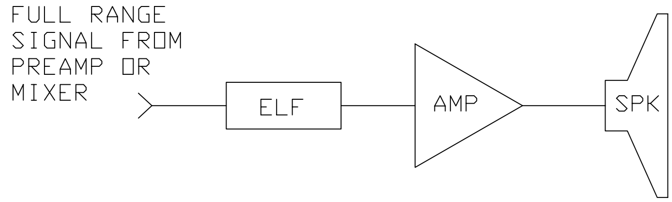


Fig 1. Simple view of ELF system connections.

No connection is required from the amplifier output back to the ELF integrator. This feedback connection sometimes used by other designs is not required with ELF because the ELF system relies on a loudspeaker operating below resonance where the loudspeakers behavior is predictable and uniform. The ELF electronics can control and protect the loudspeaker without the use of sensing devices or monitoring the amplifier's output.

ELF technology allows multiple amplifiers and loudspeakers to be operated from a single ELF integrator unit.

IMPORTANT: For best results the input to the ELF integrator should be a full frequency range signal and not a low pass filtered signal as may sometimes be available when connecting into various systems.

THE ELF INTEGRATOR

An integrator is a common electrical circuit widely used internally in electronic devices. In its basic form it consists of an op-amp with a capacitor in series with the feed back loop. The resistor in parallel with the capacitor is to keep the integrator from trying to integrate to too low a frequency where the circuit will overload due to DC voltage offsets of the op-amp .

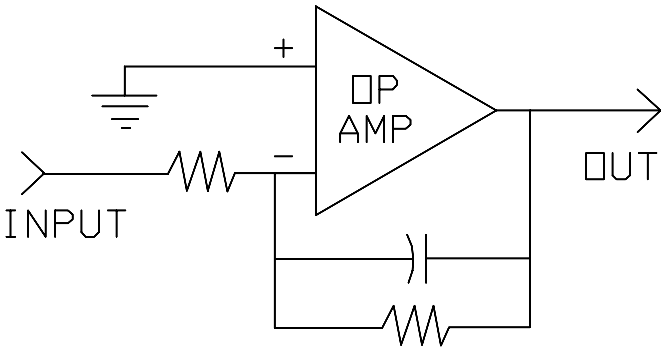


Fig 2. Simple diagram of an integrator.

The frequency response of this circuit rises at a rate of 6 dB per octave as the frequency is decreased. The ELF circuit uses two integrators in series resulting in a 12 dB per octave rise as frequency is decreased. This is the ELF dual integrator, although sometimes referred to as just the ELF integrator. An integrator has uniform phase shift with respect to frequency. A single integrator has 90 deg of phase shift and a dual integrator has 180 deg of phase shift.

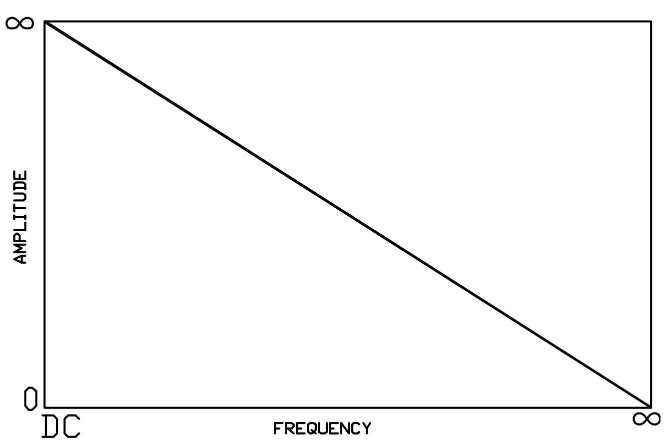


Fig 3. Theoretical frequency response of a dual integrator.

integrator $e_0 = k\int e_1 \, dt$

dual integrator $e_0 = k\iint e_1 \, dt$

e_1 = input signal

e_0 = output signal

t = time

k = constant (determined by circuit component value)

The mathematical response of an integrator will continue to raise the level as the frequency is lowered all the way down to DC, where the gain is infinite (see fig.3). Of course, you cannot build an integrator that integrates down to DC but in some specialized applications (such as astronomy and nuclear physics) liquid helium cooled integrators are operated very close to DC providing very high gain for amplifying very small signals. The ELF-1 integrator will integrate to about 2 Hertz and there is an 8 Hertz filter added to protect the system.

This simple idea "a dual integrator" has never before been used in this way in conjunction with a loudspeaker.

THE LOW PASS FILTER (conventional approach)

All conventional systems use low pass filters to roll off the high frequencies from the bass loudspeaker driver. This low pass filter is one half of the crossover between the low to mid frequencies. This is a most basic and common aspect of all non ELF systems. All low pass filters introduce, by their very nature, frequency dependent phase shift. The phase shift introduces a significant signal delay which is added to the sound, and this delay can make the bass appear to come later than the upper range sound. This explains why conventional systems sound like the lowest frequencies are coming from very far behind and not connected musically.

HOW AN INTEGRATOR IS DIFFERENT FROM A LOW PASS FILTER

The main difference between an integrator and a low pass filter is in the total system delay presented to the listener by the electronics shaping its response. An integrator/loudspeaker combination has short and uniform signal delay and a low pass filter/loudspeaker combination has long and variable signal delay, which becomes longer as the low pass filter cutoff frequency is reduced.

All conventional subwoofer systems use a low pass filter to remove the high frequencies from the loudspeaker. A passive crossover can be used between the power amplifier and the loudspeaker, or an electronic crossover can be placed before the power amplifier. The result is the same either way with the low pass filter adding considerable phase shift and therefore delay which increases as the filter cutoff frequency is reduced.

The ELF subwoofer system uses the ELF integrator to extend the low frequency response and to remove the high frequencies from the loudspeaker. This frequency and phase response of the integrator is complementary to both flatten the loudspeakers response below resonance and correct the phase response in the right direction to produce a short and fixed total signal delay of the system.

The actual time offset is small and fairly constant and reasonable to physically align. The graph in figure 5 shows the frequency response and phase response of the integrator. The flatter phase line on the right is the phase response of the integrators and the phase shift rise (increase in phase shift and therefore delay) on the left is the 8 Hertz hi pass filter used to roll off the rising integrators. The effect of the filter can be seen to a diminishing degree all the way to the upper range on the right. Compare this to the frequency and phase response of the low pass filter in figure 6.

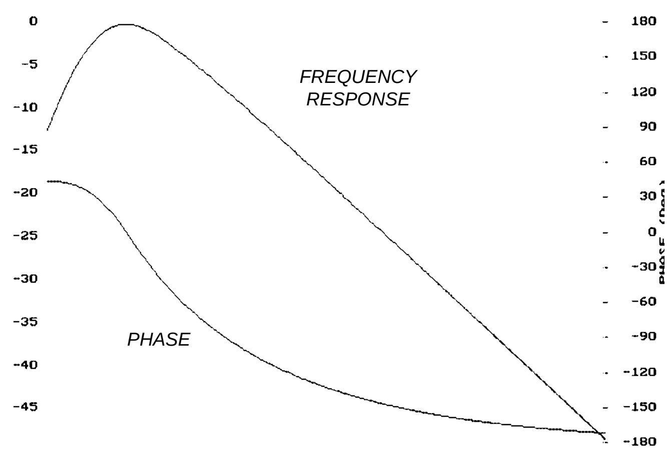


Fig 5. Frequency and phase response of the ELF dual integrator .

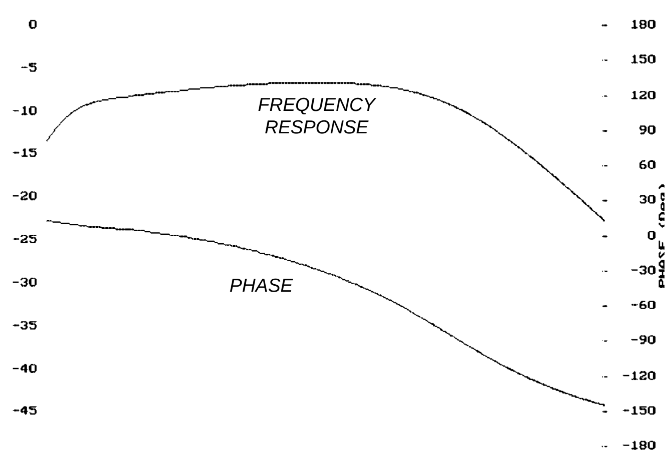


Fig 6. Frequency and phase response of an 80 Hertz low pass filter .

The important and noteworthy aspect of these two graphs is the amount and direction change in the phase response.

THE DIFFERENTIATOR / LOUDSPEAKER

A loudspeaker by its very nature, when operating below its resonance inside a sealed box, responds as a dual differentiator. This very predictable behavior below resonance is the key to the ELF system.

differentiator $e_o = k \frac{d e_1}{d t}$

dual differentiator $e_o = k \frac{d^2 e_1}{d t^2}$

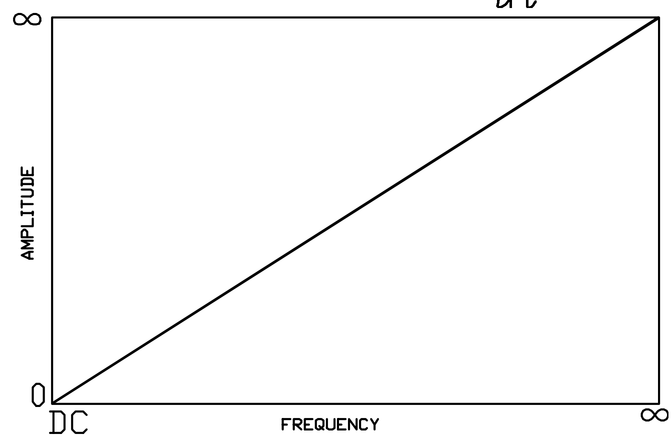


Fig 8. Theoretical response of a dual differentiator.

The mathematical response of a dual differentiator will continue to raise the level by 12 dB per octave as the frequency is raised all the way up to infinite frequency, where the gain is infinite too. Of course, you cannot build a differentiator that does this, but below resonance a loudspeaker follows this behavior precisely. In figure 9 an EL-18 Loudspeaker in a 3 cu ft sealed box is measured in half space. The 12 dB/octave roll off below resonance is typical of a loudspeaker in a sealed box.

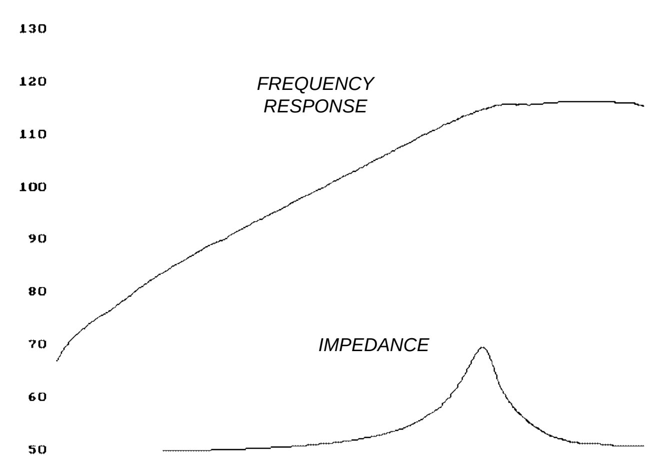


Fig 9. Typical response of a loudspeaker in a sealed enclosure.

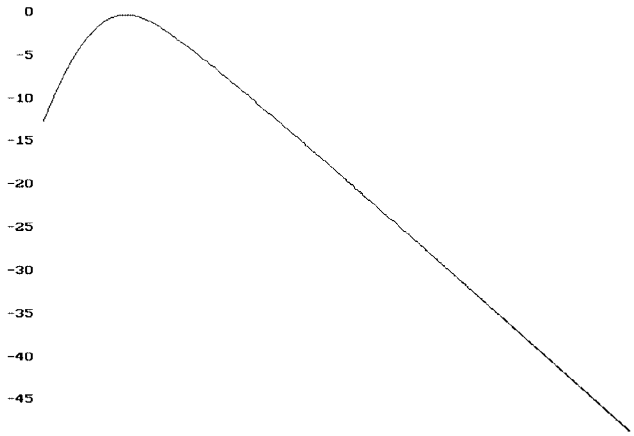


Figure 10. Shows the electrical response of the ELF output of the Bag End ELF-1 set to full low frequency bandwidth of 8 Hertz.

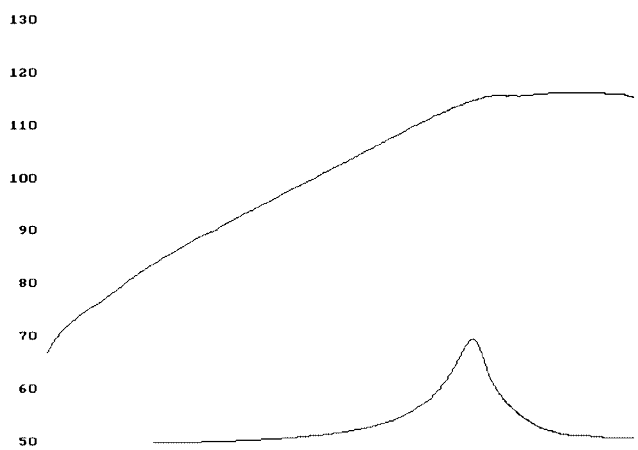


Figure 11. Shows the acoustical response of the Bag End S18E loudspeaker system measured in half space.

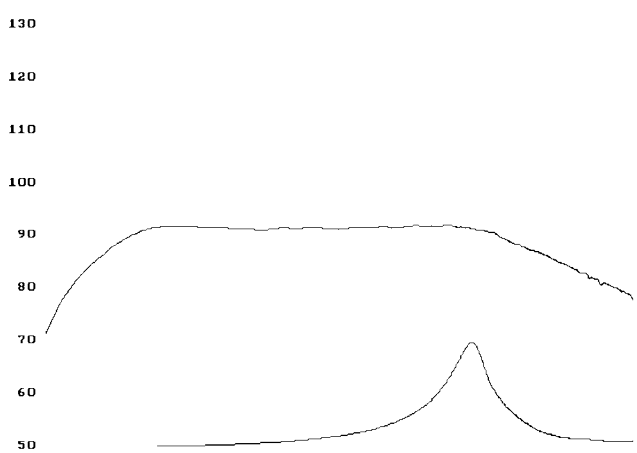


Figure 12. Shows the total acoustical response of the ELF-1 dual integrator combined with a S18E loudspeaker system measured in half space.

ELF SYSTEM FREQUENCY RESPONSE

The acoustical response of the ELF system is a combination of the ELF integrators response and the loudspeaker in the enclosures response.

ELF SYSTEM IMPEDANCE

It can further be seen in Figures 11 and 12 that the impedance of the ELF loudspeaker is uniform below resonance. Figure 12 shows at resonance the frequency response is already 1 or 2 dB down and is rolling off above. Below resonance the uniform load presented to the amplifier is an ideal load for the amplifier to drive. Contrast this to the wild impedance curves presented to amplifiers by conventional ARS systems. (Assisted Resonance System or any bass cabinet which uses both the front and rear radiation of the speaker ,ie. any ported enclosure) Since any system wants to favor the notes around its resonant frequency, the ELF minimizes this by having its response begin to roll off just before resonance.

It has been known for many years that transducers do not perform well with resonances within their operating range. This is well understood by designers of other transducers such as microphones, phono cartridges, hi frequency drivers, ect. Yet most non ELF bass system designs include one or more resonances right in the middle of their operating range. This causes the system to favor playing the notes around resonance. It is not possible to equalize away the tendency to favor the frequencies around resonance and reproduce them equally with the other frequencies.

With the uniform ELF impedance, and operating below resonance, each note is reproduced evenly and with the same emphasis, not favoring any particular frequency.

WHY RESPOND DOWN TO 8 HERTZ

Why respond down to 8 hertz? The answer is simply because the sonic quality throughout the audible bass range is improved by extending the frequency response, and thus flattening the phase response, to the highest degree possible.

The ELF is a no compromise technology with an inherently great degree of flexibility. By extending the frequency response down a full octave below what is considered to be the lowest musical note, low C on a pipe organ (16 Hz), we improve the phase response and thus reduce the delay throughout the entire audible bass range. This excellent phase response and inherently short signal delay is why subjectively the ELF system is known for its quick, tight, and musically connected bass sound throughout the entire bass range,

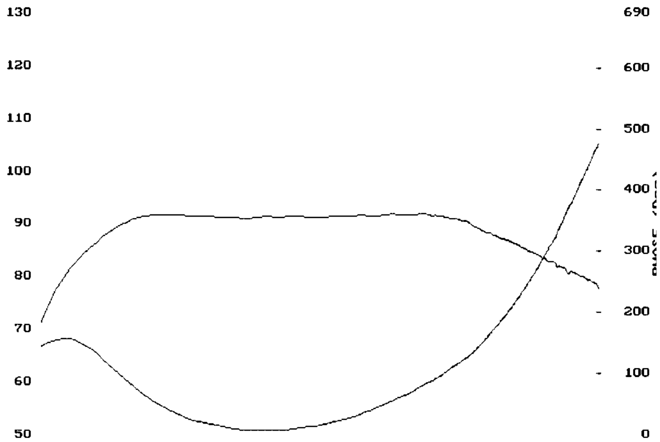


Fig 13. Frequency & Phase of ELF speaker.

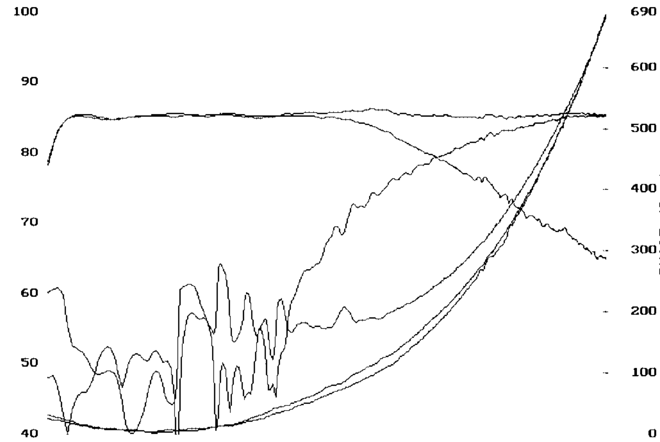


Fig 17.

not just the lowest frequencies. With its good phase response as well as its extended frequency response it can much more accurately represent the actual recording or the character of the sound being fed into the system than conventional designs and their long signal delays.

In figure 13 the frequency and phase response of the ELF-1 with the S18E loudspeaker system measured in half space shows the 6 dB down point at 90 Hertz with a phase shift of 180°. The receive delay setting on the TEF is 20.7 ms.

BLENDING AN ELF SUBWOOFER INTO THE UPPER RANGE LOUDSPEAKERS

At Bag End, and through a variety of our associate testing sites, we have been listening, learning, measuring, and designing ELF systems for over 10 years. For those of you without an acoustical laboratory or extensive test equipment it will be reassuring to know that with a little practice and your good ears you will be able to match up any ELF subwoofer to any upper range system without extensive measuring equipment. We, and others, have done this by listening and afterward we verified our settings with measuring equipment and found they measured correctly as well. ELF improves your ear's ability to quickly and accurately adjust the relative level between the subwoofer and the upper range system. If you have instrumentation this combined response is easy and interesting to measure.

In figure 17 it can be seen that the frequency response is +/- 0.5 dB from below 20 Hz to above 200 Hz. The crossover frequency is 6 dB down from the combined response as it should be. The phase of the two sections follow closely (as you would expect for a 6 dB down crossover point) and each section adds correctly to produce a flat frequency response.

Figure 17 Shows frequency response and phase response of an S18E and a TA12 loudspeaker system both individually and their combined response measured in half space. This acoustical blend is achieved with the ELF-1 settings as follows:

High pass frequency............................	120 Hz
High pass gain.....................................	unity
High pass polarity................................	+
ELF cutoff..	8 Hz
ELF gain...	+8 dB
ELF polarity...	-

When using S18E ELF enclosures these settings are recommended as a good starting point. The relative gain between ELF and the High Pass output will need to be adjusted for the quantity and type of loudspeakers used.

The 120 Hz filter is -3 dB at 120 Hz. The -3 dB point is an accepted standard way to specify filters so we use this method, but it should be noted that what is actually required is a -6 dB crossover point when coherent acoustical addition is occurring. To determine the -6 dB frequency, multiply the -3 dB frequency by 0.75.

As the upper limit of the ELF system is determined by the system resonance and significantly by the box size, the high pass filter frequency setting required will change with different ELF loudspeaker models.

Note: The + polarity on the high pass section and the - polarity on the ELF section on the ELF-1 will both produce a positive asymmetrical output at crossover when a positive assymetrical input is fed into the ELF-1.

ELF UPPER FREQUENCY CUTOFF

The upper response of an ELF system is primarily determined by the system resonance which is determined by the stiffness of the air in the enclosure and by

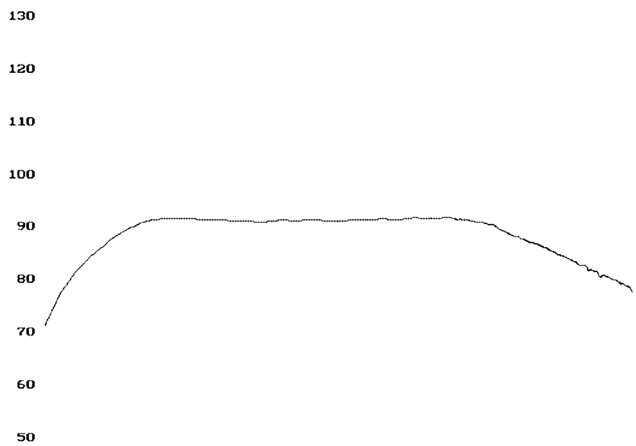


Fig. 19 Shows our S18E loudspeaker system with ELF integration.

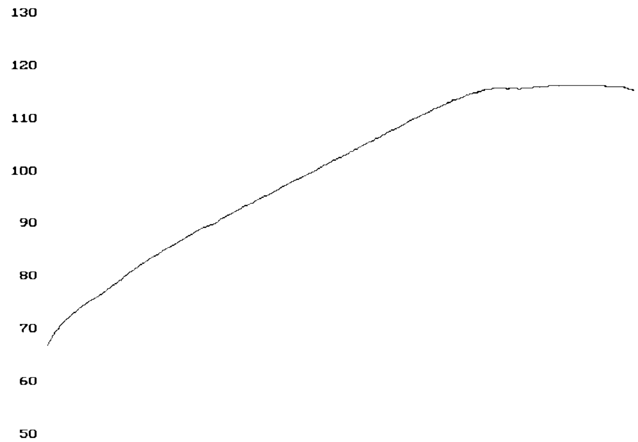


Fig. 21 EL-18 in S18E enclosure dB calibrated to dBSPL. Input signal 28V. (100 watts)

the moving mass of the driver cone and voice coil assembly. We have chosen a 3 cubic foot enclosure for our standard S18E enclosure with an upper limit of -6 dB at 90 Hertz as shown in figure 19. Several additional enclosure sizes are offered or can be built to produce a wide variation of upper cutoff frequencies with the corresponding change in overall efficiency.

HOW TO DETERMINE ELF OUTPUT SPL LEVELS

The ELF SPL output level is best determined by looking at a calibrated frequency response graph and determining the SPL level at the frequency of interest. As the level changes with frequency, a single number is not useful for design and comparison to other systems. The most power is required at the lowest frequency, therefore you may calculate the power and number of drivers required for the lowest frequency desired by simply referring to a calibrated frequency response graph for the specific driver and enclosure combination as shown in figure 20, 21, or 22.

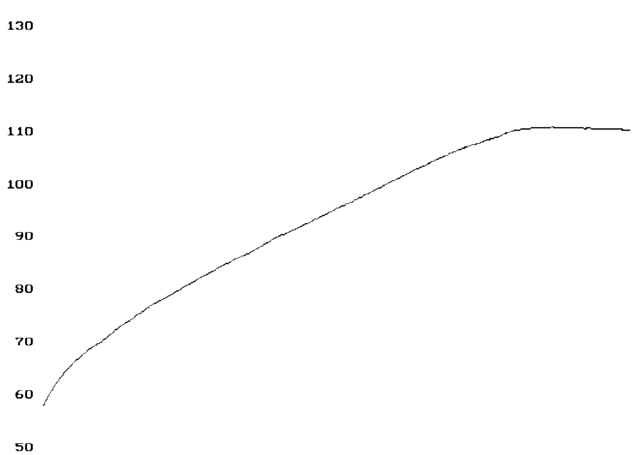


Fig. 20 EL-10 in S10E enclosure dB calibrated to dBSPL. Input signal 28V. (100 watts)

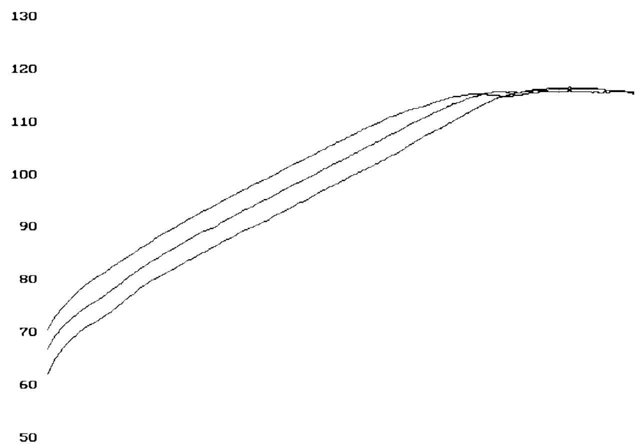


Fig. 22 EL-18 in S18E-LT (2 ft³), S18E (3 ft³), and a sealed S18B (6 ft³) enclosures dB calibrated to dBSPL. Input signal 28V. (100 watts)

Figure 21 and 22 show first the EL-18 in a 3 cubic foot enclosure and then in comparison of 2, 3, & 6 cubic foot enclosures. It can be seen that the larger the box and thus the lower resonance (and lower high frequency cutoff point when integrated) also naturally adds level to the system and thus a system designer has the additional design tool of trading off the upper crossover point and smaller cabinet size with output level. The higher the upper crossover frequency the less sensitive the system will be and the lower the upper crossover frequency the more sensitive it will be. With this trade off in sensitivity all designs will play to an equally low frequency.

SENSITIVITY COMPARISONS

The mid-range sensitivity ratings of bass drivers supplied by many loudspeaker manufacturers may not be a useful specification for determining the actual performance of the loudspeaker in the low frequency region. Many companies, as of this date, rate low frequency drivers above 100 Hertz. This specification may not be as useful in determining the actual performance of a subwoofer system in its main operating range of 20 to 100 Hertz.

Our method to determine sensitivity is to place the loudspeaker in a sealed box, specify the box volume, measure the sound pressure level at a specific distance, (1 meter) using a specified voltage input, at a specified frequency, into the known impedance, in a half space environment.

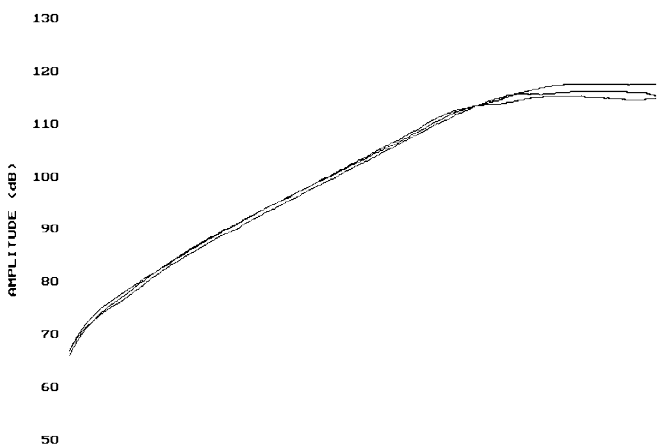


Fig. 23 Sensitivity comparison of 3 loudspeakers.

Shown in figure 23 are 3 18" drivers with their frequency response curves overlayed. Measurements were taken in a half space environment throughout the entire frequency response range of the measurement. The measurements were taken on the same day in the same box and with the same equipment and test signal.

It can be seen by the frequency response curves that the sensitivity in the bass range is within one dB, yet above resonance the levels have more variation. 2 of the 3 speakers tested, were made by other high quality U.S. speaker manufacturers, each have similar sensitivity ratings in their specifications and are generally accepted as the highest sensitivity 18" drivers available. The 3rd speaker in this comparison is the Bag End EL-18 driver.

Generally speaking, the efficiency of ELF when compared to ARS (Assisted Resonance System) designs allows one to say that in a narrow frequency range the ARS system is louder or more efficient, but not over the entire bass range and the ARS efficiency is obtained at the cost of degrading the sound quality. Roughly speaking, for an ELF design to equal the output of a conventional ARS ported design, in the narrow range of the port's efficiency, you will need a little more ELF cone area and/or more power, but the actual total internal volume of the cabinets will be considerably less. In addition, the ELF design will respond more evenly, go lower, and sound much better. So it may take a little more power for ELF to equal the output of an ARS in the narrow range of its port's resonance, but with a smaller cabinet size.

Generally and subjectively speaking, the ELF bass from a pair of S18E enclosures will have a very pleasant sound with tight, low bass and be very musical sounding. It does not have the loud boom in the upper bass range often found in vented systems. Once you become accustomed to the precision of ELF sound there is no turning back to a non ELF system.

ELF CONCEALMENT™

It is preferable to install sufficient loudspeakers and amplifiers to reproduce the sound level required. When the system is limited in capacity or an unexpectedly large signal is present, concealment is a type of protection circuit with a very musical and pleasant way of sounding even when well beyond its protective threshold. It is not part of the ELF dual integrator itself but an additional complementary ELF technology, providing absolute protection in a natural and musical way and actually concealing the fact that it is protecting the system. The ELF concealment performs dynamic control of reducing the low frequency extension. It will allow the system to play with the upper bass notes unaffected while protecting the system from overload caused by playing the lower notes louder than the amplifier and/or loudspeaker can reproduce safely and undistorted. It is very important that the concealment threshold is set to the correct level for it to function correctly and prevent amplifier clipping and/or speaker overload. For general non critical studio applications it is very acceptable for the concealment threshold light to flash intermittently but if it stays on to full intensity it means that you either have the threshold set too low or, if the threshold is set properly, that you require additional speakers and amplifiers for your application. For critical studio and mastering lab monitoring applications the concealment threshold should not be crossed as this will reduce your ability to hear what is actually being recorded. In addition, when the concealment threshold is crossed, it is changing the frequency response down low and degrading the phase response both at the lowest frequencies and into the middle bass range as well.

ELF CUT OFF FREQUENCY AND VARIOUS APPLICATIONS

For certain applications you may not want to operate the system down to 8 Hertz. The low frequency limit may be adjusted by selecting an appropriate ELF cutoff frequency. The phase response is degraded by cutting off the frequency response at a higher frequency. This higher cutoff may be needed, for example, to filter out the low frequency rumble (concert hall noise, air-conditioning, etc.) commonly found on many of todays CD recordings.

Recording Studios and Mastering Labs

When utilizing ELF in recording and mastering playback applications, the 8 Hertz response will insure proper treatment of the full spectrum. In addition, you should always note when concealment is taking place and not perform your final mix past the concealment threshold of your ELF system. With the popular trend of adding subwoofers in homes and theaters, the low frequency problems found on CDs and other recordings will need to be corrected in the recording and mastering stages so that the full benefits of a wide band response can be realized in the playback.

Commercial Cinema and Home Theater

When utilizing ELF for cinema and home theater systems you may have to raise the ELF cutoff frequency to 20 or 30 Hertz to reduce low frequency noise found on many recordings. Allow the concealment to perform its function and occasionally monitor the concealment by observing the LED indicator.

High Fidelity Home Audio

When utilizing ELF in a very fine home audio application it should be treated as a studio application. (refer to studio section) In addition, you have the added option of adjusting the ELF cutoff to any higher frequency required above 8 Hertz. This enables you to reduce low frequency noise found on some recordings.

Electric Bass Guitar

When utilizing ELF for electric bass guitar systems, depending on the instrument, you may have to raise the ELF cutoff frequency to 20 or 30 Hertz to prevent low frequency string handling noise. Allow the concealment to perform its function, and occasionaly monitor the concealment by observing the LED indicator.

Electronic Keyboards and Electronic Organs

When utilizing ELF for electronic keyboard systems, most systems will work well with an 8 Hertz ELF cutoff frequency. Allow the concealment to perform the protection function and occasionaly monitor the concealment by observing the LED indicator.

Electronic Drums

When utilizing ELF for electronic drum systems, most systems will work well with an 8 Hertz ELF cutoff frequency. Allow the concealment to perform the protection function and occasionaly monitor the concealment by observing the LED indicator.

PA Systems

When utilizing ELF for general PA systems, you may have to raise the ELF cutoff frequency to 20 or 30 Hertz to prevent low frequency noise from the microphones. Allow the concealment to perform its function but always monitor the concealment by observing the LED indicator and refer to the concealment section for a thorough understanding of this function.

General

In general you should allow the ELF hi pass cut off to be set as low as possible without allowing too much low frequency noise into the loudspeakers. Remember you are raising the ELF cut off to improve the sound quality by removing the noise, not to protect the amplifiers and loudspeakers from low frequency damage as the concealment will provide that function.

ELF CONTOUR

Designed primarily for large arrays, the contour may be used as an additional tool to shape the lower end of the frequency response for any system application. Adding contour will cause a rise in the frequency response just before the low frequency rolls off. The contour occurs just above the ELF cutoff frequency. Long arrays, perhaps 20 to 40 feet, are required for the optimum output and directivity performance of any bass system. These arrays naturally have more output in the upper bass range due to the gain added by the directivity of the array. At lower frequencies you will not receive this additional gain. Contour will then allow you the option of adding a boost at the lower frequencies to flatten out the total response of the array.

ACCURATE REPRODUCTION AT SOFT LEVELS

We are still working on documenting exactly why, but it is clear to those familiar with ELF that it is capable of reproducing clear audible bass notes at very low volume levels. One theory is that the conventional ARS (Assisted Resonance Systems) because of the several resonances within the systems range, takes an amount of time for the energy to build up within the system before it “switches on”. It may be that part of what is often assumed to be the simple Fletcher Munson loudness curve of the human ear is actually both the Fletcher Munson curve and the characteristics of these common ARS bass speaker designs. You will find the ELF system requires much less, if any, loudness compensation as it is turned down to a whisper.

STEREO SUBWOOFERS

With ELF, stereo subwoofers in certain applications can become desirable because of the inherent ELF fidelity and precision the source can be perceived to have direction and because the ELF's alignment and musical connection to the upper stereo image is excellent. This may be most effective in larger rooms and outdoors.

SIMPLE TWO WAY ELF SYSTEM CONNECTIONS

The ELF subwoofer requires a separate power amplifier to operate. This is called a 2 way system or biamping in its simple form. A typical upper range speaker may be a 2 way passively crossovered system such as the Bag End Time -Aligned® TA12 or TA15. The ELF integrator is designed to universally blend an ELF subwoofer into any other system as well. For passive upper range systems use the connections in Fig 15.

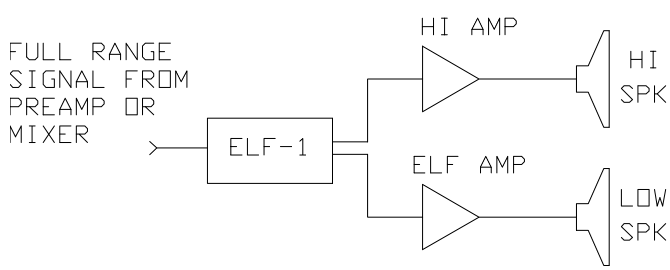


Fig. 15

MULTI-WAY CONCERT ELF SYSTEM

For larger concert systems requiring 3 or 4 way upper range, connect the output of your mixer or final equalizer to the input of the ELF-1 then connect the high pass output of the ELF-1 to the input of your existing electronic crossover as follows in Fig 16.

In concert systems we do not recommend adding the ELF onto a sub group mixer output as it is often done with conventional subwoofer systems. By allowing the lower portion of the upper range to run down into the ELF range it is most likely that you will have a large bump or dip in the upper bass frequency response. The likely resulting poor frequency response and/or poor phase response blend between the ELF and the upper range loudspeakers may cause you to use more overall EQ than otherwise necessary with diminishing returns and reduced ELF benefits.

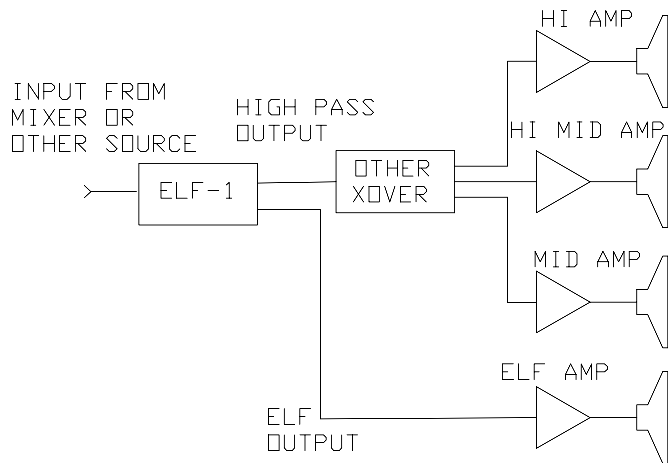


Fig. 16

In addition, the quick response and pleasant sound quality of the ELF will allow you to extend the range of the entire mix and not just a few select channels without the low frequency problems often associated with this approach.

Further benefits are provided by utilizing the high pass section CVR Limiter™ as it is a unique feature of the ELF-1, particularly good sounding, and a design circuit not common to other limiters. See section 4, ELF-1 circuit design description, for additional information on the CVR Limiter.

For large sound systems utilizing large ELF arrays refer to the section on "ELF Contour" for information on contouring long ELF loudspeaker arrays.

MEASUREMENT TECHNIQUES

When the test space is referred to as "half space" the loudspeaker under measure is buried so that the baffle is flush with level ground at least 100' feet away from the nearest tree, building, or any obstacle. The microphone is mounted with a small boom stand directly over the loudspeaker at 1 meter from the speaker baffle.

The low frequency tests have a frequency resolution of 2.8 Hertz, unless otherwise specified.

Phase measurements are relative but they do correctly indicate the phase change and/or phase direction within each measurement.

The small additional roll off below 7 Hertz includes the frequency response of the B & K 4007 microphone used.

The test instrument used in these graphs is a TEF-20, a FFT based instrument. We have attempted to minimize the many artifacts present in the TEF measurement process .

SECTION 2

REVIEW OF BASIC TYPES OF LOW FREQUENCY LOUDSPEAKER SYSTEMS

OVERVIEW

There are two basic types of systems used for producing extended bass response; one is acoustical and the other is electronic. Acoustical systems can be divided further into two general categories: Assisted Resonance Systems (ARS) that rely on wavelength dependent parameters, which require large dimensions, and Mass Loaded Systems (MLS) that are inefficient. ARS include ported passive radiator, tuned chamber and transmission line or labyrinth systems. MLS are generally closed box, stiffness controlled systems. The distinction between these two categories can be blurred if both wavelength dependent parameters and mass loading are combined in a system. Electronically Assisted Systems (EAS) include servo controlled and bass boost types. The problems and limitations associated with these systems are shown in the chart . The ARS and MLS are combined under the heading “NORMAL” and EAS are shown under the heading “SERVO.”

For all systems, the bass driver excursion is greatest at the lowest frequency to be reproduced. For a given diaphragm size, the maximum acoustical output level is limited by the maximum excursion capability of the loudspeaker driver. The excursion in the low frequency part of the range is much greater than at the higher frequencies, infact, for every halving of the frequency, the excursion is 4 times as great. For example, to produce the same acoustical output at 32 Hz (Low C) as it does at 64 Hz with a 1/8” peak to peak motion, the excursion of the bass driver diaphragm would have to be 1/2" peak to peak. The simplest system, which would be a driver operating in a closed box, is constrained by this law of physics.

ASSISTED RESONANCE SYSTEMS (ARS)

These excursion constraints led to the development of Assisted Resonance Systems (ARS) in which the acoustical output is increased beyond the normal limit of the driver excursion by producing acoustical output from a port or multiple ports.

The application of Helmholtz's principles of acoustical resonance was employed to develop ported systems, which in early times were called bass reflex systems. Another type of wavelength dependent system is the transmission line, which in its folded form was called an acoustical labyrinth. Transmission line systems rely on the output from the rear of the loudspeaker driver to assist the output from the front, after passing through a long ducting system inside the loudspeaker enclosure. Transmission line systems are of necessity the largest of the ARS types.

Ported systems have seen recent popularity for a number of reasons. The development of more scientific methods of design, based upon the work of Novak, Thiele, Small, Keele, and others has improved the chances that a design effort will result in a system that behaves as predicted. Ported systems have progressed from simple types to complex, multichamber systems. These latter systems are designed with the loudspeaker driver(s) mounted inside the enclosure and the acoustical output radiated from a single or multiple ports. All of these ARS are large, when they are required to reproduce low frequency sound, because they rely on the acoustical stiffness of the air in the enclosure as well as the mass of the air in the port to tune them to a low frequency. This requirement for large dimensions means that the size and weight of the enclosure is directly a function of the frequency to be reproduced; The lower the frequency the larger and heavier the enclosure must be. The quality of sound produced by ARS is very dependent upon the internal impedance or damping provided by the driving amplifier. The resistance of the connecting cables also can be a significant factor. This latter consideration is very important for systems which require long cable runs from the amplifier to the loudspeaker system.

The variation in impedance of the triple tuned subwoofer is an example of the problem presented to a driving amplifier. Amplifiers work best when the impedance of the load is constant. The interaction of the amplifier's internal impedance and the varying impedance presented to it by the loudspeaker, will affect the amount of power that the amplifier must deliver. It also affects the damping, or tightness of control, that the amplifier can exert upon the loudspeaker system. The upper range response of the system also must be rolled off by a low pass filter. This will introduce a signal delay in the low frequency range because all low pass filters have signal delay. Also, because the rear of the loudspeaker driver diaphragms have no loading at the lowest frequencies, where the ports act merely as vents to the outside of the enclosure, a high pass filter must be added to prevent the loudspeaker drivers from being driven beyond their capabilities and thus produce noise and distortion.

MASS LOADED SYSTEMS (MLS)

This category of system is used for home music systems where efficiency is not very important. The perceived quality of the bass reproduced by many MLS systems is usually booming and under-damped.

CHARACTERISTICS OF ELF AND OTHER SUBWOOFER SYSTEMS

SYSTEM TYPE	**NORMAL**	**SERVO**	**ELF™**
Enclosure size Enclosure weight	Large Heavy	Large Heavy	Small Light
Low pass filter required	Yes	Yes	No
Signal delay varies with design changes	Yes	Yes	No
Separate power amplifier required	Yes	Yes	Yes
Lowest frequency limited by driver resonance and enclosure volume	Yes	Yes	No
Low frequency output limited by driver excursion and amplifier power	Yes	Yes	Yes
Damping	Variable, poor to moderate. Depends upon driver system design, amplifier internal impedance, and cables because system operates above system resonance	Variable,moderate to good, depends upon system design and quality control because system operates above system resonance	Excellent. Independent of driver, amplifier internal impedance and cables
Transient Response	Poor due to long time delay of low pass filter and low damping	Moderate due to time delay of low pass filter	Excellent due to short time delay and high damping
Signal Delay	Long and variable depending on frequency of low pass filter used	Long and variable depending on frequency of low pass filter used	Short and fixed integrators used have fixed delay
Time offset from upper range system	Large	Large	Small
Driver cone mass Voice coil mass Cone area Cone excursion	Usually heavy Usually heavy Depends upon SPL Frequency dependent	Usually heavy Usually heavy Depends upon SPL Frequency dependent	Can be light Can be light Depends upon SPL Frequency dependent

ELECTRONICALLY ASSISTED SYSTEMS (EAS)

The most complicated of all the different types of bass reproducing systems is the servo control type. Servo systems are replete with complicated and interacting parameters which must be monitored and controlled in real time if the system is to work properly. Even the placement of the accelerometer used to monitor the diaphragm motion is not trivial.

CONCLUSIONS

The systems we have examined each have their own particular limitations. The perceived sound quality ranges from poor to acceptable. The size and weight of ARS, the inefficiency of MLS, and the complexity of EAS, were the motivation to find the better technology, ELF.

SECTION 3

ELF-1 EASY GUIDE TO SETUP

GENERAL

The ELF-1 replaces and connects into an audio system in the same way as a 2-way stereo electronic crossover. Inputs and outputs are clearly described on the rear of the unit. For unbalanced operation see wiring instructions on rear of unit.

Remove two mounting screws holding on front security cover to access setup switches.

It is OK to switch the setup switches while the unit is operating so that you can listen to the changes you make.

WARNING : SOME SWITCHES WILL ADD SUBSTANTIAL GAIN TO THE SIGNAL, so until you are familiar with these types of controls, keep your power amp levels low to prevent driver damage.

The system parameter settings are achieved by precise digital settings. Each switch is precisely calibrated, which makes it easy to repeat, maintain, and document the exact parameter settings.

Read each switch section carefully for the precise instructions. Generally speaking, this switching system uses a switch or a combination of switches to add or subtract a value from a particular starting point.

ELF PARAMETERS

ELF CONTOUR - Set switches all down.

The ELF contour switches are designed to tailor the lowest frequencies of very large systems or specific applications.

ELF CUT OFF - Set as required.

With all switches down, the ELF response is flat down to 8 Hertz. For a variety of reasons you may want to limit the low frequency response to a frequency above 8 Hertz. Refer to “ELF cutoff” in section 1. When setting a switch in the up position you will add that switch value to 8. The switch(s) up value plus 8 will be your new low frequency response limit. You may select any combination of switches up for a total low frequency limit from 8 Hertz to 70 Hertz in 2 Hertz increments.

ELF GAIN - Set as required.

The first switch in this group is (+ or -) up for plus and down for minus. This controls whether the rest of the gain switches will be adding or subtracting their respective values from unity gain. Unity gain is calibrated for unbalanced outputs. Balanced outputs add 6 dB to unity gain.

The value switches, 8, 4, 2, 1, & .5 are calibrated in precise dB and add together in any combination when in the up position. The added total value of switches “up” is then either added or subtracted from unity gain depending on the preceding +/- switch. This provides from 0 dB (unity gain) to 15.5 dB of gain or 15.5 dB of attenuation to the input signal.

WARNING: With all gain switches up, if you switch the +/- switch you will get a 31 dB level change.

POLARITY - When connected to amplifiers utilizing pin 2 hot on the XLR input to the amplifier, set ELF polarity to - for most applications. A positive assymetrical input will result in a postive assymetrical output at crossover with ELF polarity set to -.

SUM/DUAL - Set as required (S=Sum “up” / D=Dual “down”)

Both switches must be in the “Sum” position for ELF summed operation. In summed mode each ELF output will contain the same information. The sum feature combines the 2 channels prior to the other system parameters switches, allowing different gain and concealment settings for each ELF output.

ELF CONCEALMENT - Set as required to prevent amplifier and speaker overloads.

With all switches down the Concealment threshold is +16 dBu at the output (+22 dBu in balanced mode). To lower the threshold set the switches in the up position. The switch values combine to add up to a total dB value you then subtract from +16 dBu.

IMPORTANT : When setting the Concealment threshold, it is a good idea to set your power amplifier levels up full or provide proper security for the amplifier level settings. This will help prevent an accidental level increase above the safe operating level.

Set the concealment threshold to prevent the amplifier from clipping and select an amplifier with the appropriate power and to drive the connected speaker load. In a typical application the Concealment threshold light should come on 2 or 3 dB below the point at which the amplifier clips, and it is very acceptable for it to flash intermittently when in use. Refer to “ELF Concealment” in section 1.

OUTPUT 10 dB ATTENUATOR - To drive most power amplifiers, for best signal to noise performance, set this switch "up" in attenuation position.

The output attenuator provides additional flexibility to match the ELF-1 to a wide range of systems and applications in order to optimize the signal to noise ratio.

MUTE - For testing purposes mute is provided on each output section.

HIGH PASS PARAMETERS

HIGH PASS FREQUENCY - Typically set at 120 Hertz (120 Hz provides a 6 dB down crossover frequency of 90 Hz to be used with S18E ELF enclosures)

The High Pass filter will roll off the low frequencies to the mid/hi speaker section at a rate of 12dB per octave. With all switches down, the High Pass filter 3 dB down point is 50 Hertz. Lifting switches will raise the roll off frequency from 50 Hertz to 205 Hertz in 5 Hertz steps. Add the total of all switches in “up” position to 50 to determine the filter frequency(-3 dB point). Multiply the filter frequency by 0.75 to determine the -6 dB crossover frequency

Adjust the High Pass filter to blend with the type of ELF loudspeaker and Mid/Hi loudspeaker you are using. Refer to “Blending an ELF subwoofer into the upper range loudspeaker” in section 1.

HIGH PASS GAIN - Refer to ELF Gain.

POLARITY - Normal +
Positive assymetrical input will result in a positive assymetrical output at crossover.

STEREO / DUAL - Set as desired.

Both switches must be in the “Stereo” position to allow the high pass CVR limiter to track together in the stereo mode. “Dual” operation allows independent limiter tracking.

HIGH PASS CVR LIMITER - Set as required to prevent amplifier and speaker overloads.

With all switches down the CVR limiter threshold is +16 dBu at the output (+22 dBu in balanced mode). To lower the threshold set the switches in the up position. The switch values combine to add up to a total dB value you then subtract from +16 dBu.

IMPORTANT: When setting the Limiter threshold, it is a good idea to set your power amplifier levels up full or provide proper security for the amplifier level settings. This will help prevent an accidental level increase above the safe operating level. Setting procedure is similar to the concealment setting procedure.
OUTPUT 10 dB ATTENUATOR -To drive most power amplifiers, for best signal to noise performance, set this switch up in attenuation position.

The output attenuator provides additional flexibility to match the ELF-1 to a wide range of systems and applications in order to optimize the signal to noise ratio.

MUTE - For testing purposes mute is provided on each output section.

NOTE: Gain, concealment, and limiter thresholds are 6 dB higher for balanced operation.

LED INDICATORS

HIGH THRESHOLD - Indicates High CVR Limiter is limiting the signal. The visual brightness and reaction time of the LED as it turns both on, off, and dim follows the gain reduction and reaction time of the CVR limiter.

SIGNAL PRESENT - Indicates unit is on with a dim glow and brightens as a signal level becomes present.

LOW THRESHOLD - Indicates the ELF Concealment is reducing the low frequency extention of the system. The visual brightness and reaction time of the LED as it turns both on, off, and dim follows the amount and reaction time of the Concealment function.

INPUT/OUTPUT CONNECTIONS

The ELF-1 has balanced XLR connections for inputs and outputs. For connecting to an unbalanced line you must follow the following diagram in Fig 25.
Unbalancing instructions also appear on the back of the unit.

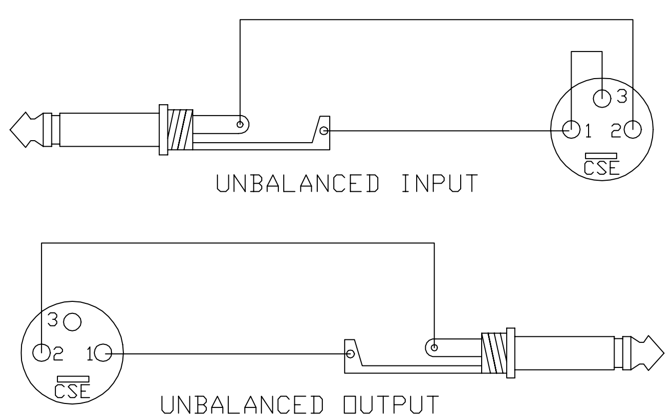


fig. 25

SECTION 4

BAG END ELF-1 ADVANCED DESCRIPTION AND SPECIFICATIONS

GROUNDING & SHIELDING

The ELF-1 chassis is grounded to the ground pin on the AC line cord as required for good safety. The signal ground is on pin 1 of the XLR connectors and connected directly to chassis ground very close to the physical location of the XLR inside the chassis.

ELF-1 ELECTRICAL RESPONSES

The ELF contour switches provide boost at the lowest frequencies. The contour center frequency is determined by the setting of the ELF Cutoff frequency, as shown in figures 26 and 27. By the way, there is no figure 28.

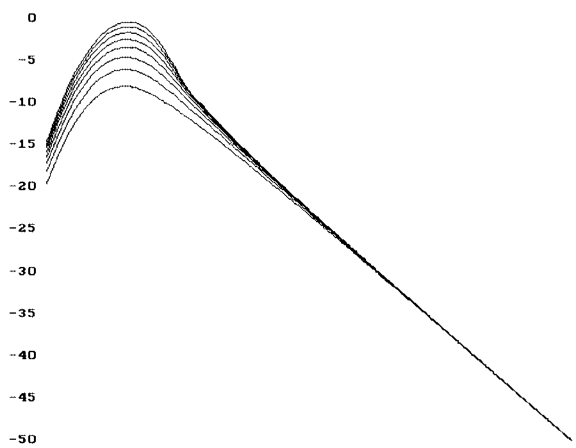


Fig. 26 Contour settings 1 through 7 overlayed with ELF cutoff set at 8 Hz.

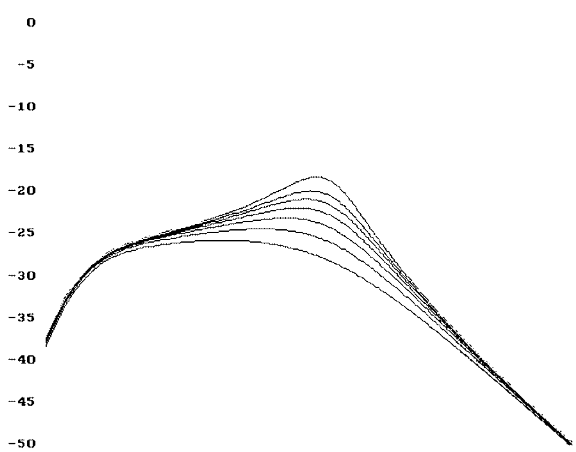


Fig. 27 Contour settings 1 through 7 overlayed with ELF cutoff set at 32 Hertz.

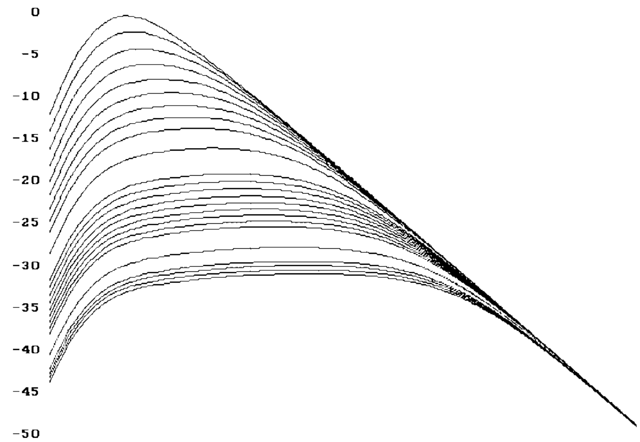


Fig. 29 ELF cutoff filter in 2 Hertz increments overlayed from 8 Hertz to 70 Hertz.

Concealment cannot properly be measured and depicted by a TEF instrument due to artifacts created by the measurement process. Figure 29 best shows the function of the concealment if you imagine dynamic control of the ELF cutoff frequency. Concealment actually has a similar shape but with greater attenuation possible.

The CVR High Pass limiter cannot properly be measured and depicted by a TEF instrument due to artifacts created by the measurement process.
Figure 30 best shows the function of the CVR limiter and its effect on the High Pass gain if you imagine dynamic control of the gain circuit.

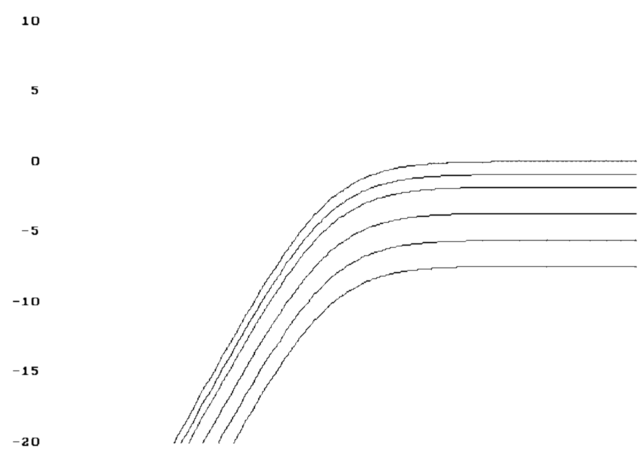


Fig 30. High Pass section output shown at various gain settings. High Pass Gain is adjustable from +15.5dB to -15.5dB in .5 dB increments.

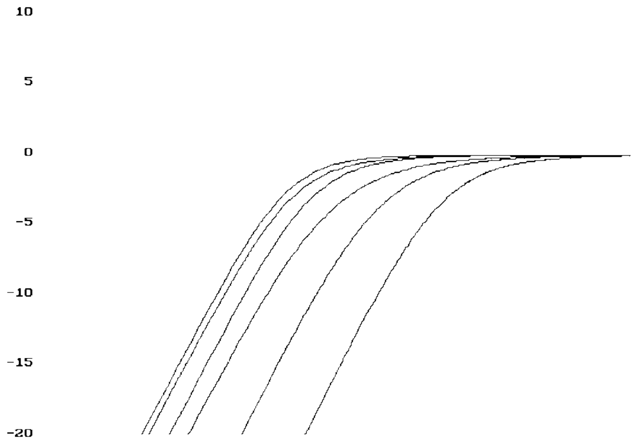


Fig. 31 High pass filter sample frequency settings -3dB at 50 Hz, 55 Hz, 65 Hz, 85 Hz, 125 Hz, and 205 Hz. Any setting is available from 50 Hz to 205 Hz in 5 Hz increments.

ELF-1 CIRCUIT DESIGN DESCRIPTION

Considering channel A, for instance:

INPUT

The audio signal is brought into the unit through standard XLR-type female connector. For optimum rejection of both radio frequency and audio frequency noise, both Pin 1 and the shell of the connector are connected to the chassis metal at the jack. It is intended that the user connect the shield of the cable to either Pin 1 or the shell or both, and this design assures the integrity of the shielded metal enclosure of the ELF-1 is continued thru the shield of the input (and output) cables.

A true-differential input is provided between Pin 2 and Pin 3 of the XLR connector, with Pin 2 considered the + input. To achieve maximum rejection of common-mode signals an Analog Devices SSM-2141 differential line receiver, incorporating precision, laser-trimmed resistors balance the circuit to a minimum of 75 dB common-mode rejection ratio up to a frequency of 1 kHz. Input impedance at 1 kHz exceeds 25 KOhms. To maintain this high common-mode rejection, the source impedance of both the + and - signals should be matched. For instance, a 5 KOhm difference between the source impedance of the + and - signals will degrade the common mode rejection ratio to about 40 dB.

Of course, for unbalanced (single-ended) sources, the - input must be grounded and there is no common mode rejection. Pin 3 is connected to Pin 1. The shield of the input cable is connected to Pin 1 and/or the shell and the signal is fed to Pin 2. The input impedance still exceeds 25 KOhms, and the full fidelity for the audio signal is maintained in this circuit for both unbalanced and balanced signals.

The signal is converted to single-ended by the input circuitry and is sent to the ELF circuitry and also to the High Frequency circuitry.

ELF SECTION

ELF GAIN LOG AMPLIFIER

The ELF section begins with a log amplifier, Analog Devices SSM-2018, that is used to control the sensitivity of the ELF circuitry. The log amplifier’s gain is controlled by a DC voltage which is determined by the settings of the ELF GAIN switches on the front panel of the ELF-1 unit. The use of this type of gain control accomplishes a low-distortion, wide-bandwidth signal path and allows precision adjustment of the gain from dB-additive switches. Precision resistors provide accurate DC currents appropriate for 8, 4, 2, 1, and 0.5 dB gain settings and these currents are summed in the gain buffer circuit which output a voltage proportional to the sum of the selected switch currents. In addition, there is a +/- switch which is a simple polarity inverter to change the polarity of the output voltage depending on whether a gain or loss is selected. In all, this approach allows a clean signal path where the signals do not have to be routed to the front panel, but are controlled remotely by DC voltages, and gives accurately repeatable settings, easily read from the control switches.

ELF CUTOFF FREQUENCY

For applications where the user desires to limit the low-frequency response, the reasons being discussed elsewhere in this manual, a high-pass filter circuit is provided. To provide a clean signal path, the filter is designed around a dual integrator circuit which is not directly in the signal path, and a filter summer op-amp, a Texas Instruments TLE-2024, which subtracts the signals which are to be rejected by the filter from the main signal. In this way, the main signal does not have to pass through the frequency selective components as it does in an ordinary filter. Front panel switches labeled 32, 16, 8, 4, and 2 Hz connect precision resistors which pass currents proportional to their frequency labels to each of the dual integrators which sum these currents along with a fixed current appropriate to 8 Hz, thus the total current is proportional to 8 Hz plus the switch settings. The signals to the integrators do have to pass through the front panel switches, so they are located on the circuit cards near the front edge.
Note that while a dual integrator is used for the cutoff filter, this dual integrator is not in the signal path and is not the ELF technology dual integrator itself.

ELF DUAL INTEGRATOR

The heart of the ELF technology is a dual integrator which provides the signal processing that compliments the operation of your transducer below resonance. Each integrator has a frequency response that is essentially a straight line tilted to fall at 6 dB/octave from the circuit limit of 8 Hz to above 20 kHz. The two ELF integrators are in series and thus the overall response falls at 12 dB/octave over the audio range. These integrators are precision, so-called, leaky integrators with a precision resistor to provide feedback below 8 Hz to keep the response as the frequency approaches 0 Hz from being infinite.

In addition, the ELF dual integrator block contains the proprietary concealment circuitry which causes the limits of integration to be raised when the concealment detector finds a signal with components that would cause overload to the amplifiers or transducers. In effect, the concealment accomplishes the same effect as raising the ELF cutoff frequency dynamically to avoid distortion when there is insufficient amplifier power or transducer capability to reproduce the output required. But the concealment approach is less obtrusive than a limiter in this channel because, for instance, if there is a 50 Hz and a 15 Hz signal present and there is insufficient headroom to reproduce the 15 Hz component to full level without distortion, the concealment circuit raises the cutoff frequency sufficiently to reduce the 15 Hz component so that it is reproduced at the maximum that the installed equipment can handle, but the 50 Hz component is not affected at all...and the audibility of the 50 Hz component is much higher than the 15 Hz component ; the overall subjective result is effective concealment with little audible side effects. Contrast this to a limiter installed in the Low-Frequency path which would have reduced the amplitude of both the 50 Hz and the 15 Hz component by the same amount, making the effect of the limiter quite audible. Further contrast this with no concealment or limiter, when the system would be overloaded and the normally essentially inaudible 15 Hz component would be made quite unpleasantly audible by the presence of its harmonics at 30, 45, 60 Hz, etc. which are very audible.

ELF CONCEALMENT SIDE-CHAIN

The concealment side-chain employs a detector which generates a DC voltage only when needed to activate the concealment circuitry in the ELF dual integrator module. The signal that is presented to the output driver circuit is also connected to an Analog Devices SSM-2122 Log amplifier in the concealment side-chain. The gain of this amplifier is controlled by switches on the front panel which provide appropriate currents which are summed and converted into a voltage which sets the gain of the amplifier. Higher gains result in reaching the threshold level with smaller signals. The output of the log amplifier is presented to a circuit, incorporating a Harris HA-4741, which computes the absolute value of the signal voltage. When the absolute value of the signal voltage exceeds a fixed threshold voltage, it is converted to a current and applied to a control integrator. The voltage output of this control integrator sets the concealment circuitry in the ELF dual integrator module.

POLARITY BUFFER

A buffer amplifier which has a remote switch-selected polarity inversion function follows the ELF dual integrator. When the switch is open (in the down or - position) the signal is passed without inversion and when the switch is closed (in the up or + position) and the control wire grounded, the signal polarity is inverted. The log amplifier (gain control circuit) inverted the signal and thus the markings on the polarity buffer switch are opposite to correct for this prior inversion. The output impedance of the polarity buffer is 10 KOhms. A mute switch is provided on the front panel which grounds the output of the polarity buffer when it is desired to silence the ELF output for setup and/or testing purposes. In addition, a switch marked 10 dB ATTN is provided that switches in a resistive voltage divider to reduce the output signal by 10 dB for cases when the following equipment is very sensitive. Reducing the signal at this point in the circuit also reduces circuit noise by the proportional amount. Finally, a switch is provided which connects the left channel buffer to the right channel buffer combining the signals for those installations that use a single-channel ELF system.

OUTPUT LINE DRIVER

A balanced output driver, Burr Brown OPA2604A, is fed to a Male XLR-type connector for the Line Output. Separate + and - amplifiers are used to provide carefully matched impedences for best driving of long lines. The output amplifiers can drive 600 Ohm loads comfortably and the output impedance is approximately 45 Ohms on each leg. Pin 1 and the Shell of the connector are connected to the shielded metal enclosure of the ELF-1 unit and we recommend that the shield of the cable be connected to either or both Pin 1 and the Shell to ensure the integrity of the shield for best results at both audio and radio frequencies. The + output is on Pin 2 and the - output is on Pin 3. When driving unbalanced (single-ended) equipment, connect the shield to Pin 1 and/or the Shell, and the signal lead to Pin 2.

HI PASS SECTION

HF GAIN LOG AMPLIFIER

A log amplifier and panel switches are provided for setting the gain of the hi-pass signal chain. The operation and circuit are essentially the same as for the ELF section so refer to the ELF GAIN section for descriptions.

HI PASS FILTER

This filter is essentially the same as the ELF cutoff filter except for operating frequencies, a dual integrator type hi pass filter is provided to establish the low frequency limit of the full range output signal. The switch settings provide integration currents for 80, 40, 20, 10, and 5 Hz which are summed when selected with a fixed current appropriate for 50 Hz. Again, the design of this circuit keeps the main signal going through the simplest circuit for clean performance and subtracts out the signal components that are to be filtered out.

LIMITER SIDE-CHAIN

A limiter side-chain is provided which operates similarly in some respects to the ELF concealment circuit side-chain. The two have similar log amplifiers, absolute value computers, fixed thresholds, and control integrators. Refer to the previous section for circuit descriptions of these sections. The control integrator section is connected to the HF gain log amplifier which is used to reduce the signal gain when the signal at the output drivers exceed the threshold selected. Therefore we avoid having a separate limiter gain-control circuit and keep the signal path cleaner.

Limiters most often encountered in audio work fall into two groups, linear detectors with linear gain controls and log detectors with log gain controls. In the case of the linear types, the attack/recovery time constants also accurately describe the dynamic time constants of the limiter. In the case of log types, attack and recovery dynamics are expressed of dimentions dB/sec. In the ELF-1 limiter, the detector is of the linear type. Don’t be confused by the log amplifier which is the first section of the limiter detector. The action of the log amplifier is simply to set the effective threshold levels and permit convenient control switch summation for threshold setting...the log amplifier is quite linear in the signal path. And the absolute value circuit used is linear and therefore a detector voltage that is compared to the fixed threshold is a linear function of the signal voltage present at the output drivers. However, the HF gain log amplifier now doing double duty as the limiter gain control cell, responds in a dB/volt manner to the voltage from the control integrator.

Thus we have a mixed linear/log limiter with interesting capabilities. When a signal exceeds the threshold, the gain is rapidly reduced to bring the output signal below the maximum that has been set. But the recovery is neither the shape of the time constants of the control integrator itself, nor so many dB/sec of those time constants, but instead is dynamically dependent on the amount of limiting that was called for.

In the case of a signal that greatly exceeded the threshold, the initial recovery is quite fast and then decreases until when nearing full recovery, the gain is restored at a very slow rate. In operation, it resembles a human operator who corrects big level changes rapidly but carefully and slowly returns the gain to full anticipating that if reduction was needed, then the gain probably shouldn’t be rushed back to full...it is likely that another reduction is necessary. Of course, this slow recovery can be accomplished with the other types of limiters by increasing the setting of the recovery times. But let a microphone fall down and make a huge signal, then the program will be suppressed for a long time, making the action of the limiter objectionable. But in the ELF-1 limiter, the huge signal caused the appropriate limiting, but the initial recovery was very fast and the subjective action of the limiter was not unpleasant. This action is automatically provided and there are no attack and release time constants to be adjusted. This continuously variable recovery limiter (CVR) is unique to the ELF-1.

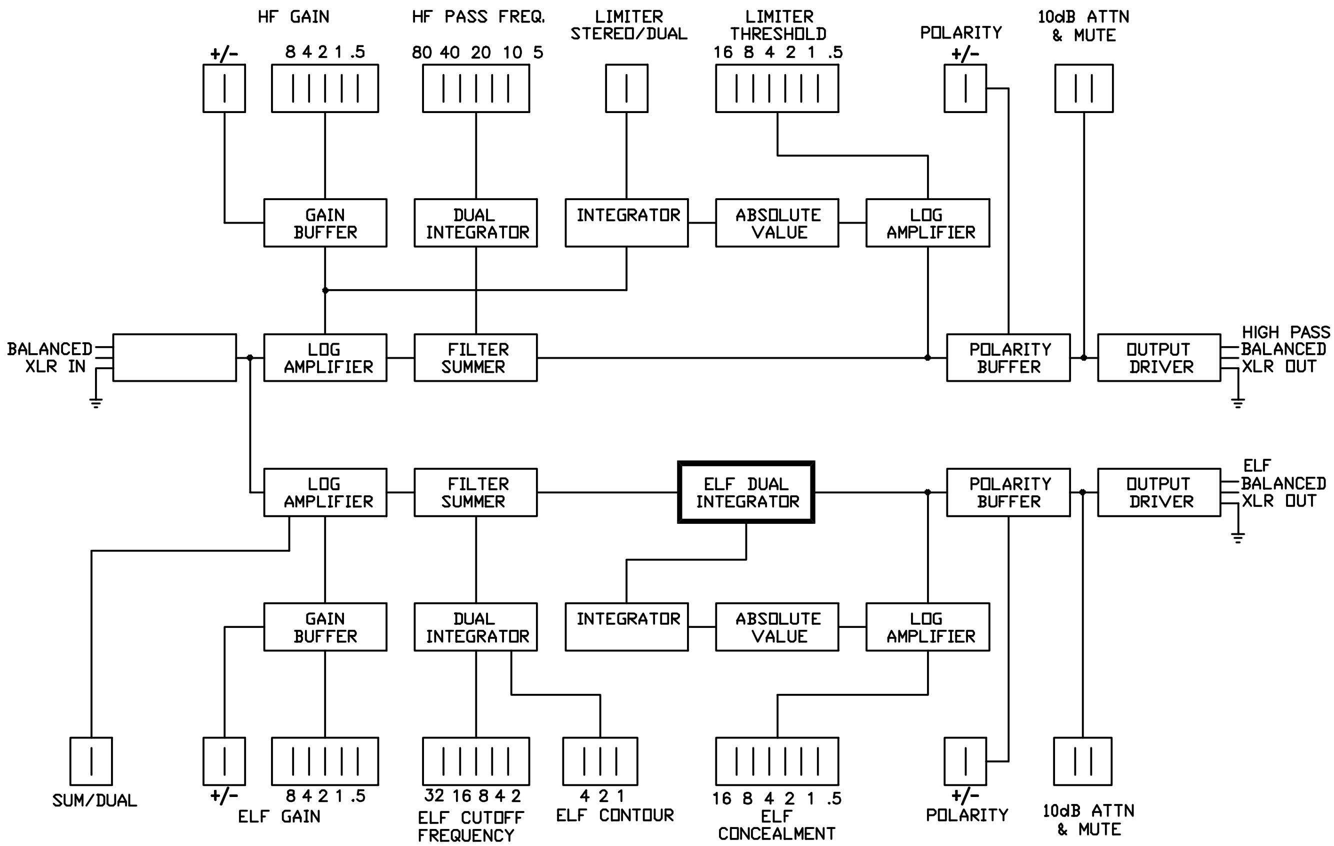
A STEREO/DUAL switch is provided for the Hi Pass limiter which connects the control integrators when the switch is in the stereo position. This provides proper stereo imaging by making the gain reductions equal in both the Left and Right channels. When the switch is in the dual position, the two limiters act independently.

POLARITY BUFFER

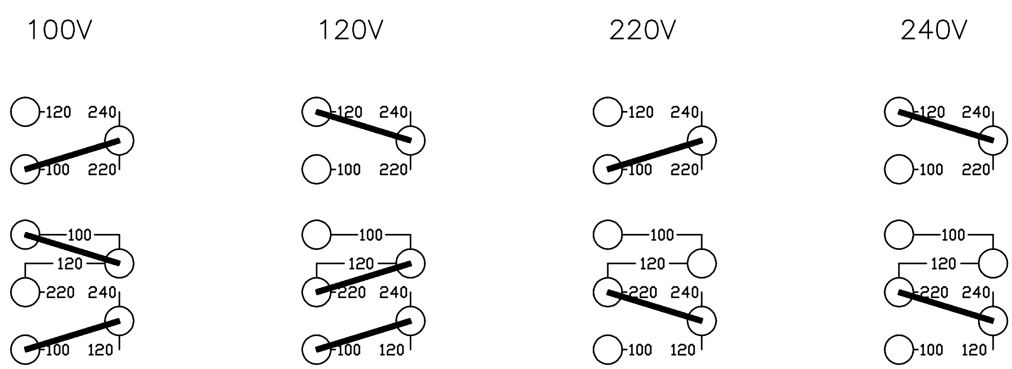
The polarity buffer is similar to the ELF polarity buffer and includes the mute and 10 dB ATTN functions. No SUM switch is provided, its place taken by the STEREO/DUAL switch described in the paragraph just preceeding.

OUTPUT LINE DRIVERS

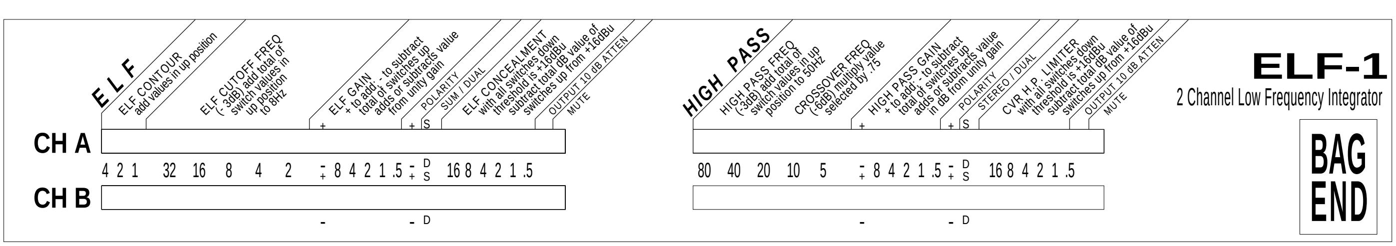
The line drivers for the Hi Pass section are identical to the line drivers for the ELF section and the same considerations apply.



System block diagram of one channel of the BAG END ELF-1.



ELF-1 power supply circuit board jumper settings for various international AC power sources.



ELF-1 front panel control switch layout.

ELF-1

General Specifications

Operating line voltages (internally selected)	100, 120, 220, 240 VAC
Power-on indication	Green LED light bars
Signal-Present indication	Green LED light bars brighten
Input connectors	XLR-type female
Input configuration	Balanced
Alternate input configuration	Unbalanced
Maximum input signal balanced	+20 dBu
Maximum input signal unbalanced	+20 dBu
Input impedance at 1K Hertz	>25K ohms
Input common mode rejection (balanced)	>75 dB up to 1KHz
Output line driver modes	Operate/Mute
10 dB output attenuator	In/out
Output polarity modes	+/-
Output connectors	XLR-type male
Output configuration	Balanced
Alternate output configuration	Unblalanced
Output impedance	< 50 ohms
Unity gain calibration	Unbalanced mode (+6 dB Balanced mode)

ELF Balanced mode specifications

ELF output modes	Sum/Dual
Maximum ELF gain	15.5 dB
Maximum ELF attenuation	25.5 dB
Minimum ELF cutoff frequency	8 Hz
Maximum ELF cutoff frequency	70 Hz
Concealment threshold exceeded indication	Red LED light bars
Maximum Concealment reduction capability at 8 Hz	44 dB
Maximum Concealment threshold	+22 dBu /+16 dBu unbalanced
Concealment threshold range	41.5 dB
Maximum output signal with concealment disabled	+24 dBm / +25 dBu
ELF circuit noise	<-85 dBu (20 Hz to 20 KHz)
ELF dynamic range	110 dB (20 Hz to 20 KHz) (Band width unweighted)

HI PASS Balanced mode specifications

Maximum Hi Pass gain	15.5 dB
Maximum Hi Pass attenuation	25.5 dB
Minimum Hi Pass filter frequency	-3dB @ 50 Hz
Maximum Hi Pass filter frequency	-3dB @ 205 Hz
CVR Limiter threshold exceeded indication	Yellow LED light bars
CVR Limiter modes	Stereo/Dual
CVR Limiter reduction capability	27 dB typical
Maximum CVR Limiter threshold	+21 dBm /+15 dBm unbalanced
CVR limiter threshold range	-41.5 dB
Maximum output signal with CVR limiter disabled	+24 dBm / +25 dBu
Hi Pass circuit noise	< -85 dBu (20 Hz to 20 KHz)
Hi Pass dynamic range	> 110 dB (20 Hz to 20 KHz) (Band width unweighted)

Physical Specifications

Line connector	3-pin Grounding IEC connector
Line protection	Fuse, 1/2 Amp
Anti-fiddle feature	Security cover provided
Enclosure	Steel, black powder coated
Enclosure mounting	1U EIA rack (1-3/4 inch)
Enclosure size	19 x 1.75 x 8.5 inches
Unit weight	10 lbs
Shipping container size	22” x 6” x 12”
Weight in shipping container	12 lbs

SECTION 5

SELECTING AN ELF INTEGRATOR FOR YOUR APPLICATION

ELF-1 integrator

The descriptions and examples in this guide are based around the ELF-1 electronics which offers convenient flexibility of all parameters via the front panel dip switches and provides the widest frequency response and dynamic range available. The ELF-1 is designed for critical applications such as mastering labs, film post production, professional recording studios, concert PA systems, and even the most discriminating home stereo system. The ELF integrators respond down to 8 Hertz which is critical to monitor and correct low frequency problems. The overall dynamic range, ELF concealment reduction capability, and the CVR limiter reduction capability is the greatest and highly desirable for live applications. The balanced 600 ohm output allows the unit to drive line level from the mix rack if desired. For any application the setup and adjustments are conveniently located behind a built in security cover and the dip switches are calibrated and easily documented for future reference. The built in power supply allows the ELF-1 to be configured to one of 4 international standard voltages.

ELF-M integrator

The ELF-M is a simplified ELF integrator offering the same ELF sound as the ELF-1 with reduced features and controls. The ELF-M is designed for the following applications: recording studios, commercial cinema and home theater, musical instruments, small PA systems, automotive sound.

The ELF-M includes stereo inputs with a mono sum ELF output and stereo hi-pass outputs. The hi-pass frequency is factory set along with the ELF cutoff frequency which may be changed within its limits by exchanging the filter resistors on the ELF-M mother board. Resistor sockets allow easy replacement and eliminate the need to solder. The stereo hi pass output is set at unity gain.The ELF-M operates on any dc voltage between 10.5 to 18.5 volts thus allowing for convenient international use as well as 12vdc automotive applications. The input is balanced. The output is not balanced (although an XLR connector is used) and it is not recommended to drive long lines or drive more than 4 typical power amplifiers in parallel.

In the ELF-M the most basic parameters, gain and concealment threshold, are flush mounted screw driver controls located on the front of the unit. Once set for the system you would rarely have to change the controls. The flush mounting of the controls helps keep them from accidentally being turned. The control dials are well calibrated and evenly spaced in dB increments.

ELF-M2 integrator

The ELF-M2 is identical to the ELF-M with the addition of 2 CVR Limiters on the left and right high pass sections. Stereo gain and CVR limiter threshold controls are flush mounted on the front. An internal jumper switch allows 3-Way operation with mid and hi gain and mid and hi CVR Limiter threshold controls.

SECTION 6

ELF-M AND ELF-M2 FREQUENCY PROGRAMING AND SPECIFICATIONS

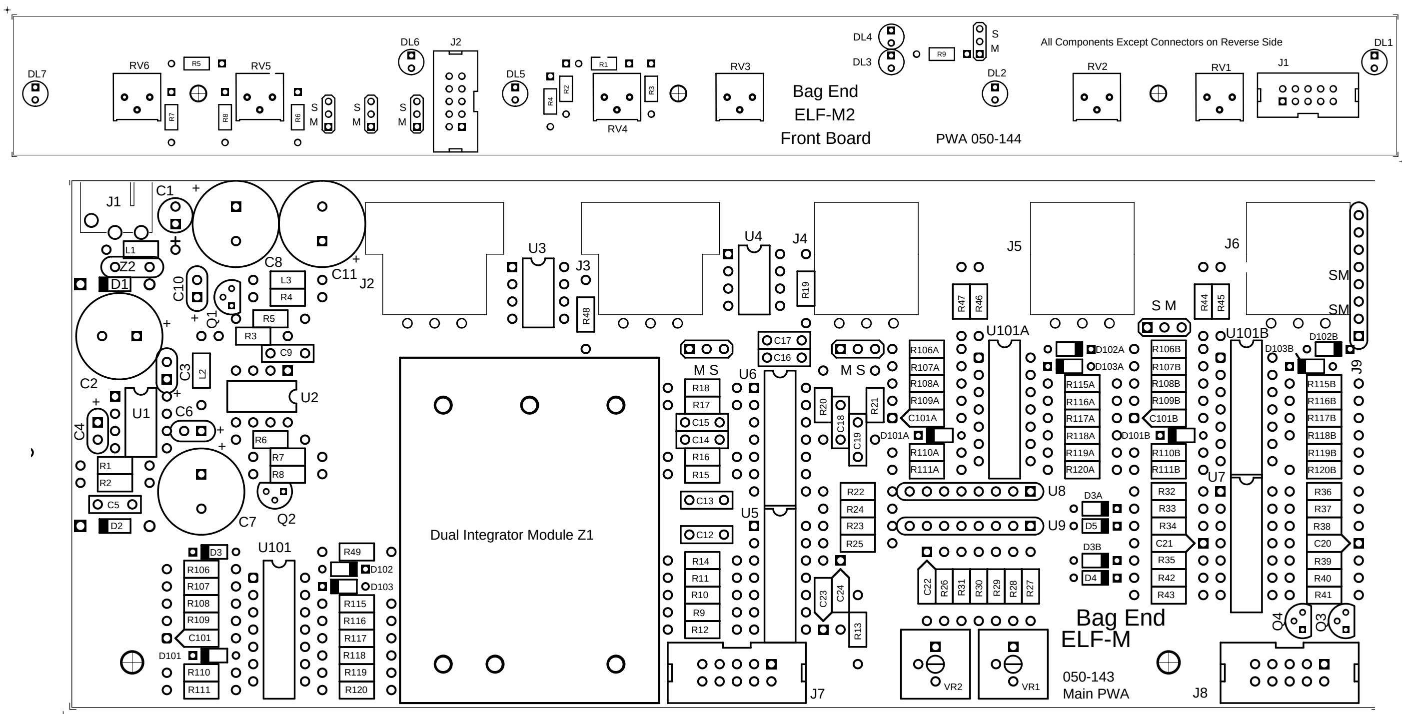
To change the ELF cutoff frequency and the hi pass frequency you may replace the indicated resistors. The replaceable resistors are mounted in plug in sockets and no soldering is required. Each resistor has a specific K factor number associated with it which is to be divided by the filter frequency selected. The filter frequency is specified as the -3dB point. This the standard way of specifying filter frequencies but should not be confused with the actual crossover frequency of the loudspeaker system. (The actual crossover frequency is at the -6dB point which may be calculated for the hi-pass by multiplying the -3dB frequency by .75, and for the low-pass by multiplying by 1.33) The result of this calculation will equal the value of the resistor in K ohms.

For example:
The factory set value for the normal stereo hi pass section is 130 Hz. R19 is part of the hi pass filter and has a factor number of 11,250.

Simply divide the factor, 11250 by the frequency selected, 130 and this equals the resistor value in K ohms, 86.5 K ohms or 11250/130 = 86.5

Each filter has two sections with two resistors with different K factor numbers. Both resistors must be calculated correctly to achieve a proper filter frequency and slope.

The procedure is to divide the K factor by the desired cutoff frequency in Hertz to find the resistor value in K ohms. Then chose the nearest standard value. For all practical purposes, you can choose the nearest 5% tolerance value and achieve very good results.



ELF-Cutoff Frequency:

For R14: divide 682 by frequency
Factory value is 18.5 Hertz / 36.5 K ohms
(682 / 18.5 = 36.8)

For R15: divide 341 by frequency
Factory value is 18.5 Hertz / 18.2 K ohms
(341 / 18.5 = 18.4)

Hi-Pass Frequency for Hi-Freq output Right Channel (and Hi output of ELF-M2 in three-way mode):

For R16: divide 11250 by frequency
Factory value is 130 Hertz / 86.6 K ohms
(11250 / 130 = 86.5)

For R17: divide 22500 by frequency
Factory value is 130 Hertz / 174 K ohms
(22500 / 130 = 173)

Hi-Pass Frequency for Hi-Freq output Left Channel (and Mid output of ELF-M2 in three-way mode):

For R18: divide 22500 by frequency
Factory value is 130 Hertz / 174 K ohms
(22500 / 130 = 173)

For R19: divide 11250 by frequency
Factory value is 130 Hertz / 86.6 K ohms
(11250 / 130 = 86.5)

Low-Pass Frequency for Mid output (ELF-M2 only):

For R20: divide 53990 by frequency
Factory value is 2000 Hertz / 27.4 K ohms
(53990 / 2000 = 27)

For R21: divide 14220 by frequency
Factory value is 2000 Hertz / 7.11 K ohms
(14220 / 2000 = 7.11)

ELF-M SPECIFICATIONS

General Specifications

Input connectors	XLR-type Female
Input configuration	Balanced
Alternate Input configuration	Unbalanced
Maximum input signal	3 V (+10 dBu)
Output connectors	XLR-type Male
Output configuration	Unbalanced
Maximum output signal	3 V (+10 dBu)
Nominal output impedance	100 Ohms
Minimum suggested load impedance	2.5 KOhms
Maximum gain	10 dB
Maximum attenuation	10 dB
Power-on Indication	1 Green LED
Operating Input Voltage	10.5 - 18.5 VDC
Operating Current Required	200 mA
Input Voltage connector	Miniature DC 2.5 mm center pin
Input Voltage polarity	Center pin +

ELF Specifications

Nominal ELF cutoff	18 Hz
Maximum ELF cutoff	70 Hz
ELF cutoff frequency programming	Plug in Resistors
ELF output mode	Sum in Stereo Mode
Concealment threshold exceeded indication	Red LED
Concealment reduction capability	30 dB
Nominal Concealment threshold	0 dBu Output
Minimum Concealment threshold	-10 dBu Output
Maximum Concealment threshold	+10 dBu Output
ELF circuit noise	< -85 dBu (20 Hz to 20 KHz)
ELF dynamic range	> 95 dB (20 Hz to 20 KHz)
	(Band width unweighted)

Hi Pass Specifications

Hi Pass filter frequency programming	Plug in Resistors
Hi Pass filters	12 dB/octave
Factory Set Hi Pass filter frequency	- 3dB @ 130 Hz/ -6dB @ 97 Hz
Hi Pass filter frequency range	50 Hz to 200 Hz
Gain	Unity
Hi Pass circuit noise	< -85 dBu (20 Hz to 20 KHz)
Hi Pass dynamic range	> 95 dB (20 Hz to 20 KHz)
	(Band width unweighted)

Physical Specifications

Enclosure	Steel, Black Powder Coated
Enclosure mounting	1U EIA Rack (1-3/4 inch)
Enclosure size	19 x 1-3/4 x 5-1/4 inches
Unit weight	6 lbs
Shipping container size	22” x 6” x 12”
Weight in shipping container	8 lbs

ELF-M2 SPECIFICATIONS

General Specifications

Input connectors	XLR-type Female
Input configuration	Balanced
Alternate Input configuration	Unbalanced
Maximum input signal	3 V (+10 dBu)
Output connectors	XLR-type Male
Output configuration	Unbalanced
Maximum output signal	3 V (+10 dBu)
Nominal output impedance	100 Ohms
Minimum suggested load impedance	2.5 KOhms
Maximum gain	10 dB
Maximum attenuation	10 dB
Mode and Power-on Indication	2 Green LED in Stereo Mode 1 Green 2 Yellow LED in Mono Mode
Operating Input Voltage	10.5 - 18.5 VDC
Operating Current Required	200 mA
Input Voltage connector	Miniature DC 2.5 mm center pin
Input Voltage polarity	Center pin +

ELF Specifications

Nominal ELF cutoff	18 Hz
Maximum ELF cutoff	70 Hz
ELF cutoff frequency programming	Plug in Resistors
ELF output mode	Sum in Stereo Mode
Concealment threshold exceeded indication	Red LED
Concealment reduction capability	30 dB
Nominal Concealment threshold	0 dBu Output
Minimum Concealment threshold	-10 dBu Output
Maximum Concealment threshold	+10 dBu Output
ELF circuit noise	< -85 dBu (20 Hz to 20 KHz)
ELF dynamic range	> 95 dB (20 Hz to 20 KHz) (Band width unweighted)

Hi Pass Specifications

Crossover and cutoff frequency programming	Plug in Resistors
Mode Selection	Internal Shunts
Crossover filters	12 dB/octave
Factory Set Hi Pass filter frequency	- 3dB @ 130 Hz/ -6dB @ 97 Hz
Hi Pass filter frequency range	50 Hz to 200 Hz
CVR Limiter threshold exceeded indication	Red LED
CVR Limiter reduction capability	15 dB
Nominal Hi Pass limiter threshold	0 dBu Output
Minimum Hi Pass limiter threshold	-10 dBu Output
Maximum Hi Pass limiter threshold	+10 dBu Output
Limiter modes	Stereo Hi - Mono Mid/Hi
Hi Pass circuit noise	< -85 dBu (20 Hz to 20 KHz)
Hi Pass dynamic range	> 95 dB (20 Hz to 20 KHz) (Band width unweighted)

Physical Specifications

Enclosure	Steel, Black Powder Coated
Enclosure mounting	1U EIA Rack (1-3/4 inch)
Enclosure size	19 x 1-3/4 x 5-1/4 inches
Unit weight	6 lbs
Shipping container size	22” x 6” x 12”
Weight in shipping container	8 lbs

SECTION 7

BAG END ELF SPEAKER SYSTEMS

CONNECTOR WIRING STANDARDS

The Bag End ELF enclosures include 2 parallel Neutrik Speak-On NL4MP connectors and a dual banana jack. Pins 1 are connected to the ELF driver with the + polarity on pin 1+. Pins 1 on each speak-on are connected in parallel along with the banana jack. Pins 2 are connected through to each other on each Speak-On connector for high frequency loop-through connections. In all Bag End upper range enclosures pins 1 and 2 also loop through internally. This allows for easy connection and paralleling of multiple loudspeakers up to the amplifiers rated load minimum impedance.

DRIVER CONFIGURATIONS

Several enclosure configurations are available for the EL series transducers and the transducers are available separately for custom ELF applications.

BAG END ELF Loudspeaker System Models

D18E-R	BLACK CARPET DOUBLE 18 ROAD VERSION ENCLOSURE
D18E-I	BLACK PAINTED DOUBLE 18 INSTALLATION ENCLOSURE
S18E-B	BROWN OILED BIRCH SINGLE 18 ELF ENCLOSURE
S18E-C	BLACK CARPET SINGLE 18 ENCLOSURE
S18E-I	BLACK PAINTED SINGLE 18 INSTALLATION ENCLOSURE
S18E-O	OAK VENEER SINGLE 18 ELF ENCLOSURE
S18ELT-C	BLACK CARPET SINGLE 18 LITE ENCLOSURE
D12E-C	BLACK CARPET DOUBLE 12 ENCLOSURE
D12E-I	BLACK PAINTED DOUBLE 12 INSTALLATION ENCLOSURE
S12E-I	BLACK PAINTED SINGLE 12 INSTALLATION ENCLOSURE
S12E-C	BLACK CARPET SINGLE 12 ENCLOSURE
D10E-O	OAK VENEER DOUBLE 10 ELF ENCLOSURE
D10E-I	BLACK PAINTED DOUBLE 10 INSTALLATION ENCLOSURE
D10E-S	WALNUT VENEER DOUBLE 10 STUDIO ELF ENCLOSURE
S10E-C	BLACK CARPET SINGLE 10 ENCLOSURE
S10E-I	BLACK PAINTED SINGLE 10 INSTALLATION ENCLOSURE

ELF Individual Transducers Models:		Recommended sealed enclosure size per driver:
EL-10	10” ELF LOUDSPEAKER	1 Cubic Foot
EL-12	12” ELF LOUDSPEAKER	1.5 Cubic Feet
EL-18	18” ELF LOUDSPEAKER	3 Cubic Feet