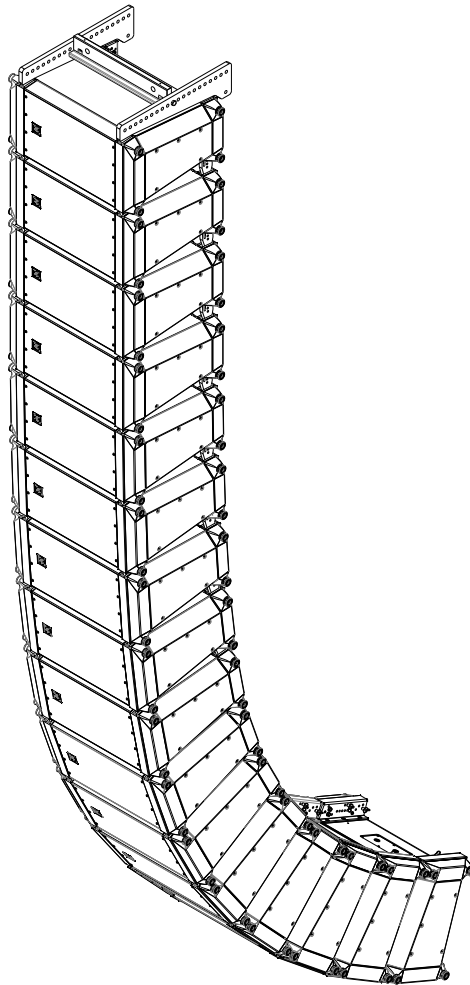


# X-LINE ADVANCE Systems

X1-212/90, X12-128, X2-212/90, X12TC-GRID, X12TE-GRID, X12PU-BGK, X12T-DOLLY, and

X12-128-DOLLY

en | Installation Manual





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# X-LINE ADVANCE Systems

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# 1 Safety

This document details general rigging practices appropriate to the entertainment industry, as they would apply to the rigging of X1 and X2 loudspeaker systems from Electro-Voice. It is intended to familiarize the user with standard rigging hardware and techniques for suspending X1 and X2 loudspeaker systems overhead. Only persons with the knowledge of proper hardware and safe rigging techniques should attempt to suspend any sound systems overhead. Prior to suspending any X1 and X2 loudspeaker systems overhead, it is essential the user is familiar with the strength ratings, rigging techniques and special safety considerations outlined in this manual. The rigging techniques and practices recommended in this manual are, of necessity, in general terms to accommodate the many variations in loudspeaker arrays and rigging configurations. As such, the user is expressly responsible for the safety of all specific X1 and X2 loudspeaker array designs and rigging configurations as implemented in practice.

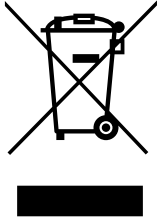
All the general rigging material contained in this manual is based on the best available engineering information concerning materials and practices, as commonly recognized in the United States, and is believed to be accurate at the time of original printing. As such, the information may not be directly applicable in other countries. Furthermore, the regulations and requirements governing rigging hardware and practices may be superseded by local regulations. It is the responsibility of the user to ensure any Electro-Voice loudspeaker system is suspended overhead in accordance with all current federal, state, and local regulations.

All specific material concerning the strength ratings, rigging techniques, and safety considerations for the X1 and X2 loudspeaker systems is based on the best available engineering information concerning the use and limitations of the products. Electro-Voice continually engages in testing, research and development of its loudspeaker products. As a result, the specifications are subject to change without notice. It is the responsibility of the user to ensure that any Electro-Voice loudspeaker system is suspended overhead in accordance with the strength ratings, rigging techniques, and safety considerations given in this document and any manual update notices. Visit our website: [www.electrovoice.com](http://www.electrovoice.com) for current product technical documentation or software. All non-Electro-Voice associated hardware items necessary to rig a complete X1 and X2 loudspeaker array (chain hoists, building or tower supports, and miscellaneous mechanical components) are the responsibility of others.

Electro-Voice  
April 2015

## 1.1 Important Safety Instructions

1. Read these instructions.
2. Keep these instructions.
3. Heed all warnings.
4. Follow all instructions.
5. Clean only with a dry cloth.
6. Do not install near any heat sources such as radiators, heat registers, stoves, or other apparatus (including amplifiers) that produce heat.






### Old electrical and electronic appliances

Electrical or electronic devices that are no longer serviceable must be collected separately and sent for environmentally compatible recycling (in accordance with the European Waste Electrical and Electronic Equipment Directive).

To dispose of old electrical or electronic devices, you should use the return and collection systems put in place in the country concerned.

## 1.2 Precautions

	These Electro-Voice loudspeakers were designed for use in an environment with ambient temperatures between -20°C (-4°F) and +50°C (122°F).
	These Electro-Voice loudspeakers are not rated for continuous outdoor conditions. However, they may be exposed to occasional short-term rain, water, or high humidity.
	Electro-Voice loudspeakers are easily capable of generating sound pressure levels sufficient to cause permanent hearing damage to anyone within normal coverage distance. Caution should be taken to avoid prolonged exposure to sound pressure levels exceeding 90 dB.

## 1.3 Suspension

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### Warning!

Suspending any object is potentially dangerous and should only be attempted by individuals who have a thorough knowledge of the techniques and regulations of suspending objects overhead. Electro-Voice strongly recommends all loudspeakers be suspended taking into account all current national, federal, state, and local laws and regulations. It is the responsibility of the installer to ensure all loudspeakers are safely installed in accordance with all such requirements. When loudspeakers are suspended, Electro-Voice strongly recommends the system be inspected at least once per year or as laws and regulations require. If any sign of weakness or damage is detected, remedial action should be taken immediately. The user is responsible for making sure the wall, ceiling, or structure is capable of supporting all objects suspended overhead. Any hardware used to suspend a loudspeaker not associated with Electro-Voice is the responsibility of others.



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## 2 Introduction

The X1 and X2 loudspeaker system line-array elements by Electro-Voice represent an important step in line-array technology for small- to large-scale fixed-installation and live sound reinforcement. The various models are designed to significantly simplify the physical assembly of a line array. Also, X1 in passive mode may be designed so that up to three elements are powered from one (1) amplifier channel, the necessary crossover and EQ functions accomplished with sophisticated internal passive networks. X2 is designed to operate in Bi-amp mode only. The individual loudspeaker drivers, Hydra planar-wave generators, acoustic waveguides, enclosures and rigging hardware were all designed specifically for the X1 and X2 product line to not only achieve the highest acoustic output with the highest fidelity, but also produce a precise wave front from each element to achieve state-of-the-art line-array performance. The X12 subwoofer elements are designed to compliment the performance of X1 and X2 full-range elements in applications where additional low-frequency output is desired.

Although the X1 and X2 full-range elements are not physically symmetrical, their acoustic polar responses are substantially symmetrical. Thus, stereo left and right arrays or left-center-right arrays may be constructed with the elements in their normal right-side-up orientation.

### 3 System overview

Each X1-212/90 full-range element consists of one (1) SMX2121 12-inch (304.8 mm) LF drivers coupled to a **MBH** (Mid Band Hydra) and two (2) ND2R 2-inch-diaphragms (50.8 mm) HF drivers. Each HF driver is mounted on a **WCH** (Wavefront-shaping Circular Hydra) planar-wave generator and vertically orientated.

X1 is designed in a two-way configuration with a 90° horizontal x 10° vertical coverage pattern and an internally selectable passive crossover/EQ network. The enclosure is trapezoidal in the vertical plane with a 10° total included angle.

Each X2-212/90 full-range element consists of one (1) DVN3125 12-inch (304.8 mm) LF drivers coupled to a MBH and two (2) ND6A 3-inch-diaphragms (76.2 mm) HF drivers. Each HF driver is mounted on a **PDH** (Pin Diffraction Hydra) planar-wave generator and vertically orientated. X2 is designed in a two-way configuration with a 90° horizontal x 10° vertical coverage pattern for bi-amp use only. A passive crossover/EQ network is neither included nor available. The enclosure is trapezoidal in the vertical plane with a 10° total included angle.

The X12-128 dual-18-inch subwoofer includes two (2) DVF4180 woofers designed specifically for subwoofer applications, providing reliable low-frequency performance at high SPL levels with low distortion and solid impact. Subwoofer elements do not have internal passive crossovers and require an active crossover and dedicated amplifier channel(s) for proper operation.

X12 is a compact rectangular dual-18-inch subwoofer element designed for use only as a ground stack subwoofer array. The X12-128 is also designed to be used in ground stack cardioid arrays.

All X1 & X2 elements are available in black and are supplied with the hardware necessary to interface one element to another.

X12TC-GRID: standard grids for up to 24 X1 or X2 elements for simple or mostly straight arrays, where extreme tilt angles are not required.

X12TE-GRID: extended grids for up to 24 X1 or X2 elements for extreme down angles in small to medium arrays and typical up or down angles in large arrays.

X12PU-BGK: Pull Up Bottom Grid Kit for X1 or X2 elements. A pull-up kit is used when the compression rigging method is being used with an array or when extreme down angles beyond the capabilities of the extended grid are required.

The three (3) different grid options (X12TC, X12TE and X12PU-BGK) are sold separately. Consult LAPS 3 for proper grid selection and array design.

X12T-Dolly: Dolly is used for transporting X1 or X2 loudspeaker systems. The dolly accommodates two (2) columns of X1 or X2 loudspeaker systems stacked three (3) high for transportation (Total of six (6) systems per dolly). Systems are secured to the dolly via their rigging pins. A rigid top cover provides a solid surface for stacking and two (2) dolly side panels provide protection for speaker grilles. The dolly may also be used as a ground stack platform, either wheeled or stationary by using the dolly top cover.

X12-128-Dolly: Dolly is used for transporting X12-128 subwoofers. The dolly will accommodate one (1) column of X12-128 subwoofers stacked two (2) high for transportation. The systems are strapped down with ratchet straps for additional protection during transport.

### 3.1 Dimensions

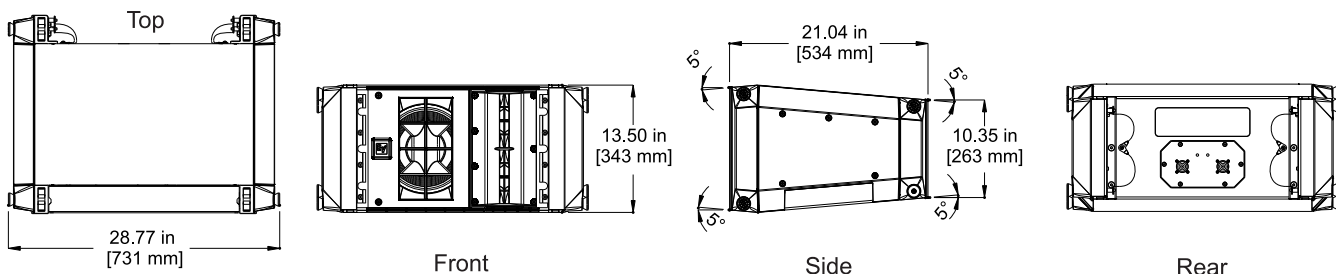


Figure 3.1: X1-212/90 dimensions

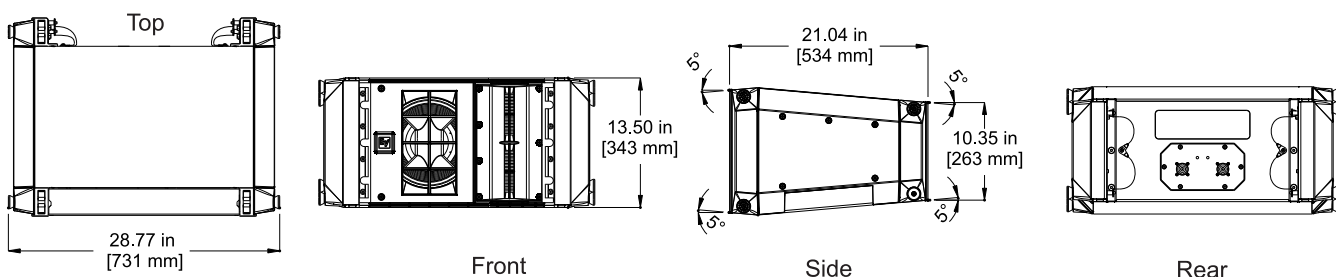


Figure 3.2: X2-212/90 dimensions

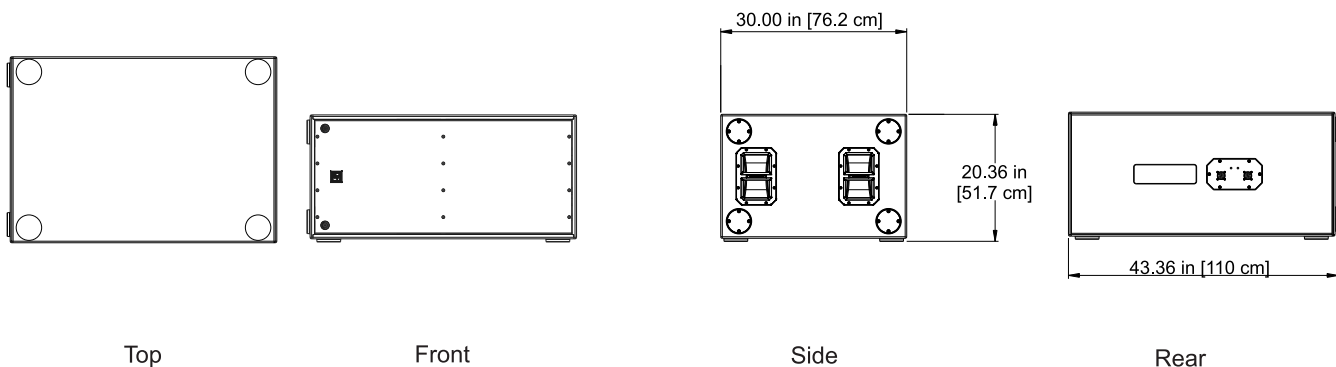


Figure 3.3: X12-128 dimensions

## 3.1.1

### Accessories dimensions

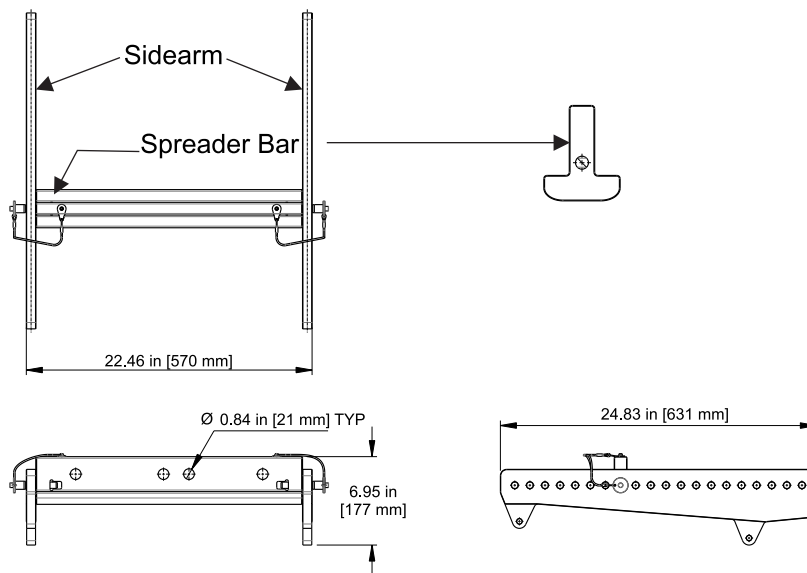


Figure 3.4: X12TC-GRID compact grid dimensions

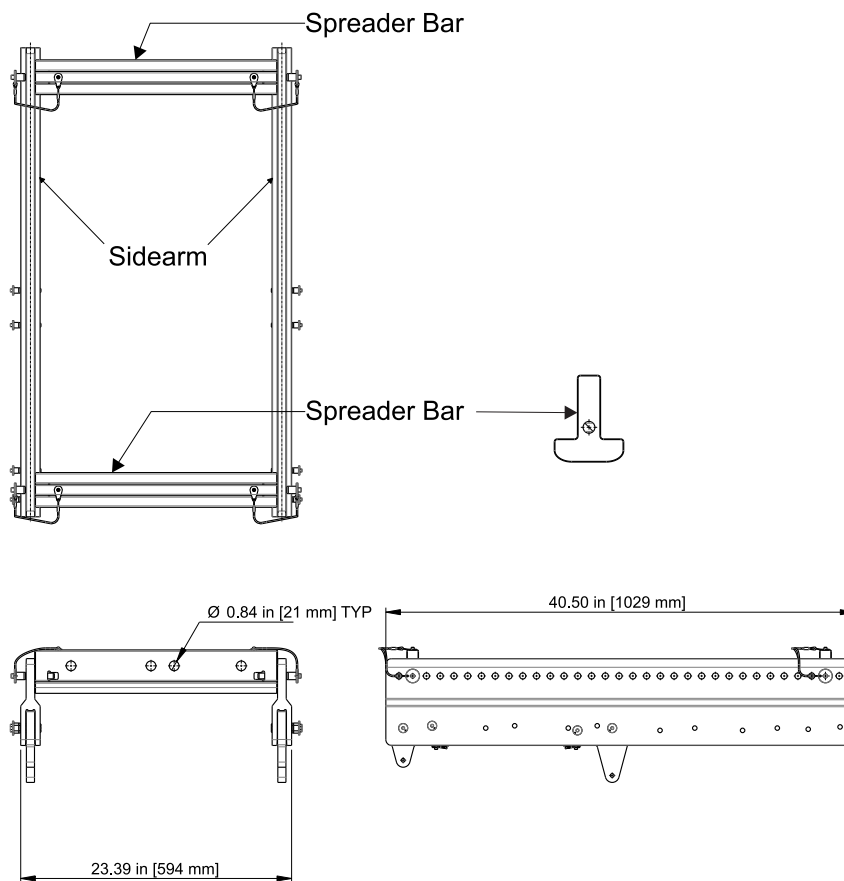


Figure 3.5: X12TE-GRID extended grid dimensions

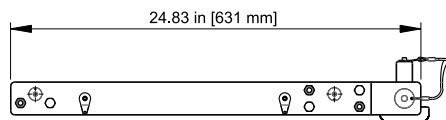
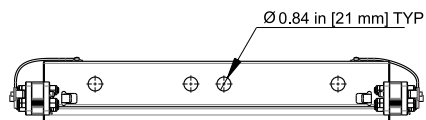
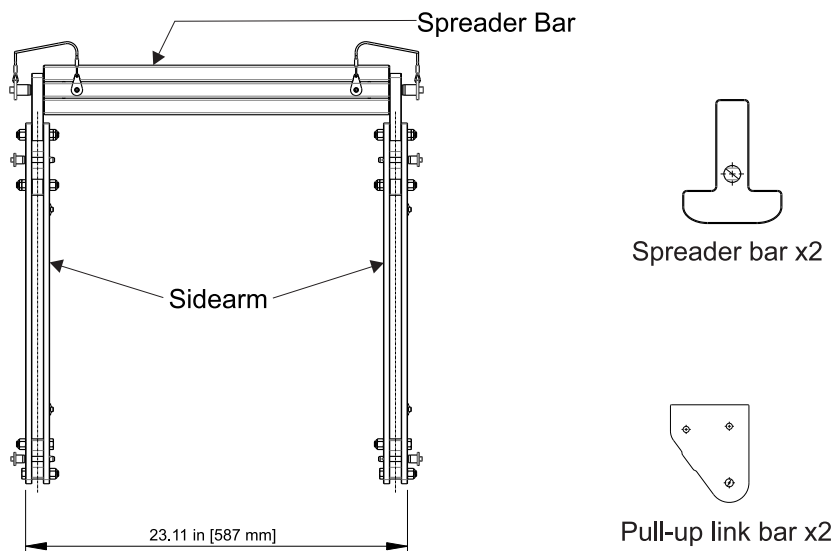
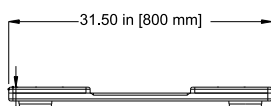
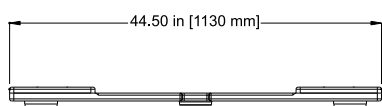
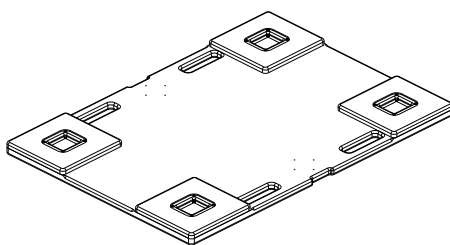
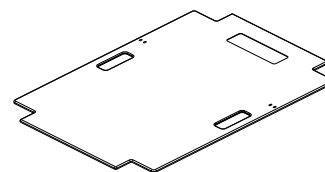


Figure 3.6: X12PU-BGK Pull-up grid dimensions

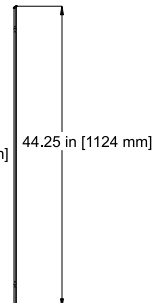
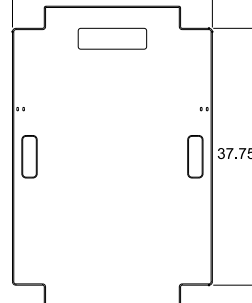


2.39 in [61 mm]

X12T-DOLLY dolly top

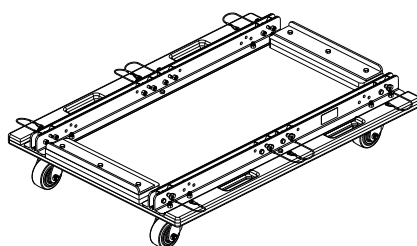


29.38 in [746 mm]



20.03 in [509 mm]

X12T-DOLLY side panel



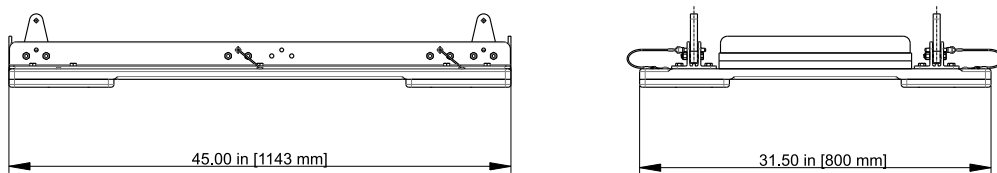
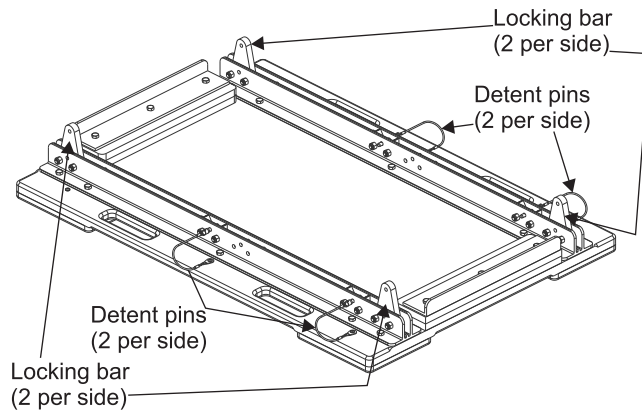
45 in [1143 mm]

31.50 in [800 mm]

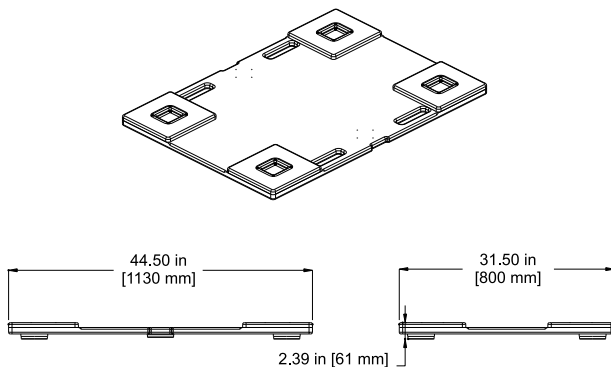
8.73 in [222 mm]

X12T-DOLLY dolly transport base

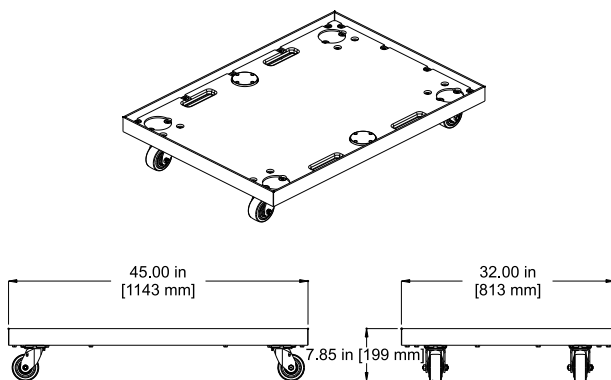
Figure 3.7: X12T-DOLLY dimensions



**Figure 3.8: X1/X2 groundstack dimensions**



**X12-128-DOLLY top**



**X12-128-DOLLY bottom**

**Figure 3.9: X12-128-DOLLY dimensions**



## 4 Designing an X1 or X2 array

### 4.1 Applications for which X-Line Advance arrays are most appropriate

The X1 and X2 loudspeaker systems are specifically designed to construct acoustically coherent line-arrays. Line-array systems typically consist of independent columns of loudspeaker enclosures. The most common implementation is a stereo sound reinforcement system with two (2) columns (left and right). Additional columns are sometimes added to cover different seating sections of a venue, e.g., seating areas that wrap around the side or back of a stage. An additional column is also used in left-center-right configurations, with the center channel for speech. In some venues, where stereo is not required, good coverage can often be obtained with a single array. A variation of such a monaural system is the exploded array, where two (2) or more widely spaced arrays are used to provide the horizontal coverage required. Also, a large number of arrays may be used in distributed systems, such as in an arena.



#### Notice!

The X1 and X2 line arrays, even though mechanically are identical, they are not designed acoustically to work in the same column.

The exact number of X1 or X2 loudspeaker systems in a column varies depending on the vertical acoustic coverage required for the specific venue. Furthermore, the relative vertical angles between the boxes and SPL also depend on the venue's acoustic coverage requirements. Acoustic design techniques are outside the scope of this document and the reader is directed to **LAPS 3** (Line Array Prediction Software) or later modeling software available from the Electro-Voice website [www.electrovoice.com](http://www.electrovoice.com) for acoustic design assistance.

Although the full-range X1 and X2 loudspeaker systems shown in *Dimensions*, page 9 are not horizontally symmetrical, their acoustical polar responses are substantially symmetrical. Thus, stereo left and right arrays, or left-center-right arrays may be constructed with the loudspeakers in their normal right-side-up orientation.

### 4.2 Determining X1 and X2 array configuration with LAPS 3

LAPS 3 is software written in MATLAB with Excel-spreadsheet-based frontend interface for determining optimum array configurations for a given venue and trim heights. The current version of LAPS 3 is downloadable from the Electro-Voice website [www.electrovoice.com](http://www.electrovoice.com).

# 5 Preparing X-Line Advance elements for installation

## 5.1 Recommended preflight procedures

For any installed sound system, certain checks made at the installer's place of business can prevent expensive on-site delays. A short-list follows, and sets the stage for proper array performance:

1. Unpack all loudspeakers in the shop.
2. Check for proper model numbers.
3. Check the overall condition of the loudspeakers.
4. Check for continuity at the loudspeaker inputs.

It is a good idea, once on-site and the loudspeakers are connected, to check again for continuity at the power-amplifier end.

## 5.2 Element configuration

After using LAPS 3 to design an appropriate array, it is recommended all necessary hardware and accessories to suspend the array are checked and accounted for. Ensure all hardware is in good working order, no defects, damage or imperfections are present, and all hardware is capable of meeting or exceeding the total load requirements of the entire array.

## 6 Rigging system

### 6.1 Overview of the flying system

The IRS (Integrated Rigging System) on X1 and X2 was developed as a faster, safer way of flying, aiming and landing a large vertical array.

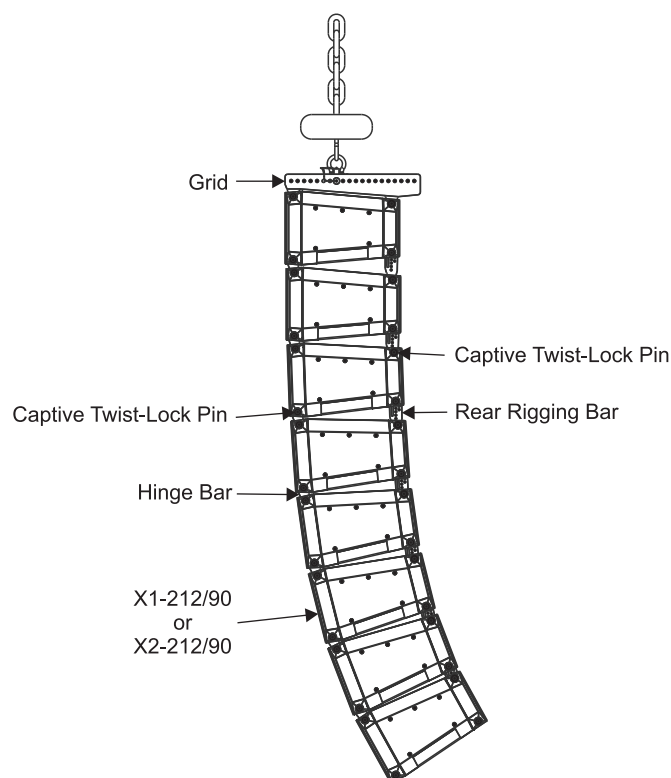


Figure 6.1: Integrated Rigging System

### 6.2 Rigging the boxes together

The individual elements are fastened together by spring-loaded captive twist lock pins. The captive twist lock pins are located at each of the four (4) upper corners and two (2) lower front corners of each box. The upper pins attach each box to the extended link bars of the box above it or grid. The pins are locked in their retracted (Open) position by grasping each pin knob and pulling out as far as it will go, then turning the knob left or right to lock the pin in the retracted position. The link bars of the box or grid above can then be dropped safely into the V-blocks located at the top corners of the aluminum rigging. There is no fumbling for pin holes because alignment is accomplished by the V-blocks. Once seated, the pins are engaged by simply twisting each knob to unlock, allowing the spring to fire the pin into position. Lower front link bars are released or retracted and locked into position the same way. Rear link bars are set to the desired splay angle position with standard quick-release pins.

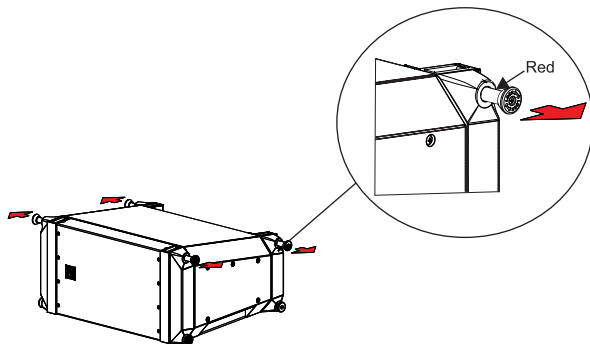
To **rig the boxes together**, do the following:



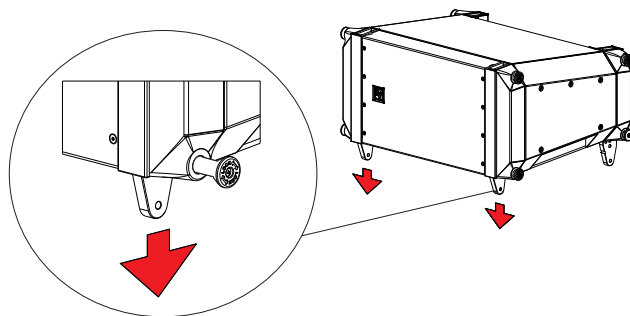
**Notice!**

Before flying the array verify the captive twist lock pins are fully engaged in the rigging (no red showing between the pin knob and the box).

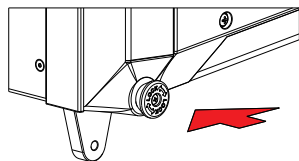
1. Pull and twist **four (4) captive twist lock pins** on the top of the lower enclosure.  
*Four (4) captive twist lock pins are locked in the retracted (open) position.*



2. Extend the **two (2) front link bars** on the bottom of the upper enclosure.



3. Lock the **two (2) captive twist lock pins** for the two (2) front link bars.



4. Guide the **link bars** of the box or grid above into the V-blocks located at the top corners of the aluminum rigging.
5. Twist the **four (4) captive twist lock pins** top of the lower enclosure.  
*Four (4) captive twist lock pins are unlocked in the engaged (Closed) position.*

## 6.3 Setting rear link angles

The rear link angle is selected by choosing corresponding holes in the white ANGLE SELECT sections of the rear rigging on each side (0°, 0.5°, 1°, 1.5°, 2°, 3°, 4°, 5°, 6°, 8°, 10°) as determined by LAPS 3. Unless the rigging is locked into a rigid configuration by secondary pins in the lower black ANGLE LOCK sections, the elements always default to 0° when lifted. Use of the bottom pull-up grid accessory enables the array to be easily compressed with each element stopping at its pre-selected splay angle. Smaller arrays may be rigidly pinned by lifting the rear of each box until it hits the pre-selected angle stop, then inserting a second pin per side into the appropriate hole in the ANGLE LOCK section. There is no fumbling for pin holes because when lifted, the rigging will stop at the pre-selected position.

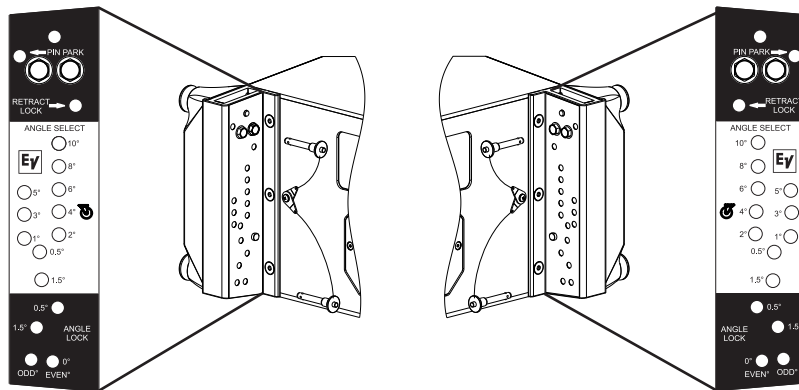
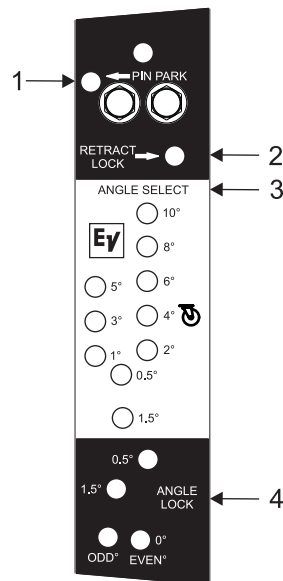


Figure 6.2: X1/X2 Rigging Hardware

### Rear link angle selection



1. **PIN PARK** is used to park the unused pin.
2. **RETRACT LOCK** is used to lock the link bar in stored position.
3. **ANGLE SELECT** (in the white section) is used to set the desired splay angle from the report from LAPS 3. This is used for both fixed-pin angles and rear-rigging compression pull up.
  - **0.5, 1, 1.5, 2, 3, 4, 5, 6, 8, and 10°** are the available angles for selection. For a 0° angle, use the 0° angle hole in the Angle Lock section below.

## X-LINE ADVANCE Systems

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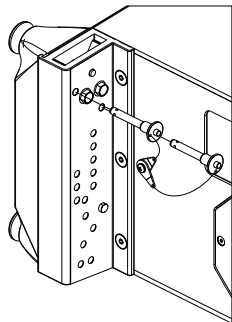
- **DOLLY WHEEL** (the 4° hole) is used to secure the bottom box of a stack to a dolly.
- 4. **ANGLE LOCK** (in the bottom black section) is used to lock the rear link bar for fixed-pinned angles. Except for a 0° angle, this section is not used for rear-rigging compression pull up.
- **0.5° and 1.5°** are used to lock those two (2) angles.
- **ODD°** is used to lock the odd number angles.
- **EVEN°** is used to lock the even number angles and the 0° angle.

### Single pin and double pin

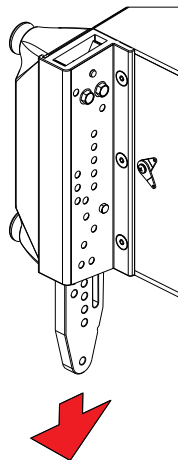
Single pin compression method is used when a pull-up to the grid is employed to pull the rear rigging together into compression. Double pin is used to set the rear rigging at fixed angles. Ensure both sides of the loudspeaker are pinned identically.

To **single pin or double pin**, do the following:

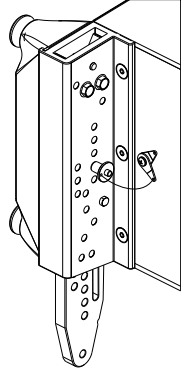
1. Release the **quick-release pin** from RETRACT LOCK hole.



2. Lower **rear link bar**.

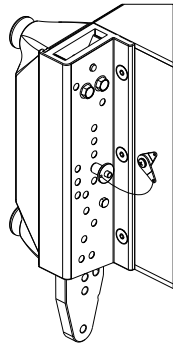


3. Insert **quick-release pin** into desired ANGLE SELECT degree hole.  
*Verify pin is thoroughly pushed in and the blue button is released.*

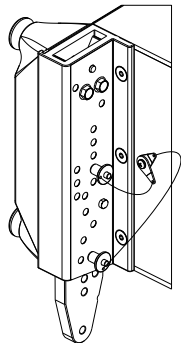


4. If using **single pin repeat steps 1-4** on the other side of the loudspeaker.  
*Repeat this process on all elements in the array setting the angles per the report from LAPS 3.*
- 3.
- OR
- If using **double pin** continue to the next step.

5. Double pin: Push the **rear link bar** up until it contacts the stop pin in the angle select hole.



6. Insert the second **quick-release pin** into desired ANGLE LOCK hole.  
*Verify pin is thoroughly pushed in and the blue button is released.*



7. **Repeat steps 1-7** on the other side of the loudspeaker.  
*Repeat this process on all elements in the array setting the angles per the report from LAPS 3.*

## 6.4 Deciding which grid configuration to use

Choosing a grid is determined by the system down or up angles in combination with the number of elements in the array and the splay angle between them. To determine which grid model will achieve your desired angle or where the safety limitations are for the arrays, please use LAPS 3 to design your array, and observe all warnings and limitation messages displayed by the software.

### 6.4.1 X12TC-GRID compact grid

The X12TC-GRID compact grids are appropriate for arrays where extreme up or down angles are not required. It is rated for a maximum hang of up to 24 X1 or X2 elements in a single column. Use LAPS 3 to determine if X12TC-GRID combined with the number of elements will achieve the acoustical coverage in the venue at a safe working load. For more information, see *Rigging structural strength ratings and safety factors*, page 54



#### Notice!

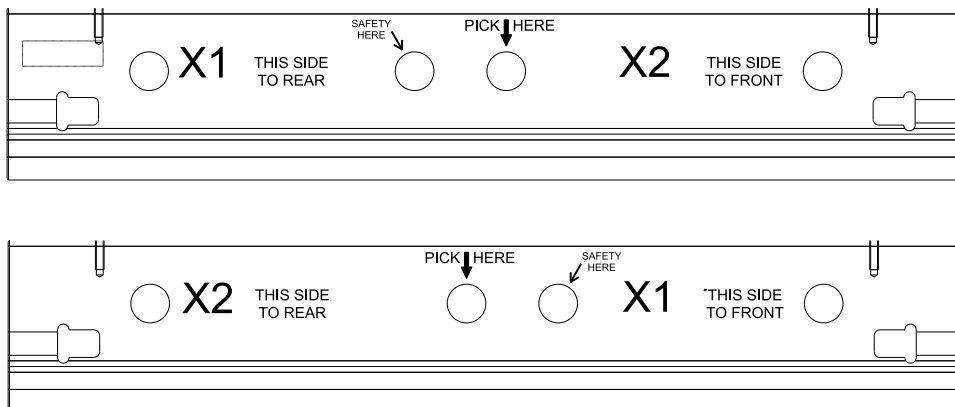
X12TC-Grid comes with one (1) spreader bar only. The use of a second spreader bar is not recommended with this grid.

X12TC-GRID includes one (1) spreader bar and two (2) sidearms. The spreader bar has four (4) 0.84-inch (21.4 mm) holes through it for use as attachment points. The hole near the center of the bar labeled PICK HERE is used for lifting a single point hang. This hole is slightly off-center to compensate for the center of gravity of the respective X1 and X2 systems. Pay close attention to which way the spreader bar is oriented with respect to the loudspeaker systems. Compare the wording on the left end of the spreader bar to the input panel label on the loudspeaker. For an X1 system, the bar should read X1 THIS SIDE TO REAR and for an X2 system it should read X2 THIS SIDE TO REAR.



#### Caution!

Verify the correct spreader bar orientation before lifting the array. Failure to comply with this instruction results in the entire array tilting to one (1) side at an unsafe angle.



**Figure 6.3: X1/X2 spreader bar**

The hole labeled SAFETY HERE is for attachment of a safety line if required by local regulations. If used, ensure there is minimal slack in the safety line but it is not so tight as to interfere with the vertical alignment of the array hanging from the pick point. The two (2)



outer holes may be used for lifting as a two-point lateral hang, often useful to prevent twisting of the array. In this situation, lifting and suspension lines must not exceed  $15^\circ$  from vertical and both points must be lifted equally so the array is never more than  $\pm 5^\circ$  from horizontal during the lift.



**Caution!**

Do not lift an array by attaching directly to the sidearms.  
Lift with the supplied spreader bar(s) only.

The compact grid sidearms are usually attached with the excess overhang at the rear to allow for greater down-angle possibilities. For situations where more up-angle is possibly required, such as covering a high balcony in a theater, the grid can be reversed with the excess grid length overhanging the front of the array.

**Installing the X12TC-GRID to an X1 or X2 loudspeaker**

When the compact grid with its single spreader bar is used, the trim angle of the array is determined by the front-to-back attachment position of the spreader bar. This information is provided by LAPS 3, a function of the array makeup and desired vertical aiming.



**Caution!**

Verify each end of the spreader bar is pinned in the same number hole on both sidearms.  
Ensure the pins attaching the grid sidearms are fully locked into the holes in the ends of the spreader bar.



**Notice!**

Using the PICK HERE alone requires a tie-off to stabilize the horizontal rotation of the array.

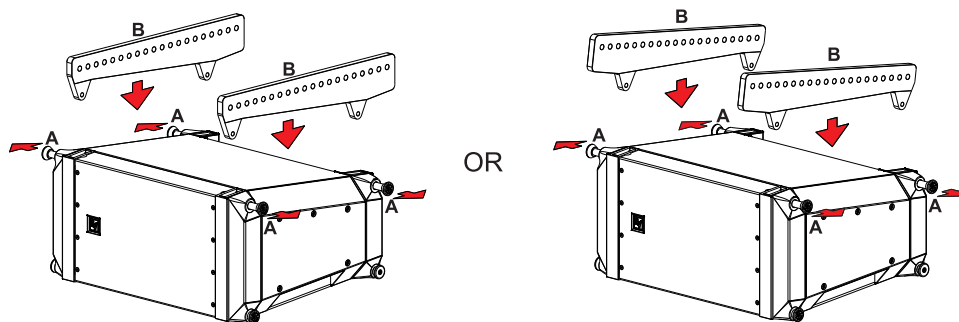


**Notice!**

Before flying the array verify the captive twist lock pins are fully engaged in the rigging (no red showing between the pin knob and the box).

To **install the X12TC-GRID**, do the following:

1. Pull and twist **two (2) captive twist lock pins (A)** on one side of the loudspeaker.  
*Two (2) captive twist lock pins are locked in the retracted (Open) position.*



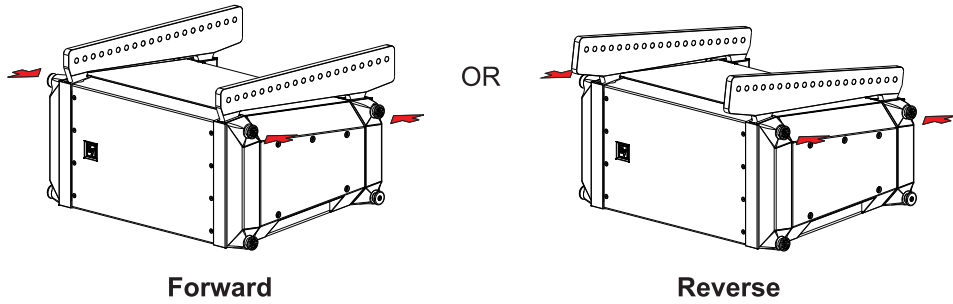
**Forward**

**Reverse**

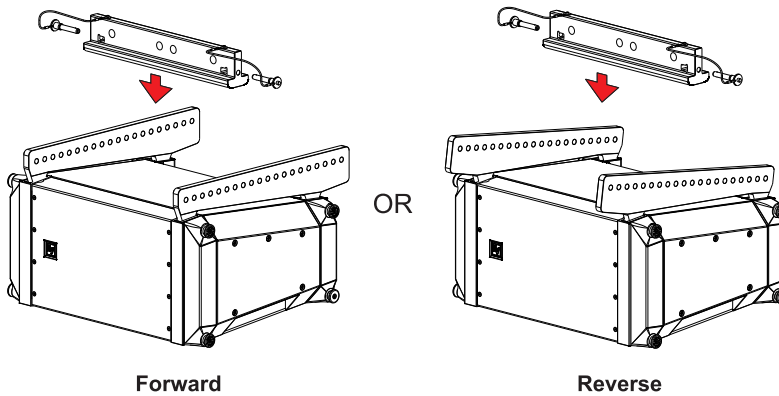
2. Guide **one (1) sidearm (B)** into the rigging tubes until it is fully seated in the V-blocks.

# X-LINE ADVANCE Systems

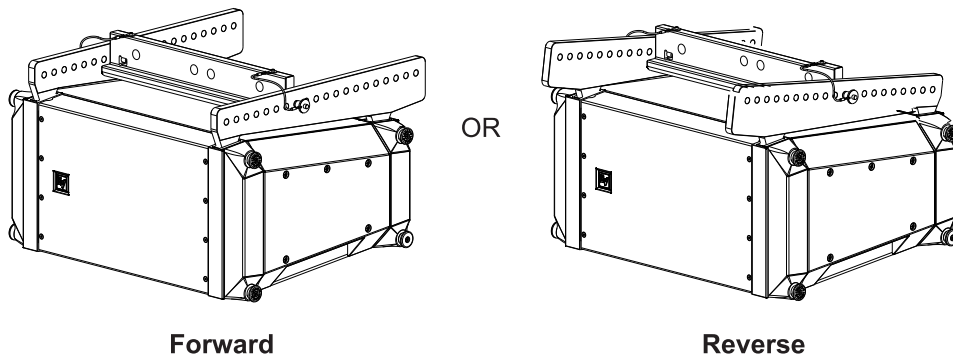
3. Twist the **two (2) captive twist lock pins**.  
*Two (2) captive twist lock pins are unlocked in the engaged (Closed) position.*



4. Repeat **steps 1-3** on the opposite side of the loudspeaker.  
*Two (2) sidearms are attached to the loudspeaker.*
5. Attach **one (1) spreader bar** to the **two (2) sidearms** using the hole locations from LAPS 3.

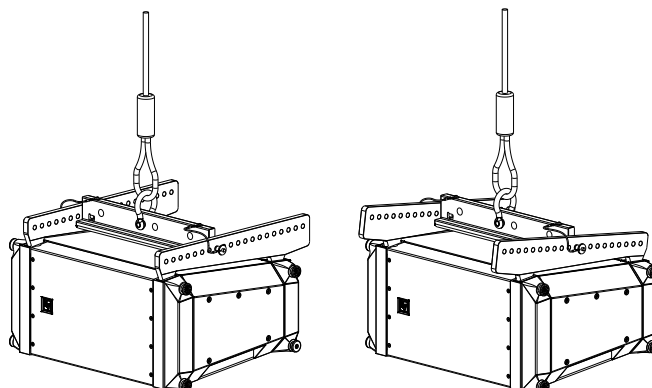


6. Verify the **spreader bar** is correctly oriented for the model of loudspeaker (X1 or X2) being rigged.



7. Attach a **5/8-inch shackle** to the hole labeled PICK HERE on the spreader bar.  
*Ensure the shackle is rated for overhead lifting.*

8. Attach the lifting **cable/chain** to the shackle.



**Forward**

**Reverse**

9. Verify all **hooks, pins, shackles, and other associated rigging components** are properly positioned and secure before lifting the array.

## 6.4.2

### X12TE-GRID extended grid

X12TE-GRID extended grid is available for flying arrays that require greater up or down angles than what are possible with the X12TC-GRID compact grid. The front and rear link bars are adjustable in three different positions to facilitate the extreme up-angles sometimes required in venues with multiple high balconies. The additional length of the X12TE-GRID also enables more extreme down-angles from a single point than would otherwise be possible. Note that de-rating occurs as the angle becomes more extreme. Consult LAPS 3 for limitations in a particular array configuration. The X12TE-GRID is also required in order to use the X12PU-BGK pull-up grid to aim an array using the rear compression rigging method. The X12TE-GRID comes with two spreader bars to allow the use of two motors to provide easy angle control of large arrays, especially when compression rigging is used. The resulting fore-and-aft pick points also provide better horizontal stability than a typical rear tie-off point.

Each spreader bar has four (4) 0.84-inch (21.4 mm) holes through it for use as attachment points. The hole near the center of the bar labeled PICK HERE is used for lifting a single point hang. This hole is slightly off-center to compensate for the center of gravity of the respective X1 and X2 systems.

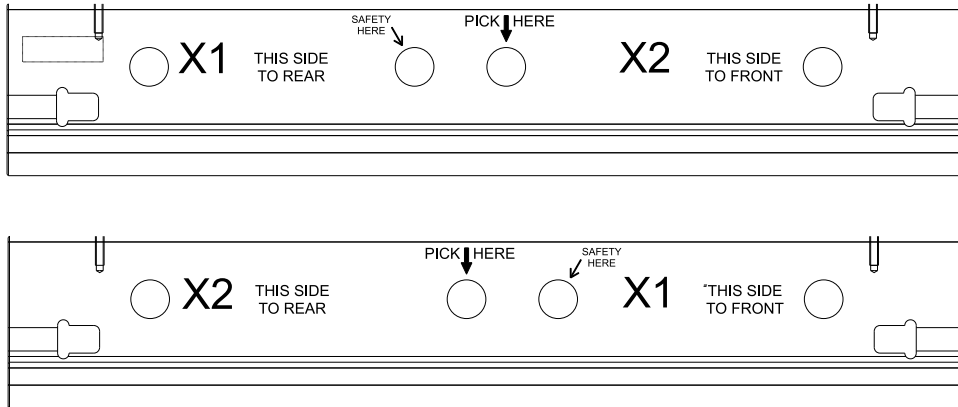
Pay close attention to which way the spreader bar is oriented with respect to the loudspeaker systems. Compare the wording on the left end of the spreader bar to the input panel label on the loudspeaker. For an X1 system, the bar should read X1 THIS SIDE TO REAR and for an X2 system it should read X2 THIS SIDE TO REAR.



#### **Caution!**

Verify the correct spreader bar orientation before lifting the array.

Failure to comply with this instruction results in the entire array tilting to one (1) side at an unsafe angle.



**Figure 6.4: X1/X2 spreader bar**

The hole labeled SAFETY HERE is for attachment of a safety line if required by local law. If used, ensure there is minimal slack in the safety line(s) but it is not so tight as to interfere with the vertical alignment of the array hanging from the pick point. The two (2) outer holes may be used for lifting as a two-point lateral hang, often useful to prevent twisting of the array or in situations where a 4-point hang is required with two (2) spreader bars. In this situation, lifting and suspension lines must not exceed 15° from vertical and all points must be lifted equally so the array is never more than ±5° from horizontal during the lift.



**Caution!**

Do not lift an array by attaching directly to the sidearms.  
Lift with the supplied spreader bar(s) only.

**Installing the X12TE-GRID to an X1 or X2 loudspeaker**



**Caution!**

The extended grid sidearms are heavy and likely to tip if not secured, potentially causing damage and/or personal injury if one (1) should fail.  
Always maintain a good grip on the sidearm until both twist-lock pins are fully engaged.



**Caution!**

Verify each end of the spreader bar is pinned in the same number hole on both sidearms.  
Ensure the pins attaching the grid sidearms are fully locked into the holes in the ends of the spreader bar.

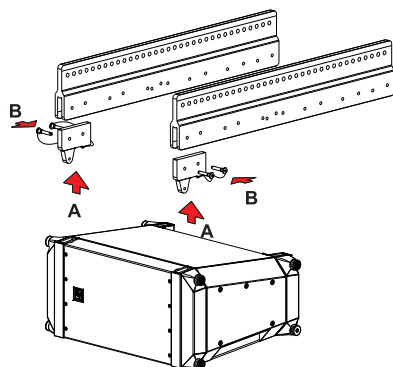


**Notice!**

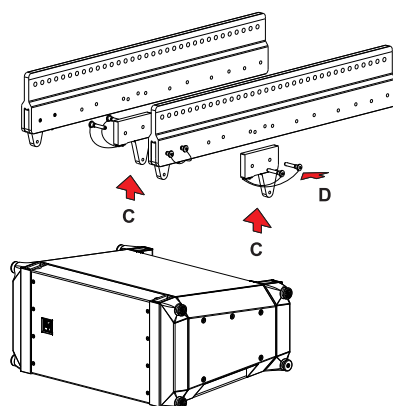
Before flying the array verify the captive twist lock pins are fully engaged in the rigging (no red showing between the pin knob and the box).

To **install the X12TE-GRID**, do the following:

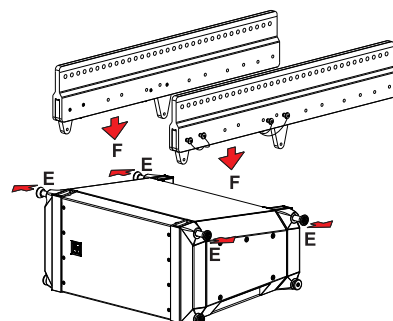
1. Attach **front link bars (A)** to the sidearms.  
*Consult LAPS 3 for the A, B, or C position of the front link bar for the particular array being flown.*



2. Insert the attached **quick-release pins (B)**.  
*Verify all quick-release pins are inserted completely through the sidearm and securely locked in position.*
3. Attach **rear link bars (C)** to the sidearms.  
*Consult LAPS 3 for the rear link bars position corresponding to the A, B, or C position of the front link bar for the particular array being flown.*

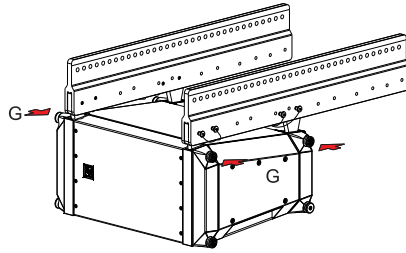


4. Insert the attached **quick-release pins (D)**.  
*Verify all quick-release pins are inserted completely through the sidearm and securely locked in position.*
5. Pull and twist **two (2) captive twist lock pins (E)**.  
*Two (2) captive twist lock pins are locked in the retracted (open) position.*

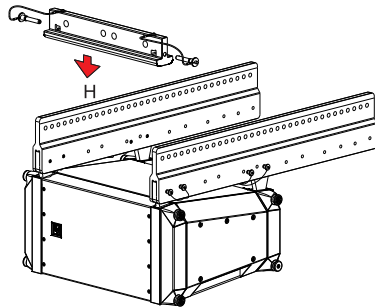


6. Guide **one (1) sidearm (F)** into the rigging tubes until it is fully seated in the V-blocks.  
*Keep a good grip on the sidearm until both pins are completely engaged through the rigging.*

- Twist the **two (2) captive twist lock pins (G)**.  
*Two (2) captive twist lock pins are unlocked in the engaged (Closed) position.*

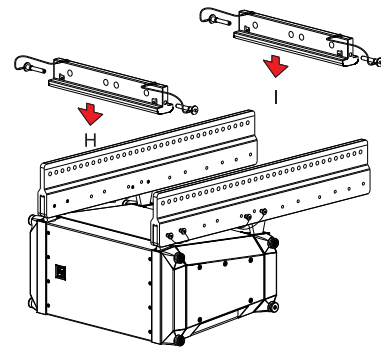


- Repeat **steps 6-8** on the opposite side of the enclosure.  
*The second sidearm is attached to the loudspeaker.*
- Verify the **spreader bar** is correctly oriented for the model of loudspeaker (X1 or X2) being rigged.  
*Both spreader bars must face the same way with their pick point holes aligned.*
- Attach a single **spreader bar (H)** to the two (2) sidearms at the hole position determined by LAPS 3.



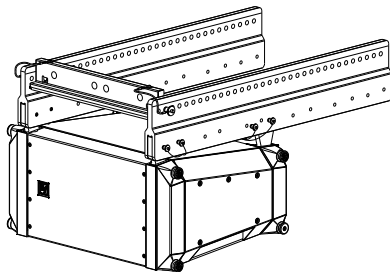
**Single**

OR



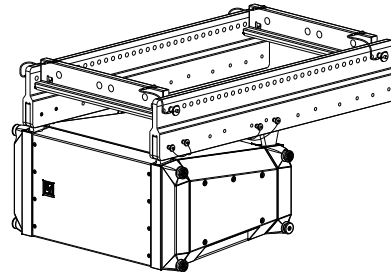
**Dual**

- If using two (2) motors and two (2) spreader bars, attach **one (1) spreader bar (H)** at hole #1 and **one (1) spreader bar (I)** at hole #33.



**Single**

OR



**Dual**

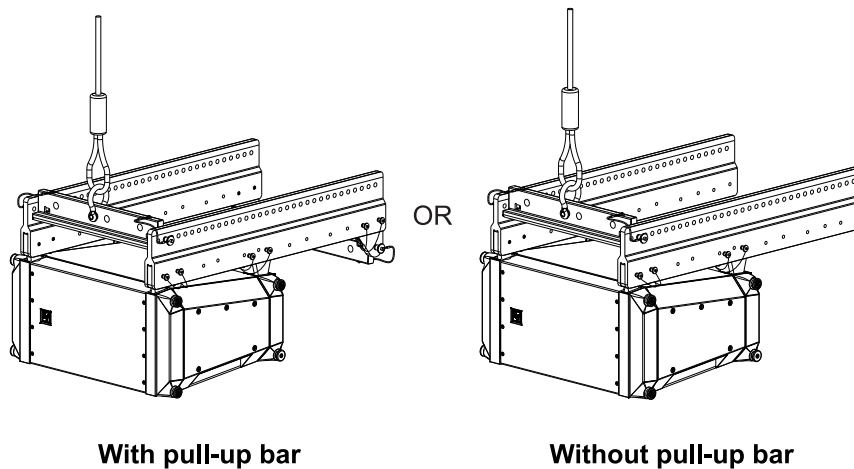
- Attach a **5/8-inch shackle** to the hole labeled PICK HERE on the spreader bar(s).  
*Ensure the shackle is rated for overhead lifting.*
- Attach the **lifting cable/chain(s)** to the shackle(s).
- Verify all **hooks, pins, shackles, and other associated rigging components** are properly positioned and secure before lifting the array.

**X1 or X2 Extended Grid Rigging Configurations**

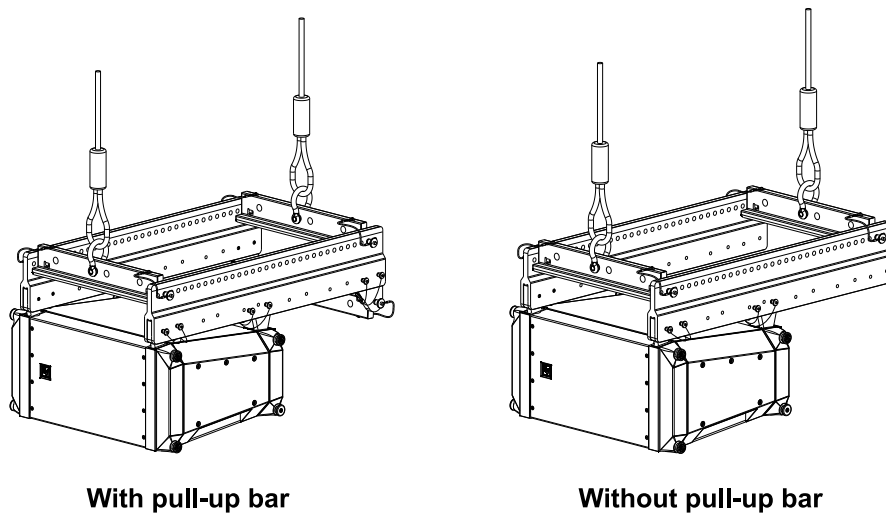


**Caution!**

Do not lift an array by attaching directly to the sidearms.  
Lift with the supplied spreader bar(s) only.



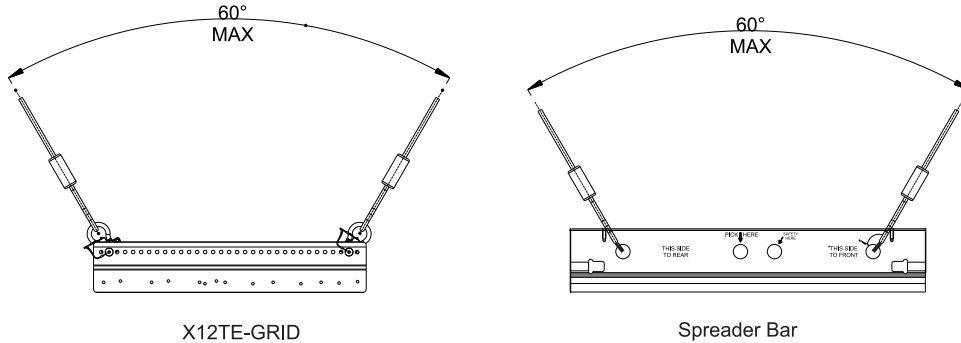
**Figure 6.5: X12TE-GRID - Single**



**Figure 6.6: X12TE-GRID - Dual**

## 6.4.3 X12PU-BGK pull-up kit

X12PU-BGK pull-up kit is used when the compression rigging method is being used with an array or when extreme down angles beyond the capabilities of the extended grid are required. This is a way to achieve extreme down angles, such as might be encountered in a distributed arena system. When using one (1) X12TC-GRID and one (1) X12PU-BGK in this fashion, the angle between the suspension lines must never be allowed to exceed 30°. For maximum angles, restrictions and limitations, consult LAPS 3 and follow all warning, limitations and restrictions recommended by the software.



**Figure 6.7: Double pick point maximum angle**

For rear-rigging compression, the user must build a pull-up assembly. The X12PU-BGK includes two (2) spreader bars and two (2) pull-up link bars. One (1) spreader bar attaches to the X12PU-BGK bottom. The other spreader and the two (2) pull-up link bars attach to the bottom of the X12TE-GRID top grid at the rear-most attachment position. The pull-up assembly attaches between the two (2) spreader bars. The remaining components of the pull-up assembly must be provided by the user.

A lever hoist will be used for the pull-up assembly. The user extends the chain from the hoist and attach to the pull-up spreader bar on the X12TE-GRID using a 5/8 shackle. One (1) end of a 3-foot-long (or one-meter-long) wire rope sling attaches to the bottom hook of the hoist. The other end of the wire rope sling attaches to the spreader bar on the X12PU-BGK using a 5/8-inch shackle.

The user provides the two (2) 5/8-inch shackles, wire rope sling, and lever hoist. Electro-Voice recommends using a wire rope sling with a load rating of at least 2400 pounds (or 1100 kg) for vertical configuration. Electro-Voice recommends using a Columbus-McKinnon model 653 lever hoist having a 1.5-ton rating and 20 feet of chain.

Using these components, the pull-up assembly accommodates a quantity of 8 to 20 X1 or X2 loudspeaker systems. This pull-up assembly has been modeled in LAPS 3. If a different pull-up assembly is used, the angle at which an array hangs may differ from what LAPS 3 predicts.

Proper spreader bar orientation must be maintained when used in conjunction with the pull-up grid. Always orient bars to the system model when viewed right-side-up, and then simply rotate the top pull-up spreader bar upside-down before attaching to the pull-up bars at the rear of a X12TE-GRID. Do not swap ends! Correct orientation puts the pick holes of all spreader bars in alignment in the same vertical plane. The spreader bar at the bottom of an array will always be oriented right-side-up.



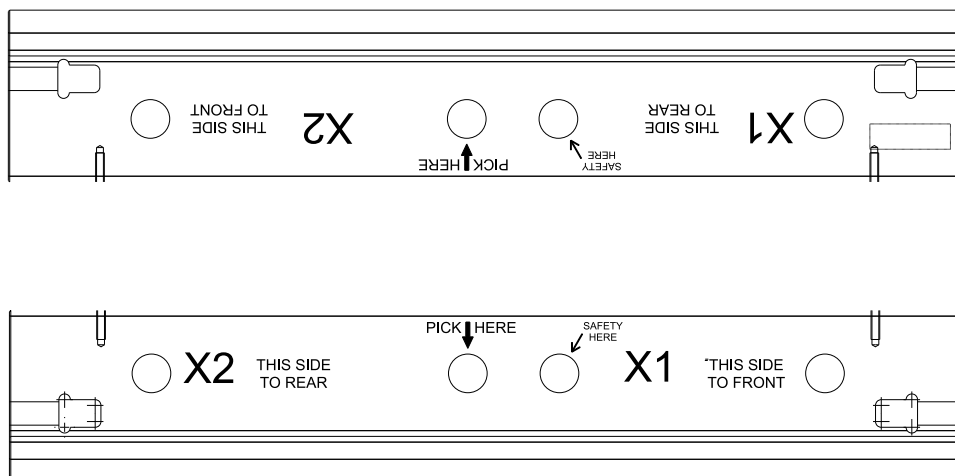


Figure 6.8: X1/X2 spreader bars properly orientated for use with pull-up grid for X2 array.

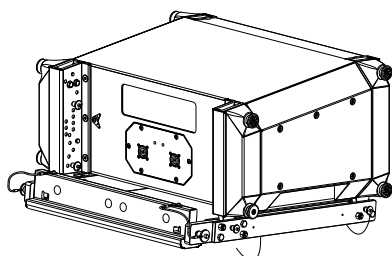


Figure 6.9: X12PU-BGK installed

#### Using the X12PU-BGK with an X12TE-GRID for compressing an X1 or X2 array

The X12PU-BGK pull-up bar is installed on the bottom-most element in the array.



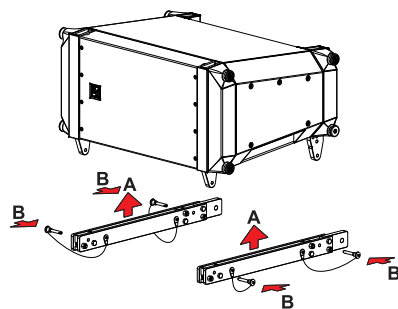
#### Caution!

Verify each end of the spreader bar is pinned in the same number hole on both sidearms. Ensure the pins attaching the grid sidearms are fully locked into the holes in the ends of the spreader bar.

To **install the X12PU-BGK**, do the following:

1. Extend and lock the **front link bars**.
2. Extend and lock the **rear link bars**.
3. With the sidearm V-blocks facing up and the solid bar facing the rear, guide the **V-blocks** on the extended link bars (A).

*Do not release the sidearm until it is securely attached to the loudspeaker.*



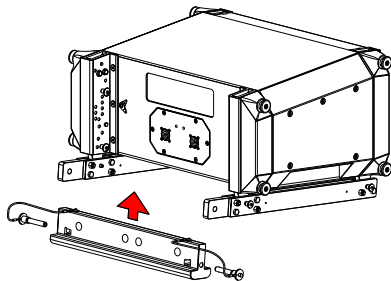
4. Insert the attached **quick-release pins (B)** through each sidearm and link bars, front and rear.

*Ensure all quick-release pins are completely through the sidearms and securely locked.*

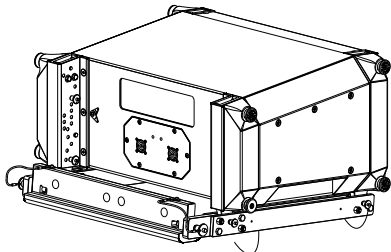
## X-LINE ADVANCE Systems

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5. Attach a **spreader bar** to the two (2) side arms in the rear.



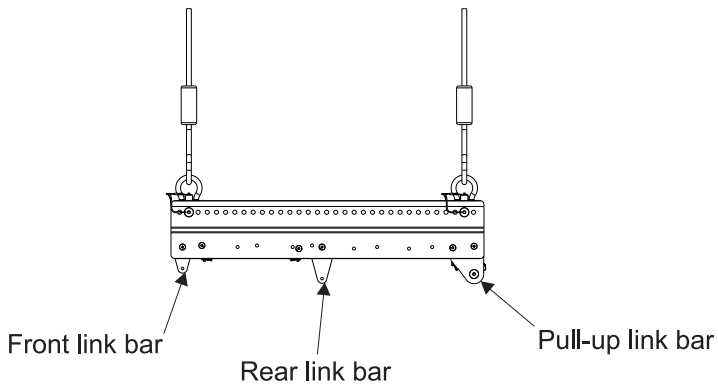
6. X12PU-BGK is assembled.



### Using the X12PU-BGK with the X12TE-GRID

To **use the X12PU-BGK with the X12TE-GRID**, do the following:

1. Attach the **two (2) pull-up link bars to the sidearms.**



2. Insert the attached **quick-release pins.**

*Verify all quick-release pins are inserted completely through the sidearm and securely locked in position.*

For more information, see *X12TE-GRID using X12PU-BGK to pull-up to grid*, page 43.

## 6.5 X12T-DOLLY and X12-128-DOLLY

X12T-Dolly: Dolly is used for transporting X1 or X2 loudspeaker systems. The dolly accommodates two (2) columns of X1 or X2 loudspeaker systems stacked three (3) high for transportation (Total of six (6) systems per dolly). Systems are secured to the dolly via their rigging pins. A rigid top cover provides a solid surface for stacking and two (2) dolly side panels provide protection for speaker grilles. The dolly may also be used as a ground stack platform, either wheeled or stationary by using the dolly top cover.

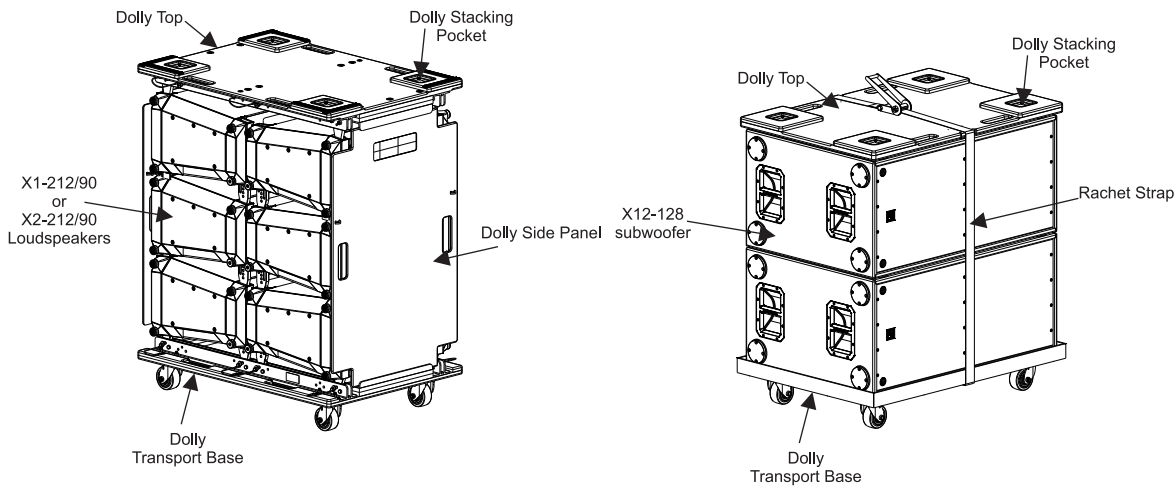
X12-128-Dolly: Dolly is used for transporting X12-128 subwoofers. The dolly will accommodate one (1) column of X12-128 subwoofers stacked two (2) high for transportation. The systems are strapped down with ratchet straps for additional protection during transport.

### Notice!

#### Dolly stacking limits



X12T-DOLLY accommodates two (2) columns of X1 or X2 loudspeaker systems stacked three (3) high for transportation. The dolly is designed for a total of six (6) loudspeakers per dolly. X12-128-DOLLY accommodates one (2) column of X12-128 subwoofers stacked two (2) high for transportation. The dolly is designed for a total of two (2) subwoofers per dolly.



## 6.5.1 Stacking X1 & X2 loudspeakers onto a X12T-DOLLY



### Caution!

Two (2) person lift and placement is recommended for the heavier loudspeakers. Single person lift and placement of heavier loudspeakers could cause injury.



### Caution!

Ensure the correct dolly pins are released from the dolly base. There are four (4) dolly pins for each stack on the dolly base. There is a total of eight (8) pins on the dolly base. If the column of enclosures is lifted with the dolly pins still locking to the speakers to the base, the dolly base will lift and tip. Property damage and personal injuries may occur.



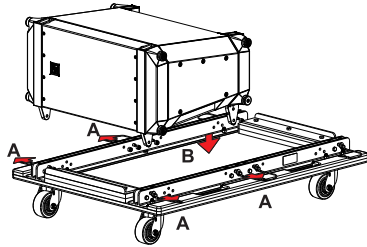
### Notice!

#### Dolly Wheel (the 4° hole):

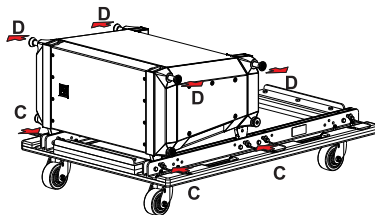
The bottom element to be landed on the dolly base must be pinned in 4° hole (Ⓢ) in the ANGLE SELECT section. Compress the rear link bars until they contact the angle select pin and lock by adding a second pin in the EVEN holes of the ANGLE LOCK section. Ensure the two (2) front link bars are lowered and locked.

To **stack X1 or X2 loudspeakers onto a dolly**, do the following:

1. Release the **four (4) dolly pins (A)** on the dolly.  
*All four (4) dolly lock pins are released and hanging from the dolly.*

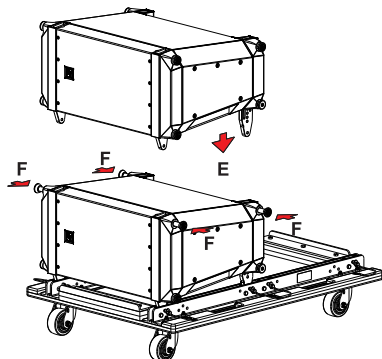


2. Guide the **loudspeaker (B)** onto the dolly with the grille facing out.
3. Insert the **four (4) dolly pins (C)** to lock the loudspeaker onto the dolly.  
*Ensure the dolly pins are secure.*



4. Pull and twist the **four (4) captive twist lock pins (D)**.  
*All four (4) captive twist lock pins are in the unlock position.*

5. Guide the next **loudspeaker (E)** onto the stack.  
*Ensure the loudspeaker rear link bars angles are set to 0° EVEN.*



6. Twist the **four (4) captive twist lock pins (F)**.  
*All four (4) captive twist lock pins are in the lock position. Ensure the loudspeaker is secure.*
7. Repeat **steps 4-6** to add up to three (3) X1 or X2's in a single column.
8. Rotate the **dolly**.
9. Repeat **steps 1-6** to stack the second column.



The loudspeakers can be transported on the dolly. For more information, see *Transporting X1 or X2 loudspeakers*, page 47.

## Groundstacking X1 or X2 loudspeakers

The dolly top is designed to be used as a groundstacking kit. Maximum recommended groundstack height is six (6) elements.

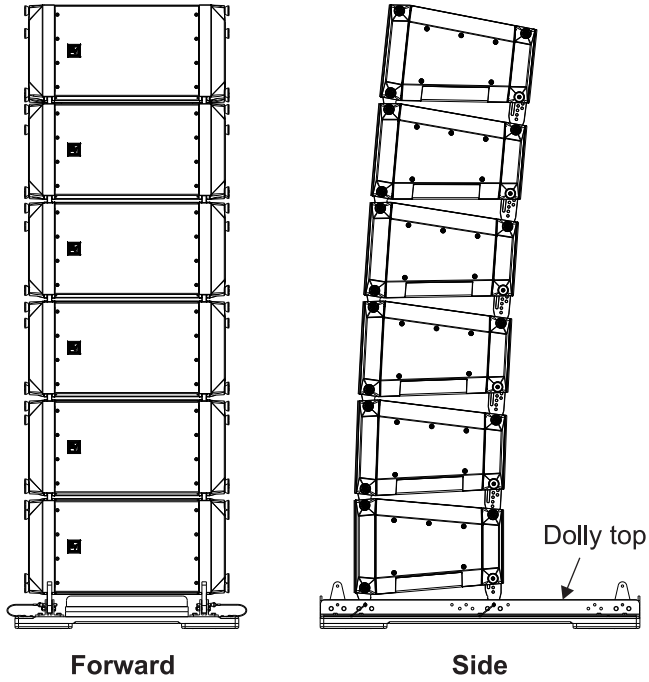


Figure 6.10: X1 or X2 groundstacking

## 6.5.2 Stacking X12-128 subwoofer(s) onto a X12-128-DOLLY

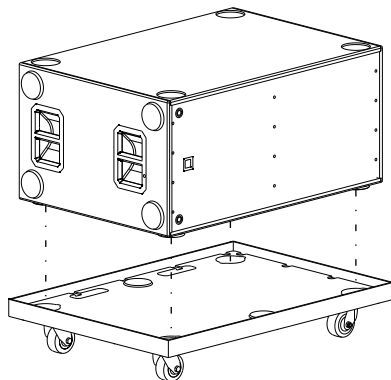


### Caution!

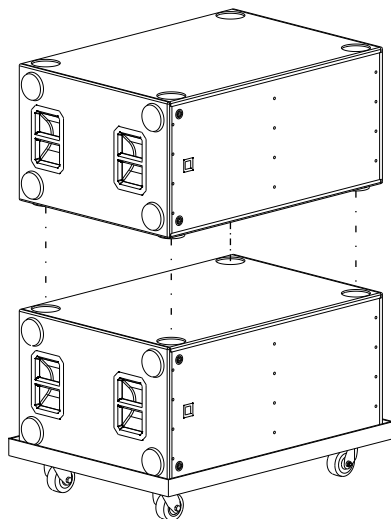
Two (2) person lift and placement is recommended for the heavier loudspeakers. Single person lift and placement of heavier loudspeakers could cause injury.

To **stack X12-128 subwoofers onto a dolly**, do the following:

1. Guide **one (1) subwoofer** onto the dolly.



2. Guide a second **subwoofer** onto the stack.

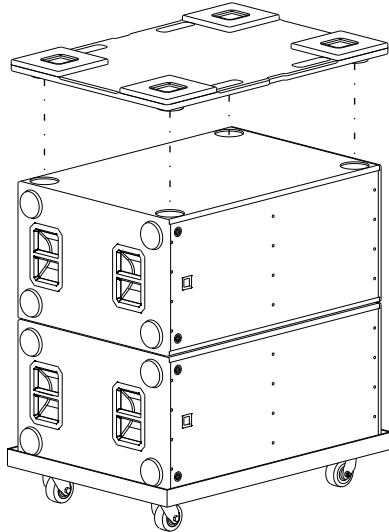


### Transporting subwoofers

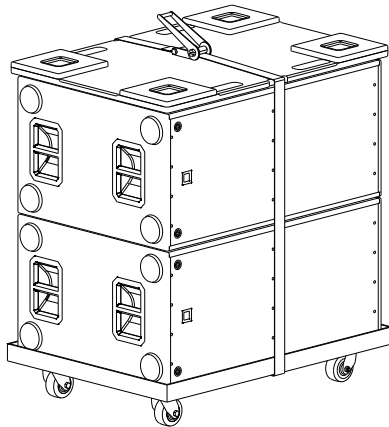
The subwoofer dolly can be used for long-range transport.

To **prepare subwoofers for transport**, do the following:

1. Place the **dolly top** onto the stack.



2. Run the **ratchet strap** under the dolly.  
*The ratchet strap is flat against the subwoofers and it is not twisted.*
3. Align the **ratchet strap** on the strap cutout on the dolly top.
4. Tighten the **ratchet strap**.  
*Dolly contents secured for transport.*





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## 6.6 Assembling and flying an array

Use LAPS 3 to design the array.

### 6.6.1 Flying arrays from the dolly

Arrays can be flown from the dolly and angles set before the array is lifted.

**Caution!**

When suspending any Electro-Voice loudspeaker array overhead, the working-load limit must never be exceeded for the individual enclosure rigging point, for the overall enclosure, or for any of the rigging accessories.

**Caution!**

Do not lift an array by attaching directly to the sidearms.  
Lift with the supplied spreader bar(s) only.

**Caution!**

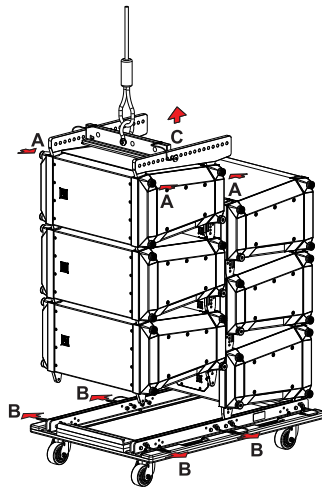
Ensure the correct dolly pins are released from the dolly base. There are four (4) dolly pins for each stack on the dolly base. There is a total of eight (8) pins on the dolly base. If the column of enclosures is lifted with the dolly pins still locking to the speakers to the base, the dolly base will lift and tip. Property damage and personal injuries may occur.

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To **fly an array from a dolly**, do the following:

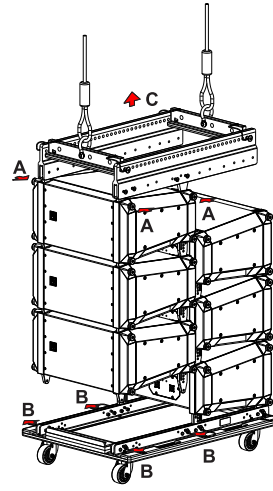
1. If using the **X12TC-GRID**, choose the forward or reversed orientation.  
OR  
If using the **X12TE-GRID**, preassemble each sidearm with front and rear link bars in the appropriate A, B or C position.
2. Pull and twist **four (4) captive twist lock pins**.  
*Four (4) captive twist lock pins are locked in the retracted (Open) position.*
3. Place **one (1) grid sidearm** into the rigging tubes of the first stack to be lifted and engage both V-blocks on that side.  
*Ensure the sidearm is secure before releasing it.*

- Twist the **two (2) captive twist lock pins (A)** to the unlock position.  
*Ensure the pins are engaged in the closed position.*



X12TC-GRID

OR



X12TE-GRID

- Repeat steps 3-4** on the opposite side.  
*The grid is attached to the column of enclosures.*
- Using a single spreader bar with X12TC-GRID, install **one (1) spreader bar** between the sidearm's in the appropriate hole as determined by LAPS 3.  
OR  
If using two (2) spreader bars with X12TE-GRID, install **one (1) spreader bar** at hole #1 and install **one (1) spreader bar** at hole #33.
- Attach a **5/8-inch shackle(s)** to the pick point on the spreader bar(s).  
*Ensure the shackle is rated for overhead lifting.*
- Attach the **hoist chain hook** to the shackle.
- Disengage all **four (4) dolly pins (B)** from the bottom rigging on the column to be lifted.
- Verify all **hooks, pins, shackles, and other associated rigging components** are properly positioned and secure before lifting the array.
- Lift column of **enclosures (C)**.  
*A single column of three (3) loudspeakers is on the dolly.*
- Roll the **dolly** out from under the lifted column.
- Turn the **dolly** around.

For more information, see *X12TC-GRID compact grid, page 20* or *X12TE-GRID extended grid, page 23*.

### Adjusting the splay angles

Use the report from LAPS 3 to set the angles to build the array. The angle between boxes is set on the box above. If using compression, the unused quick-release pins should be placed in the PIN PARK holes. If using a fixed hang, lift the bottom rear of each successive box starting from the bottom until it hits the stop at the selected angle.



#### Notice!

Use of a separate cable pick to support the weight of cabling is recommended, especially on very tall arrays.

Cable weight can change the aiming angle of an array.

To **set the splay angle**, do the following:

1. Insert an attached **quick-release pin** in the correct ANGLE SELECT hole.
2. **Repeat step 1** on the opposite side.

*Verify both sides are identical.*

3. Single pin compression method place the **second pin** in PIN PARK.  
OR

Double pin compress the boxes until the **rear link bars** contact the angle select pin.

Insert the other attached **quick-release pins** into the corresponding holes in the lower black ANGLE LOCK section.

*For example: 0.5°, 1.5°, EVEN numbered or ODD numbered degrees.*

4. Connect the speaker **cables** to the input panels.

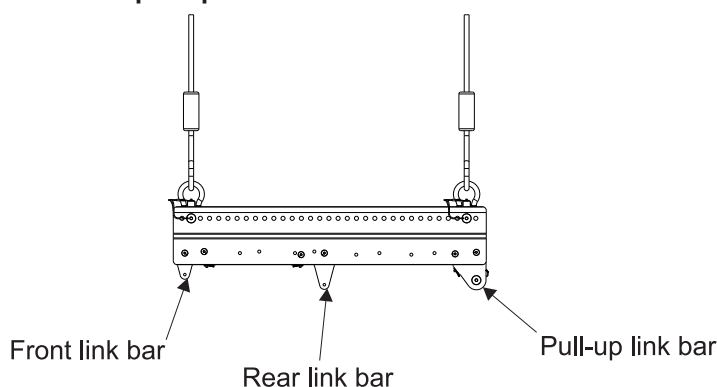
For more information, see *Setting rear link angles*, page 17.

#### For single pin compression method add a pull up assembly to X12TE-GRID only

These instructions apply only to the X12TE-GRID and using the second spreader bar with the X12PU-BGK to pull-up to the grid. If you are using the X12TC-GRID, skip this section and continue to the next section.

To **add the pull-up assembly to the X12TE-GRID**, do the following:

1. Attach the **pull-up link bars** to the rear of the X12TE-GRID.

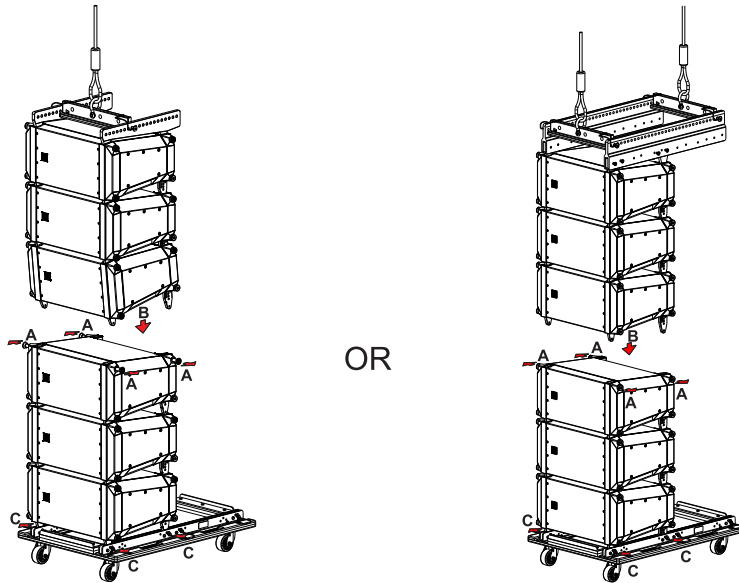


2. Attach the **spreader bar** to the pull-up link bars on the top grid.
3. Attach a **5/8-inch shackle(s)** to the pick point on the spreader bar(s).  
*Ensure the shackle is rated for overhead lifting.*
4. Attach the **chain hook** from the pull-up hoist to the shackle.

For more information, see *X12PU-BGK pull-up kit*, page 28.

## Adding additional elements to the array

1. Verify all **hooks, pins, shackles, and other associated rigging components** are properly positioned and secure before lifting the array.
2. Lift the first **column** high enough to allow the next column on the dolly to be positioned below it.
3. Pull the **four (4) captive twist lock pins (A)** on the top enclosure of the next column.  
*All four (4) captive twist lock pins are in the unlock (Open) position.*



X12TC-GRID

X12TE-GRID

4. Lower the suspended **column (B)** guiding the front link bars into the front V-blocks of the waiting column.  
*Continue lowering until the rear link bars have also seated into the rear V-blocks.*
5. Twist the **four (4) captive twist lock pins.**  
*Four (4) captive twist lock pins are unlocked in the engaged (Closed) position.*
6. Release the **four (4) dolly pins (C)** on the dolly.  
*All four (4) dolly lock pins are released and hanging from the dolly.*
7. **Repeat steps 1-6** to add additional columns to the array.

For more information, see *Setting rear link angles, page 17.*

If you are using the X12TE-GRID to pull-up to the grid, continue to *X12TE-GRID using X12PU-BGK to pull-up to grid, page 43.*

## 6.6.2 X12TC-GRID with pull-back to venue

Using a X12TC-GRID combined with the X12PU-BGK an array can be pulled up to the venue.

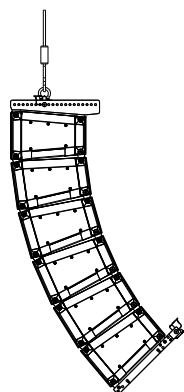


### Notice!

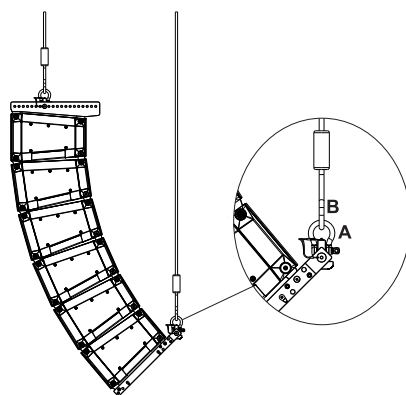
Only the double pin method is allowed when pull back to the venue is planned. Do not use single pin compression method in this instance.

To **pull-back to the venue**, do the following:

1. Attach the **X12PU-BGK bottom section with spreader bar** to the bottom element.

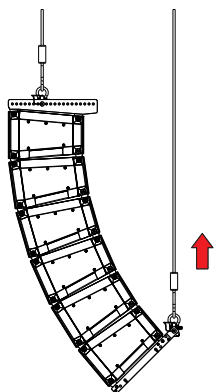


2. Attach a **5/8-inch shackle (A)** to the pick point on the spreader bar. *Ensure the shackle is rated for overhead lifting.*



3. Attach the pull-back **hoist chain hook (B)** to the shackle.
4. Verify all **hooks, pins, shackles, and other associated rigging components** are properly positioned and secure before lifting the array.

- Lift the **array** to the desired height.



- Adjust the **top grid hoist** and **bottom pull-back hoist** to tilt the array to the angle recommended by LAPS 3.

For more information, see *X12TC-GRID compact grid*, page 20 and *Flying arrays from the dolly*, page 37.

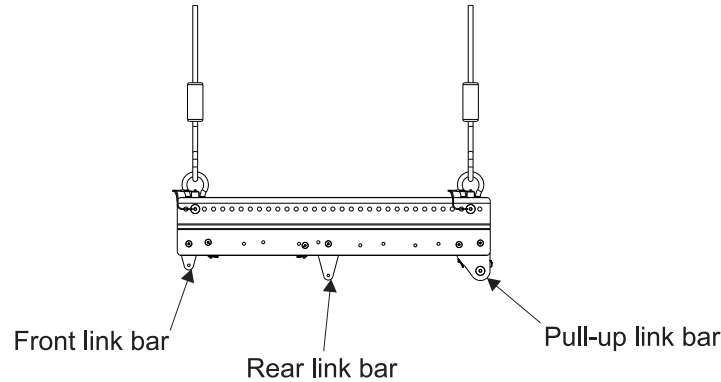
### 6.6.3

#### X12TE-GRID using X12PU-BGK to pull-up to grid

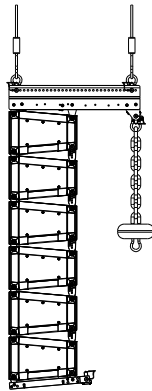
Using a X12TE-GRID combined with the X12PU-BGK can be pulled up to the grid.

To **pull-up to the X12TE-GRID**, do the following:

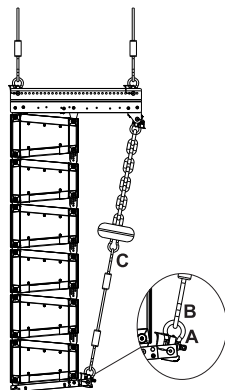
1. Attach the **two (2) pull-up link bars to the sidearms**.



2. Insert the attached **quick-release pins**.  
*Verify all quick-release pins are inserted completely through the sidearm and securely locked in position.*
3. Attach the **X12PU-BGK** bottom section to the bottom element.

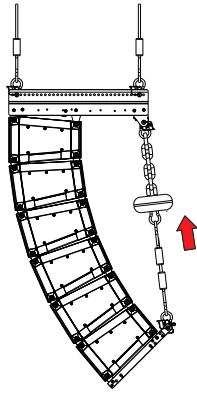


4. Attach a **5/8-inch shackle (A)** to the pick point on the spreader bar.  
*Ensure the shackle is rated for overhead lifting.*



5. Attach **one (1) end (B)** of the 3-foot wire rope sling to the shackle.
6. Attach the **opposite end (C)** of the 3-foot wire rope to the pull-up hoist.
7. Attach a **chain bag** to the pull-up hoist and insert the **unextended chain** into the chain bag.
8. Verify all **hooks, pins, shackles, and other associated rigging components** are properly positioned and secure before lifting the array.

- Lift with the **pull-up host** to raise the bottom element to compress the rear rigging of all the elements in the array.



- Lift the **array to the desired height**.
- Adjust the **front and rear grid hoists** to tilt the angle recommended by LAPS 3.



### Caution!

LAPS 3 will report the force required to compress the rear rigging of all the elements. Applying excess force can cause damage to the rigging. The use of a load cell is recommended.

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For more information, see *X12TE-GRID extended grid*, page 23, *X12PU-BGK pull-up kit*, page 28 and *Flying arrays from the dolly*, page 37.

### 6.6.4

#### Storing empty dollies

Six (6) or more dollies can easily be stored in the floor space of one (1).

**X12T-DOLLY:** Place the two (2) dolly side panels on top of each other with their carpeted sides together on the dolly base between the transport rails. Pick up the top cover with link bars pointing down and set it squarely onto the dolly base so as to nest the four (4) link bars into the V-blocks on each corner. Insert an attached dolly pin into each corner V-block to lock the two parts together.

**X12-128-DOLLY:** Nest the top cover into the dolly base and secure with ratchet strap. There is enough clearance between the wheels that the ratchet mechanism does not interfere with stacking. Once secured in this manner, dollies may be stacked on top of one another. Wheel locations are the same for both dollies, as are the corresponding wheel pockets on their top covers. Use caution when moving a tall stack of dollies. While the wheel pockets prevent the dollies from rolling off of each other they are not enough to keep the stack together if the bottom one (1) stops abruptly on an obstruction like the bottom of a ramp. If this is likely to be encountered, use ratchet straps to tie the entire stack together.



## 6.6.5 Landing arrays onto a dolly

Landing the array elements directly onto a dolly makes transportation easier.



### Notice!

#### Dolly stacking limits

X12T-DOLLY accommodates two (2) columns of X1 or X2 loudspeaker systems stacked three (3) high for transportation. The dolly is designed for a total of six (6) loudspeakers per dolly. X12-128-DOLLY accommodates one (2) column of X12-128 subwoofers stacked two (2) high for transportation. The dolly is designed for a total of two (2) subwoofers per dolly.



### Notice!

#### Dolly Wheel (the 4° hole):

The bottom element to be landed on the dolly base must be pinned in 4° hole (Ⓣ) in the ANGLE SELECT section. Compress the rear link bars until they contact the angle select pin and lock by adding a second pin in the EVEN holes of the ANGLE LOCK section. Ensure the two (2) front link bars are lowered and locked.

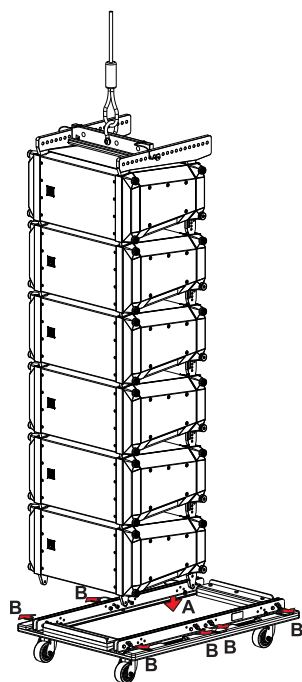
To **land an array onto a dolly**, do the following:

1. Lower the **array (A)** to a convenient working height above the floor.
2. If single pin compression method was used, carefully reverse the **hoist** and uncompress the back of the array so the hoist has not tension and all of the elements in the array have returned to the 0° position.

OR

If double pin method was used, lift up slightly on the rear of each of the bottom **three (3) elements** and remove the quick-release pins from the lock holes. Gravity will cause the unlocked rigging splay to revert to 0° position.

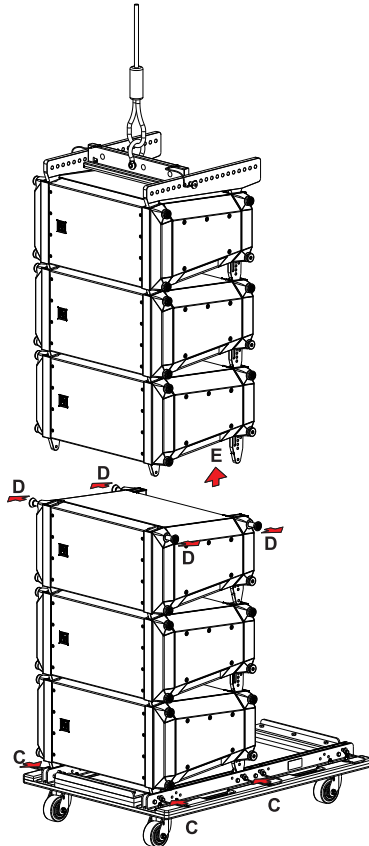
3. Disengage the **eight (8) dolly pins (B)** on the dolly base.  
*All eight (8) dolly pins are disengaged and hanging from the dolly.*



## X-LINE ADVANCE Systems

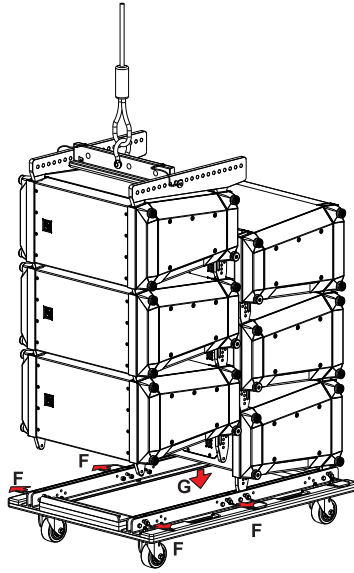
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4. Verify the **V-blocks** are unobstructed and clear.
5. Position the empty **dolly** under the array.
6. Ensure **grilles** are facing out.
7. Lower the **array** until the link bars engage the V-blocks on the dolly.  
*Guide the array to land the link bars onto the dolly rails.*
8. Insert the **four (4) dolly pins (C)** to lock the enclosures onto the dolly.  
*Verify pin is thoroughly pushed in and thorough both sides of the rail.*



9. Pull and twist the **four (4) captive twist lock pins (D)**.  
*All four (4) captive twist lock pins are in the unlock position.*
10. Lift the **column of enclosures (E)**.  
*A single column of three (3) elements is on the dolly.*
11. Rotate the **dolly**.
12. Repeat **step 2** ensuring the **elements** are set to 0° position.  
*Verify the front link bars are extended and locked and rear link bars of the bottom element are set and locked at 4° (see Notice regarding the Dolly Wheel).*

13. Repeat **steps 6-8** on this **column (G)**.



14. Insert the **four (4) dolly pins** to lock the enclosures onto the dolly.  
Verify pin is thoroughly pushed in and through both sides of the rail.

### Removing the grid



#### Caution!

The extended grid sidearms are heavy and likely to tip if not secured, potentially causing damage and/or personal injury if one (1) should fail.

Always maintain a good grip on the sidearm until both twist-lock pins are fully engaged.

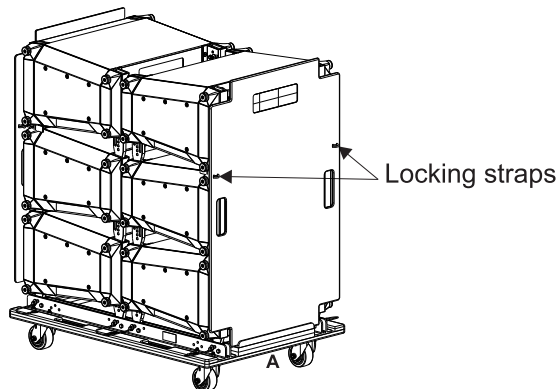
1. Remove the **5/8-inch shackle** from the spreader bar(s).
2. Lift **hoist motor** to a safe height.
3. Remove **spreader bar**.
4. Pull and twist the **four (4) captive twist lock pins**.  
*All four (4) captive twist lock pins are in the unlock position.*
5. Remove the **grid sidearms**.

### Transporting X1 or X2 loudspeakers

The loudspeaker dolly can be used for long-range transport.

To **prepare loudspeakers for transport**, do the following:

1. Ensure the **scribble strip** is facing out and the **carpet** is towards the grilles.
2. Insert a **dolly side panel** into the dolly base (**A**) to cover the grilles.

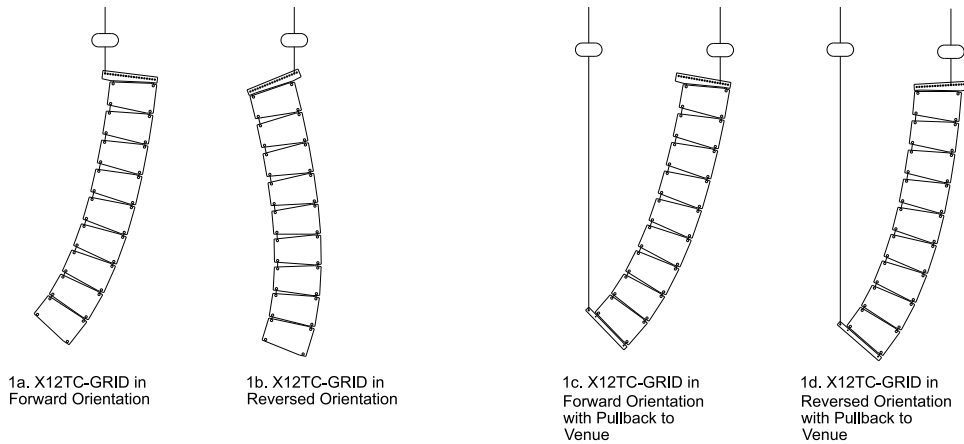


3. Secure the **locking straps** to the top and bottom captive twist lock pin knobs to secure side panels.
4. **Repeat steps 1-3** on the opposite side.
5. Guide and land the **dolly top** link bars to align with the front V-blocks of the top elements.
6. Ensure the **dolly top** has captured the dolly side panels.
7. Push and twist the **eight (8) captive twist lock pins**.  
*All eight (8) captive twist lock pins are in the lock position. Ensure the loudspeakers are secure.*

## 6.7 Array building techniques

### 6.7.1 Multiple ways to fly the X12TC-GRID

X12TC-GRID can be flown in two (2) different ways—with a single grid pick point and with a single grid pick point plus a pullback to the venue. Additionally, the grid has two (2) orientations forward and reversed. In LAPS 3, the user must choose which way the grid will be flown, plus the orientation of the grid.



**Figure 6.11: Flying the X12TC-GRID**

#### Single grid pick point:

In the forward orientation (1a), a small section of the grid extends behind the rear of the loudspeaker, enabling more down tilt.

In the reversed orientation (1b), a small section of the grid extends in front of the loudspeaker, enabling more up tilt.

Choose the pick point on the grid to achieve the desired angle as reported by LAPS 3.

#### Single grid pick point with a pullback to the venue:

A pullback to the venue is used when more down tilt is required than can be achieved by a single grid pick alone. The X12PU-BGK is used at the bottom of the array.

The most common orientation would be to use the grid in the forward position (1c).

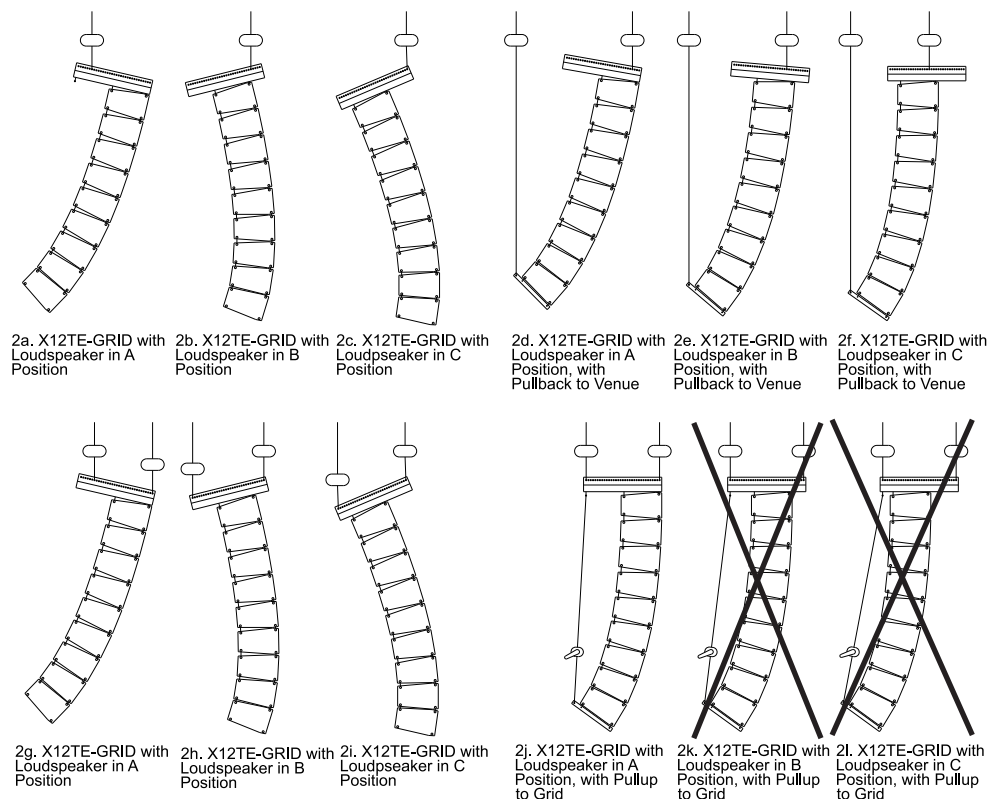
The grid can also be used in the reversed orientation with a pullback to the venue (1d). The purpose of the pullback is to enable greater down tilt.

Choose a grid pick point near the front of the grid. This tilts the array up slightly, which makes it easier to build because the bottom of a flown box will be a closer match to the top box on a dolly stack.

For more information, see

## 6.7.2 Multiple ways to fly the X12TE-GRID

X12TE-GRID can be flown in four (4) different ways—with a single grid pick point, with a single grid pick point plus a pullback to the venue, with two (2) grid pick points, and with two grid picks points plus a pull-up to the grid. Additionally, the loudspeakers may be attached to the grid in three different positions. In LAPS 3, the user must choose which way the grid will be flown, plus the attachment position of the loudspeakers.



**Figure 6.12: Flying the X12TE-GRID**

### Single grid pick point:

With the loudspeakers attached in the A position (2a), a large section of the grid extends behind the rear of the loudspeaker, enabling the maximum amount of down tilt.

With the loudspeakers attached in the B position (2b), a portion of the grid extends both behind and in front of the loudspeaker, enabling moderate tilt both up and down.

With the loudspeakers attached in the C position (2c), a large section of the grid extends in front of the loudspeaker, enabling the maximum amount of up tilt.

Choose the pick point on the grid to achieve the desired angle as reported by LAPS 3.

### Single grid pick point with a pullback to the venue:

A pullback to the venue should be used when more down tilt is required than can be achieved by a single grid pick alone. The X12PU-BGK is used at the bottom of the array.

The most common orientation would be to use the grid with the loudspeakers attached in the A position (2d).

A pullback to the venue can also be used with the loudspeakers attached in the B position (2e) or in the C position (2f). Choose a grid pick point near the front of the grid. This will tilt the array up slightly, which will make it easier to build because the bottom of a flown box will be a closer match to the top box on a dolly stack.

### **Double grid pick points:**

Always attach the two grid pick points at the front-most and rear most attachment points on the grid.

With the loudspeakers attached in the A position (2g), the maximum down tilt can be obtained.

With the loudspeakers attached in the B position (2h), moderate down-tilt and up tilt can be obtained.

With the loudspeakers attached in the C position (2i), the maximum up tilt can be obtained.

The user must adjust the front and back hoist motors to achieve the angle reported by LAPS 3.

### **Double grid pick points plus a pull-up to the grid:**

Using a pull-up to the grid enables the loudspeaker to be lifted off the dollies with the boxes hanging straight at 0°, then pull the boxes their correct angle using a hoist in the pull-up assembly.

The X12PU-BGK is used at the bottom of the array.

Always attach the two grid pick points at the front-most and rear most attachment points on the grid.

Always attach the loudspeakers in the A position, furthest away from the pick point (2j).

It is not recommended to use a pull-up to the grid with the loudspeakers in the B position (2k) or the C position (2l). Because the B and C positions are so close to the pull-up attachment point on the grid, excessive forces result in the pull-up assembly.

With large arrays, it is possible for a single grid pick point to be in a safe condition once the pull-up is pulled into compression, but the user would pass through an unsafe condition while building an array. Therefore we recommend using two grid pick points to avoid the possibility of an unsafe condition.

For large arrays, the force required to pull the rear rigging of all boxes into compression may exceed the pull-up assembly maximum rating. If this occurs, it may be necessary to pin several boxes at the top of the array at fixed angles. If so, LAPS 3 will return a message telling the user how many boxes to fix pin.

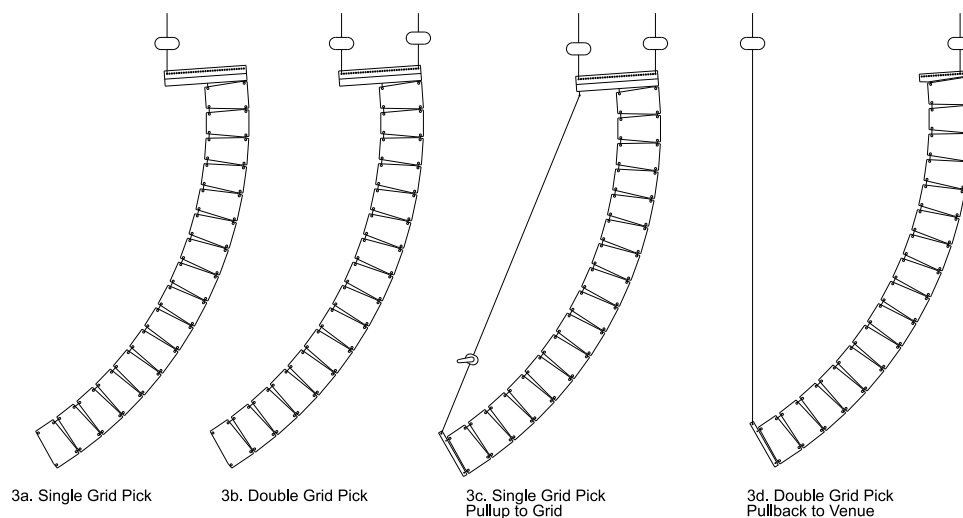
For more information, see .

## **6.7.3**

### **Array build strength considerations**

LAPS 3 reports when the working-load limits for any of the elements in the array are exceeded. Having an understanding of the structural advantages and disadvantages of different array build configurations allows the user to select the best option to meet their needs.

*Comparing array structure strengths* shows the same array constructed in four (4) different ways: single grid pick point, single double grid pick points, double grid pick points with a pull-up to the grid, and single pick point with a pullback to venue. Because the array construction is different, the forces throughout the array are different. This results in different structural ratings.



**Figure 6.13: Comparing Array Structural Strengths**

The arrays in Figures 3a and 3b are the weakest. The highest force in both of these arrays will be on the rear rigging points of the top box. The long length of the X12TE-GRID extended behind the loudspeaker acts as a large lever arm (like a wrench) that significantly increases the force on the top enclosure rear rigging. Another way to visualize this is to think of the grid being held in a fixed position. Because the center of gravity of the entire loudspeaker column is so far towards the back, the column will tend to rotate counterclockwise to tilt up. The rear rigging of the top enclosure will be in tension resisting the rotation.

Whenever a large portion of grid is extended behind the top loudspeaker as shown in Figures 3a and 3b, fewer boxes will be allowed to be suspended before the working-load limit of the top box rear rigging is exceeded. This condition most commonly occurs with the X12TE-GRID with the loudspeakers are in the A position. The same condition can occur when a large portion of grid is extended in front of the top loudspeaker. This could occur with a steep up-tilt angle with the X12TE-GRID with the loudspeakers in the C position on the grid. The X12TC-GRID is not subject to this condition, because the grid is just slightly longer than the loudspeaker enclosures.

The array in Figure 3d is the strongest because the load is shared between the top and bottom of the array. This configuration will allow the highest number of boxes to be suspended and is most commonly employed when a greater down-tilt angle is required.

Unless extreme down-tilt angles are employed, the highest forces in the array in Figure 3d will be on the rigging of the top box. The X12PU-BGK bottom grid does not have as high of strength rating as the top grids X12TC-GRID or X12TE-GRID. In the unlikely event that the working-load limits of the X12PU-BGK are exceeded, one of the top grids may be substituted.

The array configuration shown in Figure 3c has greater capability than those shown in Figure 3a and 3b, but less capability than the array shown in Figure 3d. In this case, the load of the loudspeaker column is shared between the rigging attachment points of the top box and the pull-up assembly. However, the pull-up to the grid introduces forces that otherwise would not exist due to gravity alone. For the array configuration in Figure 3c, the highest forces typically occur at either the top box or at one of the boxes near the bottom of the array.

## 7 Subwoofer arrays

The X12-128 is designed for multiple applications. It may be used as a forward standard array or as a cardioid array. It has rubber feet on the bottom for horizontal orientation or on one (1) side panel for vertical orientation.

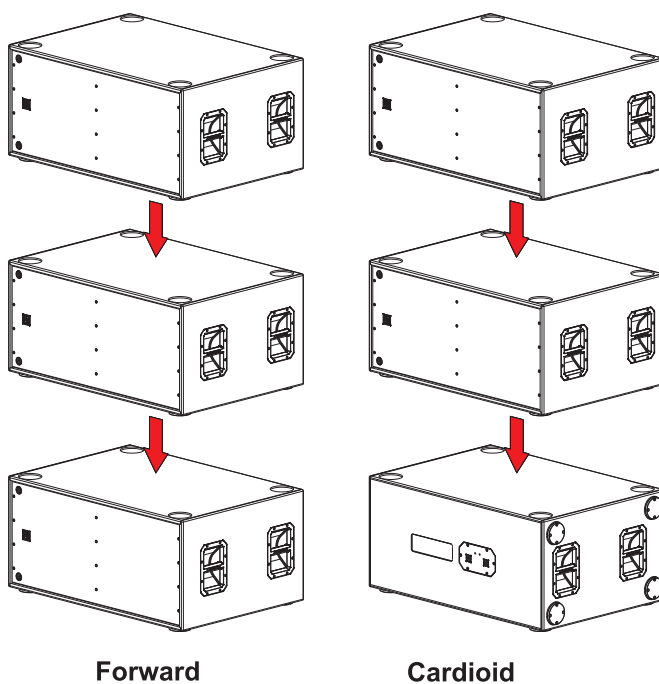
In the input panel you have a choice to connect the subwoofer in either parallel (4 ohm) or dual (8 ohm) modes for optimum subwoofer array control.

### 7.1 Subwoofer array configuration



#### Notice!

For cardioid arrays you must use the correct system setting processing and amplifying forward firing and rear firing subwoofers separately.

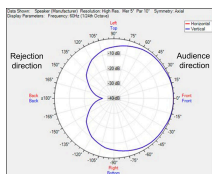




## 7.2 Subwoofer cardioid options

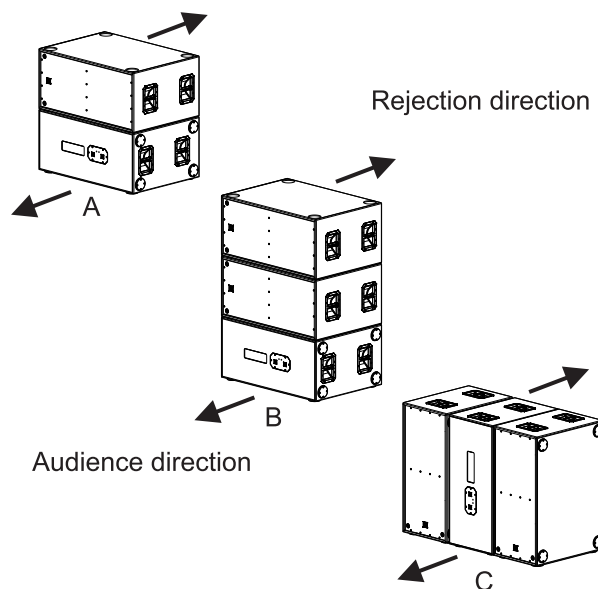
The X12-128 cardioid subwoofer arrays can be used to direct the output of an array of subwoofers in order to limit excessive amounts of bass in undesired areas. These arrays can be used to keep bass off of a stage, provide more consistent bass coverage in the audience, and reduces bass in the surrounding area.

Multiple X12-128 can be arrayed to create a cardioid polar pattern.



**Figure 7.1: Cardioid pattern top view**

The rejection may be less in smaller indoor environments than in larger outdoor environments. The subwoofers must be physically placed in one (1) of the options shown.



**Figure 7.2: X12-128 Cardioid Options**

### **Cardioid option A:**

Two (2) X12-128 subwoofers orientated horizontally. Direct the top subwoofer towards the audience and the bottom subwoofer away from the audience (Rejection direction).

### **Cardioid option B:**

Three (3) X12-128 subwoofers orientated horizontally. Direct the top two (2) subwoofers towards the audience and the bottom subwoofer away from the audience (Rejection direction).

### **Cardioid option C:**

Three (3) X12-128 subwoofers orientated vertically. Direct the left and right subwoofers towards the audience and the center subwoofer away from the audience (Rejection direction).

## 8 Rigging structural strength ratings and safety factors

### 8.1 Structural introduction

The X1 and X2 loudspeakers systems, grids and accessories were designed as a complete system to ensure safety and compatibility. The maximum possible number of X1 or X2 loudspeaker systems may be suspended in a single column is 24 while maintaining an 8:1 safety factor. For more information, see *Working-load limit and safety factor definitions*, page 56.

The actual forces on the rigging components within an array will depend on the specific configuration of the loudspeakers and grids. The tilt angles of the individual boxes, grids and the entire array will change the forces in the rigging components throughout an array. Pick points from the grid, pull backs to the venue, and pull ups to the grid will also affect load distribution. The result is that the actual maximum number of X1 and X2 systems will be dependent on the array configuration.

All components are included as part of the Electro-Voice line array prediction software LAPS 3. The software calculates the forces throughout the array and informs the user of the limitations. LAPS 3 also reports the loads for the pick points going to the venue.

### 8.2 Structural rating overview

Designing a safe structural array is a very complex process best left to experienced professionals. There are two (2) independent strength considerations, together, that give a complete description of the overall structural capabilities of any loudspeaker system; these are:

1. The strength of each individual enclosure rigging point; which is the combined strength of the rigging tube, hinge bars, link bars, quick-release rigging pins internal rigging straps, external tie plates, bolts, and enclosure.
2. The total strength of the overall array; which is a function of the combined forces from all of the rigging points acting on the rigging components and the array as a whole.

For grids, there are two (2) independent strength considerations, together, give a complete description of the overall structural capabilities of the grid; these are:

1. The strength of each individual grid rigging point; which is the combined strength of the bolts, grid side arms, and spreader bars, and quick-release pins.
2. The total strength of the overall grid; which is a function of the combined forces from all of the rigging points acting on the rigging components, and the grid as a whole.

In any system loudspeaker array, the forces acting on each loudspeaker system (on each individual rigging points and on the overall enclosure) and the forces acting on each grid rigging accessory (on each sidearm and spreader bar and on the overall grid grids and spreader bars) vary varies with each array configuration. Determining those forces throughout an array requires complex mathematical calculations.

To make the X1 and X2 systems both safe and easy to use, Electro-Voice engineers have built calculations into the LAPS 3 software, enabling a user to immediately determine if an array is safe without having to do a complex structural analysis.

## 8.3 LAPS 3 structural evaluations simplified structural rating guidelines

Using a combination of computer modeling, destructive and non-destructive testing, Electro-Voice engineers have developed calculations to determine the forces within an array that act on the loudspeaker systems and grid rigging accessories. The results of these calculations are compared to the working-load limits of each loudspeaker and grid element, and their individual components.

LAPS 3 will take into account all the complex factors to ensure that an array is strong enough to maintain an 8:1 safety factor. If a particular array designed by a user exceeds a working-load limit, the software will return warning messages. The messages will provide information describing what is causing the overload, and will offer suggestions to the user for changes that can be made to the array to eliminate the overload. The user can then decide the best solution for their particular application.

LAPS 3 will also report the loads on the rigging pick points (typically hoist motors) that suspend the array from the venue. The software assumes that these rigging points are plumb vertical. The user must calculate the increased tension in the suspension lines if they are angled.



### Caution!

The user should never apply a load that exceeds the working-load limits of any of the rigging components or complete loudspeaker systems described in this manual.

The user should never exceed the safety limitations reported by LAPS 3 or higher.

## 8.4 Specific safety considerations

### X1 and X2 loudspeaker systems

The X1 and X2 loudspeaker systems must only be suspended using the Electro-Voice grids. The X12TC-GRID and X12TE-GRID should be used as top grids. For a pull back to a venue or a pull up to grid, the X12PU-BGK may be used as the bottom grid. For an extreme down angle, the X12TC-GRID may also be used at the bottom.

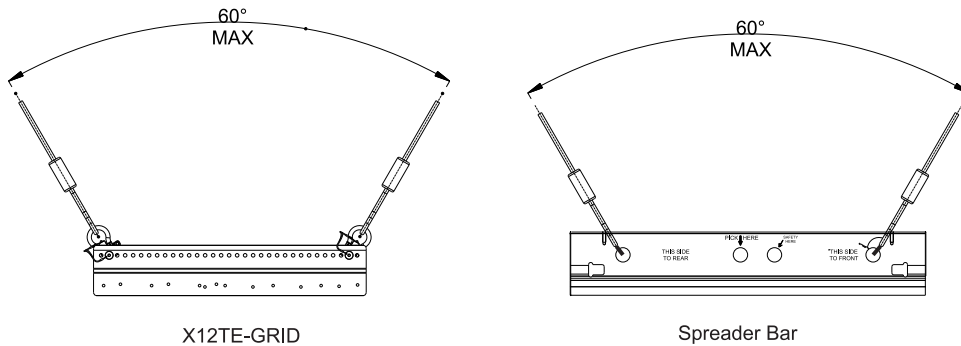
The X1 and X2 rigging and grids were designed to be tilted up or down (front to back tilt). However, they are not intended to hang sideways. Columns of X1 or X2 loudspeaker systems must never be angled off being hanging plumb vertical  $\pm 5^\circ$ .

### X12TC-GRID and X12TE-GRID top grids

The X12TC-GRID and X12TE-GRID top grids may be suspended using one (1) or two (2) spreader bars. Additionally, one (1) or two (2) pick points may be used with the spreader bars.

When multiple pick points are used to suspend the grids from a venue roof, LAPS 3 calculates the loads on the pick points assuming that the suspension lines are plumb vertical. If the lines are angled, the loads will be increased on both the grid and hoist motors and building

supports. The user is responsible for determining the resulting increased loads. When suspending the X12TC-GRID and X12TE-GRID top grids with multiple pick points, the pick lines must be plumb vertical  $\pm 30^\circ$ .



**Figure 8.1: Double pick point maximum angle**

### **X12PU-BGK bottom pull-up grid**

The X12PU-BGK bottom grid was designed to have a pick angle that varies front to back (for tilting an array down, but was not intended for side pulls. The X12PU-BGK is only rated over side-to-side pull angles of  $\pm 5^\circ$ .

LAPS 3 reports the tension required to pull the rear rigging of the loudspeaker enclosures into compression when the X12PU-BGK is used with the X12TE-GRID. Never exceed the tension reported by LAPS 3.

LAPS 3 calculates the loads on the X12PU-BGK when used as a pull up/back to the venue assuming that the suspension lines are plumb vertical. If the line is not vertical, the loads will be different than the calculated value. The user is responsible for determining the load when not vertical.

The X12PU-BGK is intended to be used as a bottom grid for pull-up applications only. Never use the X12PU-BGK as a top grid.

## **8.5**

### **Working-load limit and safety factor definitions**

The structural ratings for all of the X-Line Advance series rigging components and complete loudspeaker systems are based on test results in which parts were stressed to failure. Manufacturers typically present the structural-strength ratings of mechanical components or systems as either the WLL (working-load limit) or the ultimate-break strength. Electro-Voice chooses to present the structural-load ratings of the X1/X2 loudspeaker systems as the working-load limit. The working-load-limit rating represents the maximum allowable load to be applied to a mechanical component or system.

The working-load limits for the X1 and X2 loudspeakers systems, grids, accessories and complete arrays described in this manual are based on a minimum 8:1 safety factor. The safety factor is defined as the ratio of the ultimate-break strength divided by the working-load limit, where the ultimate-break strength represents the force at which a part structurally fails. For example, if a part has a working-load limit of 1,000 lb (454 kg), it would not structurally fail until a force of at least 8,000 lb (3,629 kg) was applied, based on an 8:1 safety factor.

However, the user should never apply a load to that part that exceeds 1,000 lb (454 kg). The safety factor provides a margin of safety above the working-load limit to accommodate normal dynamic loading and normal wear.

**Cautions for working-load limits and safety factors**

The working-load limits defined by the manufacturer of any rigging component should never be exceeded. Electro-Voice bases the working-load limits of its X1 and X2 products on a minimum of an 8:1 safety factor. Other manufacturers of rigging components may base their working-load limits on safety factors other than 8:1. For example, 5:1 safety factors are fairly common amongst rigging manufacturers because many regulatory agencies call for a minimum safety factor of 5:1.

When an X1 or an X2 loudspeaker system is installed where local regulations only require a safety factor of 5:1, Electro-Voice insists the working-load limits of the X1 and X2 rigging is never exceeded and an 8:1 safety factor be maintained for the X1 and X2 loudspeakers.

The user is cautioned that some local regulations may require safety factors higher than 8:1. Electro-Voice insists the user maintain the higher safety factor as required by the local regulations throughout the entire X1 and X2 installation. It is the responsibility of the user to ensure any X1 or X2 system installation meets all applicable local, state or federal safety regulations.

### 9 Rigging inspection and precautions

**Loudspeaker systems:** Prior to each use, inspect the enclosures for any cracks, deformations or missing or damaged components that could reduce enclosure strength. Inspect the rigging pins, hinge bars, linking bars and rigging tubes for cracks, corrosion or other deformations that could reduce their strength and integrity. Hardware that is bent or showing signs of more than cosmetic surface corrosion should be replaced immediately.

**Grids:** Prior to each use, inspect the grid sidearms, spreader bars, linking bars, and rigging pins for any cracks, corrosion, missing or damaged parts or any other deformation that could reduce their strength and integrity.

Verify there are no missing rigging pins and all lanyards are securely attached. Hardware that is bent or showing signs of more than cosmetic surface corrosion should be replaced immediately.

**Lifting Hoists:** Prior to each use, inspect the lifting hoist(s) and associated hardware (including motor(s), if applicable) for any cracks, deformation, broken welds, corrosion, missing or damaged components that could reduce the hoist strength. Replace any damaged hoists. Never exceed the limitations or maximum recommended load specified by the hoist manufacturer. Always follow manufacturers' recommendations for operation, inspection, and certification. Always raise and lower the load slowly and evenly, avoiding any rapid changes in speed or shifting loads that could result in a sudden jolt to the suspended system or the structure from which it is suspended.

**Building, Tower or Scaffold Supports:** Prior to each use, the strength and load-bearing capabilities of the building, tower or scaffold structural supports should be evaluated and certified by a professional engineer as being adequate for supporting the intended rigging system (including the loudspeakers, grids, chain hoists, and all associated hardware). Prior to each use, inspect the building, tower or scaffold structural supports for any cracks, deformation, broken welds, corrosion, missing or damaged components that could reduce the structural strength. Damaged structural supports should be replaced or repaired and recertified by a professional engineer. Never exceed the limitations or maximum recommended load for the supports.

**Miscellaneous Mechanical Components:** Prior to each use, inspect all mechanical components (chain, wire ropes, slings, shackles, hooks, fittings, ratchet straps, etc.) for any cracks, deformation, broken welds, slipping crimps, fraying, abrasion, knots, corrosion, chemical damage, loose screws, missing or damaged components that could reduce the maximum strength specified by the component manufacturer. Replace any damaged mechanical components immediately. Never exceed the limitations or maximum recommended load for the mechanical components.

## 10 Technical data

### X1-212/90 and X2-212/90

	X1-212/90	X2-212/90
Frequency Response (-3 dB):	57 Hz - 16 kHz <sup>1</sup>	52 Hz - 19 kHz <sup>1</sup>
Horizontal Coverage:	90°	
Vertical Coverage:	Array dependent	
Rec. High-Pass Frequency:	50 Hz	
Max Calculated SPL:	143 db Peak <sup>2</sup>	146 db Peak <sup>2</sup>
Configuration:	Passive, Bi-amp	Bi-amp
Passive Crossover Freq.:	1600 Hz	NA
Passive Axial Sensitivity:	98 dB (1 W/1 m) <sup>4</sup>	NA
Passive Power Handling:	500 W continuous, 2000 peak	NA
Passive Impedance:	8 Ω (nominal, 6.4Ω (min))	NA
LF Transducer:	SMX2121, 12-in (305 mm) driver	DVN3125, 12-in (305 mm) driver
LF Axial Sensitivity:	98 dB (1 W/1 m) <sup>4</sup>	101 db (1 W/1 m) <sup>4</sup>
LF Power Handling:	400 W continuous, 1600 W peak	500 W continuous, 2000 W peak
LF Impedance:	8 Ω (nominal), 6.1 Ω (min)	8 Ω (nominal), 6.1 Ω (min)
HF Transducer:	2 x ND2R, 2-in (51 mm) diaphragm compression driver	2 x ND6A, 3-in (76.2 mm) diaphragm compression driver
HF Axial Sensitivity:	110 dB (1 W/1 m) <sup>4</sup>	112 db (1 W/1 m) <sup>4</sup>
HF Power Handling:	120 W continuous, 480 W peak <sup>3</sup>	150 W continuous, 600 W peak <sup>3</sup>
HF Impedance:	8 Ω (nominal, 6.0 Ω (min))	8 Ω (nominal), 6.0 Ω (min)
Connectors:	Dual NL8 type connector	
Enclosure:	13-ply weather resistant birch with EVCoat	
Grille:	16 GA powder coated galvanized	
Suspension:	IRS – Integrated Rigging System	
Dimensions (H x W x D):	13.5 in x 28.77 in x 12.04 in (342.9 mm x 730.8 mm x 534.4 mm)	
Net Weight:	92 lb (41.7 kg)	93 lb (42.2 kg)
Shipping Weight:	106 lb (48 kg)	107 lb (48.5 kg)

1. Full-space anechoic array performance with FIR-Drive preset.
2. Full-space measurement of HF section of 4 elements. SPL adjusted for 1m distance.
3. AES 2-1984 power test.
4. Full-space anechoic measurement of a single element.

# X-LINE ADVANCE Systems

## X12-128

	<b>X12-128</b>
Frequency Response (-3 dB):	27 - 200 Hz <sup>1</sup>
Coverage (H x V):	Omni directional
Rec. High-Pass Frequency:	27 Hz
Max Calculated SPL:	141 dB continuous, 147 db peak <sup>1</sup>
Configuration:	Parallel Mode: Both woofers are internally wired in parallel on Pins 1+/1-. Dual Mode: Each woofer is wired separately on Pins 1+/1- and 2 +/2-.
Axial Sensitivity:	105 dB (1 W/1 m) <sup>1</sup>
Passive Power Handling:	4000 W continuous, 16,000 W peak <sup>2</sup>
Impedance:	(1) 4 ohm (Parallel Mode), (2) 8 ohm (Dual Mode)
LF Transducer:	2 x 18 in DVF4180
Connectors:	(4) NL8 type connectors (Two (2) in front and two (2) in back)
Enclosure:	13-ply weather resistant birch with EVCoat, internally braced
Grille:	14 GA powder coated galvalneal
Dimensions (H x W x D):	20.375 in x 43.500 in x 29.875 in (51.75 cm x 110.49 cm x 75.88 cm)
Net Weight:	195 lb (88.45 kg)
Shipping Weight:	205 lb (93.2 kg)

1. Half-space anechoic measurement of single element.
2. AES 2-1984 power test.

### Accessories

#### X12TC-GRID compact grid:

	<b>X12TC-GRID</b>
Dimensions (H x W x D):	7.0 in x 24.0 in x 24.8 in (177 mm x 610 mm x 631 mm)
Net Weight:	24.7 lb (11.2 kg)
Shipping Weight:	26.0 lb (11.8 kg)

#### X12TE-GRID extended grid

	<b>X12TE-GRID</b>
Dimensions (H x W x D):	10.5 in x 24.0 in x 40.5 in (267 mm x 610 mm x 1029 mm)
Net Weight:	78.5 lb (35.6 kg)
Shipping Weight:	82.0 lb (37.2 kg)



**X12PU-BGK pull up bottom grid kit**

	<b>X12PU-BGK</b>
Dimensions (H x W x D):	4.0 in x 24.0 in x 25.2 in (102 mm x 610 mm x 635 mm)
Net Weight:	36.7 lb (16.6 kg)
Shipping Weight:	39.0 lb (17.7 kg)

**X12T-DOLLY X1 or X2 loudspeaker dolly**

	<b>X12T-DOLLY</b>
Dimensions (H x W x D):	873 in x 31.5 in x 45 in (222 mm x 800 mm x 1143 mm)
Net Weight:	168 lb (76.2 kg)
Shipping Weight:	184 lb (83.5 kg)

**X12-128-DOLLY subwoofer dolly**

	<b>X12-128-DOLLY</b>
Dimensions (H x W x D):	7.85 in x 32 in x 45 in (199 mm x 813 mm x 1143 mm)
Net Weight:	110 lb (49.9 kg)
Shipping Weight:	125 lb ( 56.7 kg)

## 11 References

### 11.1 Rigging (printed)

[1] W.E. Rossnagel, L.R. Higgins & J.A. MacDonald, Handbook of Rigging for Construction and Industrial Operations, McGraw-Hill Book Company, New York, NY, USA (2009).

[2] H. Donovan, Entertainment Rigging, <http://www.riggingbooksandprograms.com>, Rigging Seminars, Seattle, WA, USA (2002).

[3] J.O. Glerum, Stage Rigging Handbook, Southern Illinois University Press, Carbondale, IL, USA (2007).

[4] P. Carter, Backstage Handbook, Broadway Press, New York, NY, USA (1994).

[5] J. A. Klinke, Rigging Handbook, ACRA Enterprises, Inc., Stevensville, MI, USA (2012).

[6] Wire Rope Technical Board, Wire Rope Users Manual, American Iron and Steel Institute, Stevensville, MD, USA (2005).

[7] D. L. Hall, Rigging Math Made Simple, Spring Knoll Press, Johnson City, TN (2014).

[8] Newberry, W.G., Handbook for Riggers, Newberry Investments Company, Calgary, Alberta, Canada (1989).

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1. \*All other trademarks are property of their respective owners.

### 11.2 Mechanical engineering (printed)

[1] R.C. Hibbeler, Engineering Mechanics Statics & Dynamics, Pearson Prentice Hall, Upper Saddle River, NJ, USA (2012).

[2] R.C. Hibbeler, Mechanics of Materials, Pearson Prentice Hall, Upper Saddle River, NJ, USA (2012).

[3] J.L. Meriam & L.G. Kraige, Engineering Mechanics, Volume One - Statics, John Wiley & Sons, Inc., New York, NY, USA (2011).

[4] J.L. Meriam & L.G. Kraige, Engineering Mechanics, Volume Two - Dynamics, John Wiley & Sons, Inc., New York, NY, USA (2012).

[5] J.E. Shigley & C.R. Mischke, Mechanical Engineering Design, McGraw-Hill Book Company, New York, NY, USA (2014).

### 11.3 Rigging (websites)

[1] <http://www.rigging.net>

[2] <http://www.cmworks.com/>

## 12 Notes

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