MIXER ANATOMY SECTION

The Mixer in a Nutshell

In reading about mixers, you'll run across a lot of technical terms that authors toss around as if the readers knew what we were talking about. In this section, you'll learn the terms used to describe the workings of a mixer, such as preamp, bus, channel, insert, path, group, equalizer, and in-line and split monitoring. Then finally, we'll take a signal flow safari using the block diagram of a Mackie 1604-VLZ PRO as our map.

Mixers come in all shapes and sizes from palm-sized to yards-long studio consoles, but they have a lot in common. A simple stereo mixer you'd use to record your band with two mics, has the same basic function as the gargantuan monster consoles required for building a movie sound track from 48 tracks of audio, a dozen tracks of dialog, and hundreds of sound effects. The bigger console has more inputs and outputs, but it mixes just the same.

When is it a mixer and when is it a console? That's like asking is it a violin or a fiddle? Generally, we use the term "console" when it's in the studio because it serves as the control center. In sound reinforcement or industrial applications, unless the operator is trying to impress a new-found friend, hoping for some after-the-show extra curricular activity, it's usually called a "mixer," since in that application, mixing is its main function. Like the concert violinist who refers to his instrument as "my fiddle," we'll use both terms here so we don't get too stuffy.

What a Mixer Does

The two basic functions of a mixer are routing and summing of audio signals. The mixer brings signals in from the outside world, allows you to manipulate them with a set of tools, and sends them back out to another unit in the recording or sound reinforcement system.

What happens along the path between in and out is a function of the controls you have available and how you use them. Faders or volume controls adjust the relative loudness of the incoming signals. All Mackie mixers include an Equalizer (EQ) section that allows you to shape the frequency balance of individual sounds to correct for deficiencies at the input, create new sounds, or help blend sounds. Other controls allow you to add effects such as reverberation or delay.

A mixer is a collection of controls and indicators – controls that allow you to route, modify, and combine signals, and indicators to show you how things are set. Controls consist of knobs and switches. An indicator can be a dot on a knob indicating its position, a button up or down, a light on or off, or a meter.

There are a lot of knobs, buttons, and lights on a mixer, but don't let that intimidate you. Many of them are repeated many times over, so all you need to learn is one set and you'll have it licked.

Playing With Blocks

A block diagram can tell you nearly everything about the functional capability of a mixer and how to use its various inputs, outputs, and controls. It's like a road map. Learn to follow a block diagram and you can figure out how to get a signal through just about any console (or any other piece of equipment for that matter).

A block diagram is neither a schematic diagram, pictorial, or engineering drawing, but it contains elements of each. It won't tell you the noise figure of an amplifier or how many bits an A/D converter uses, but it will show you how a signal gets from one point to another, what switches and controls are in its path, and what inputs and outputs are available.

Let's tour a mixer using the 1604-VLZ PRO block diagram as our road map. It contains just about all the elements you'll encounter on any mixer. We won't trace every path, but enough to get you familiar with the symbols and the process, and you can take it from there.

Since a mixer contains the same circuitry duplicated many times, a block diagram will typically show only the first of many identical circuits. If a mixer has 16 input channels, expect to see full details on only one channel. If there are four subgroup busses, although they'll all be shown, you may see only one subgroup fader, insert jack, and output. You'll have to go to the spec sheet to find out how many "duplicates" there are.

Symbols

The electronic industry has developed standard symbols for components in schematic diagrams, but block diagrams aren't quite so standardized – you may have to make some guesses when first seeing an unfamiliar diagram.

In Mackie's block diagrams, input and output connectors are shown using their standard schematic symbols. Nearly all of the 1/4" jacks on the console are of the tip-ring-sleeve construction - they're illustrated like this on the diagram.

Not everybody uses such descriptive symbols, so if a spec sheet says an input is balanced and the block diagram shows a single circuit jack (or just a block or an arrow), you have to trust 'em.

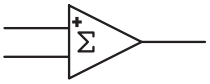
We use a circle with an arrow diagonally across it to represent a rotary control. A vertically oriented rectangle with a diagonal arrow represents a slide fader.

In general, an arrow through a symbol indicates that whatever the symbol represents is adjustable.

Switches are represented by a "wiper" pivoted at one end, with the other end pointing to one of the possible switch positions.

With the exception of the effect selection switch on mixers with built-in effects, all the switches used in Mackie mixers are two-position switches, meaning that the wiper connects to one or the other of two points, one of which might go nowhere to represent that the switch in the "off" position. The wiper can be either an input or output depending on the switch's function. You may find multi-position switches on other block diagrams.

An amplifier is represented by a triangle with the point going in the direction of the signal flow. Mackie represents amplifiers with balanced inputs by showing two leads going into the triangle (labeled + and -) indicating which input is "hot."



An amplifier with the Greek letter Σ (sigma is the standard mathematical symbol for summation) inside the triangle is a summing amplifier. A summing amplifier has a gain of 1 (unity, or 0 dB) unless it needs to make up for a loss of gain in preceding circuitry. Unity gain amplifiers are often used as buffers, isolating an input or output from the outside world.

Mackie represents resistors or attenuators on a block diagram as rectangles; capacitors use their standard schematic symbol; and lights look like little suns. If you have an idea as what to expect, you can usually guess the meaning of a symbol.

Block diagram convention is with signal flow from left to right and from top to bottom, so you'll usually find inputs on the left side of the diagram and outputs on the right.

A dot at the intersection of two lines indicates a connection, while lines crossing without a dot are just crossing en route.

The Bus – A Mixer's Basic Framework

The term "bus" is common in many electrical-based technologies. Your computer has several busses that distribute data and control signals among the plug-in cards. The circuit breaker box in your basement has busses that distribute electrical power from the pole on the street to the various circuits in your home or studio. The word in the singular form, has only one "s." It comes from the British "omnibus", a common means of mass transportation, which is usually 30 minutes late.

The fundamental purpose of a mixer is combining signals from several sources to one or more outputs. The place where they come together is the bus. In a monophonic mixer, all of the input signals are sent, at their desired volumes, to a single bus, to which the output is also connected.

In a stereo mixer, incoming signals are combined to a pair of busses, corresponding to the mixer's left and right outputs. In a multi-bus mixer, each input can be assigned to one or more busses, with those busses feeding individual tracks of a multitrack recorder, effects processors, the mixer's main stereo outputs, or even another mixer.

Busses are represented by a series of parallel vertical lines, usually somewhere near the center of the block diagram. You'll find a series of horizontal lines connecting to each bus and going off in both directions. Those arriving from the left represent paths from input sources to the bus, while the lines going

off to the right represent paths leaving the bus, heading toward an output.

The number of busses is one measure of a mixer's complexity. A stereo mixer has a main left and right bus and perhaps a couple of auxiliary busses to feed signals to effects devices or monitor speakers. A multitrack recording console typically has a large number of auxiliary busses, as well as several subgroup busses.

Hey! What gives with this 1604? The ads say it's a 4-bus mixer, but there are eighteen vertical, parallel lines on the block diagram!

No, you're not looking at the wrong diagram. The folks who write the ads are talking about one specific type of bus, the subgroup bus. It has the main left and right busses, several auxiliary send busses, a solo bus, and a headphone cue bus, too.

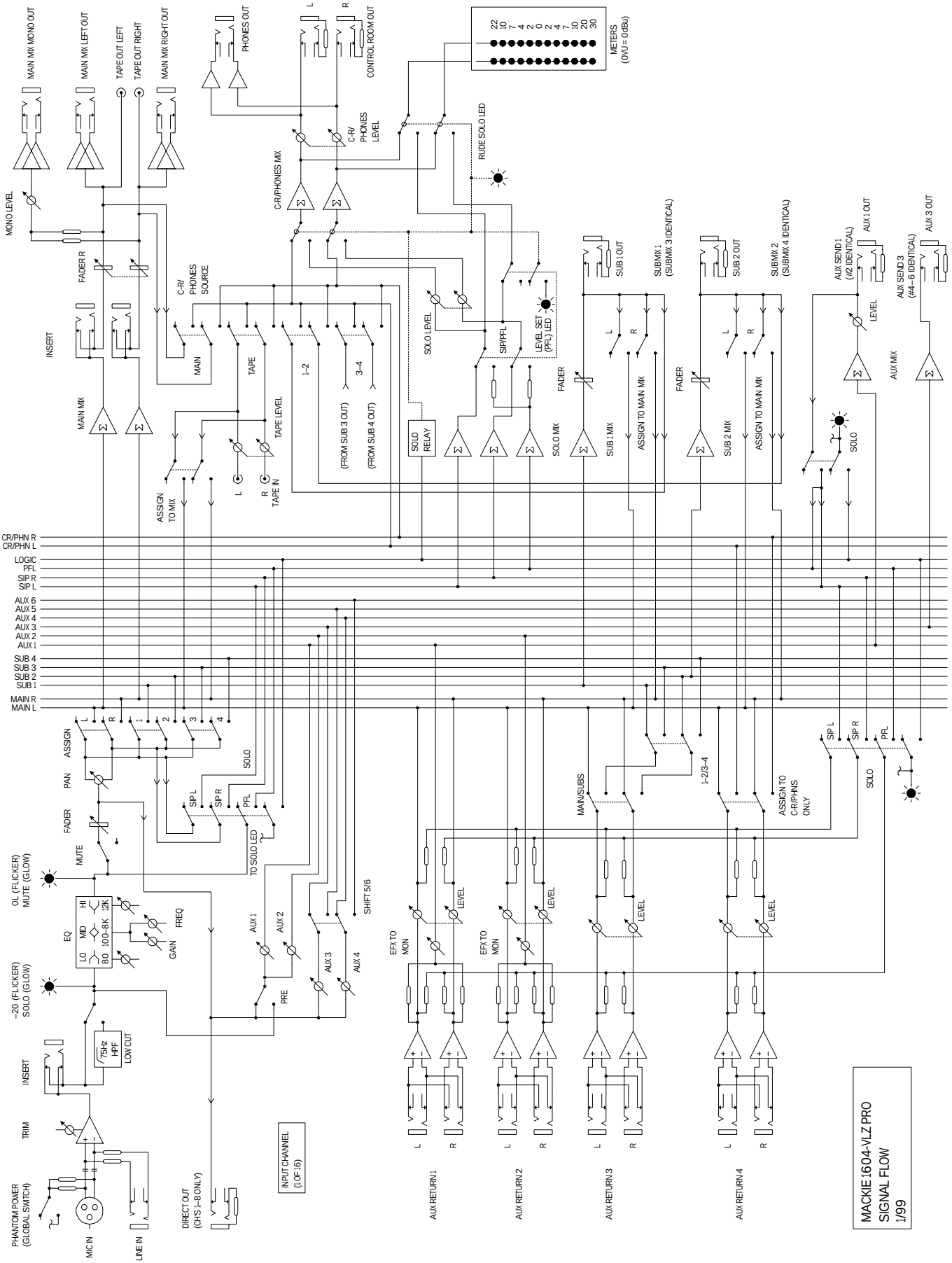
The important thing to recognize is that every bus has several inputs and one output, though that output may go to more than one destination (including another bus).

Your Tour is About to Start – Please Board the Bus

The primary signal path through the mixer begins with a mic or line input, and ultimately ends up at the main outputs. We'll trace through this path first.

We're using the 1604-VLZ PRO as an example shown on the next page, but what follows will apply to any mixer. Open up the block diagram and sing along.

Block Diagram Example: 1604-VLZ PRO



The channel input section is located in the upper left corner of the diagram. The signal from the microphone or line input is first amplified by the mic preamp.

Note that the mic input is also connected, through a pair of resistors and a switch, to the phantom power supply, which provides operating voltage for condenser microphones right from the mixer. The "global switch" note on the diagram means that a single switch controls phantom power for all of the microphone inputs together.

The rotary control above the mic preamp is the input trim control. The preamp boosts the low level microphone signal up to the operating level of the console. Trim allows you to adjust the preamp for optimum gain. (We'll tell you what's optimum later.)

Just below the mic connector is the line input jack. Note that the signal goes from this jack through a pair of resistors, directly to the mic preamp input. These resistors form an attenuator, which reduces the line level signal to approximately that of a microphone. This allows the mic and line inputs to share the same high quality circuitry.

The channel insert jack follows the preamp. This jack looks like the line input jack though it's used in a different way.

The tiny arrows on the jack denote switch contacts that are normally closed, but that open when a plug is inserted. Following the signal path through the switch, you'll see that without a plug inserted in the jack (the normal state), it's as if the jack wasn't there. Inserting a plug pushes the switch contacts apart, breaking the normal signal path. The tip contact of the jack now carries the preamp output signal while the ring contact becomes an input to the next stage.

Using what's commonly known as an Insert cable, (see the Tips section for a wiring diagram) you can insert a compressor or some other signal processor into the console's signal path.

A low-cut filter follows the insert jack. The switch immediately following the filter selects whether it's engaged or bypassed. The equalizer (EQ) section follows the filter. The 1604's equalizer is always in line, but if you peek at the 8-Bus block diagram you'll see a switch that completely bypasses the EQ. This bypass switch allows you to compare the equalized and "flat" signal, and provides a more direct signal path if no EQ is required.

The mute switch follows the equalizer. This is simply an on/off switch that disconnects the input section from the rest of the circuit.

Next comes the fader which adjusts the volume of the channel signal. The fader feeds the pan control where the signal splits into two branches, each going to a separate bus. The bus assign switches tell it where to go – to the main stereo busses or to pairs of subgroups. (Note: Mono mixers have no PAN controls or ASSIGN switches.)

Hopping Off The Bus

The assign switches operate in pairs, as indicated by the dotted lines connecting two switches. The topmost switch connects the panned signals to the main Left and Right busses. Other bus assign switches send the signals to subgroup busses 1-2 and 3-4.

To save paper and an owl habitat or two, the block diagram shows only one input channel. In reality there are sixteen identical channels, with their associated EQ, faders, and bus assign switches, each capable of being switched to your choice of busses.

Signals assigned to each bus are added together by a summing amplifier. Follow the lines going to the right from the bus and you'll find it.

The main mix summing amplifiers go through another set of insert jacks where a final outboard processor (typically a stereo compressor or equalizer) can be patched into the stereo mix. From here, the output level is adjusted by the left and right master faders, and finally through line driver amplifiers to the output connectors.

The amplifiers feeding the main L/R outputs are represented by a pair of overlapping triangles rather than a single triangle, This is Mackie's way of indicating that the amplifier has a balanced, differential output.

The left and right outputs are mixed at equal levels through two resistors to provide a monophonic mix. The MONO level control adjusts the volume of this mix, then another amplifier follows, providing the separate mono output. From the block diagram, you can see that the level of the mono output is affected by both the main faders and the MONO level control.

An Auxiliary Route

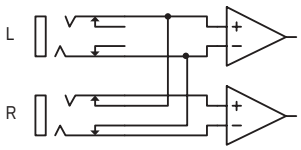
In a mixer, a signal is often "copied" so that it can be used for more than one purpose. A copy of the channel input signal is placed on the AUX busses which feed the AUXiliary outputs (or sends).

Locate the AUX 1 and AUX 2 controls on the block diagram and look back toward the channel input. Notice that the source for these two controls is switch-selectable. They can get their input either directly from the mic preamp, or after the equalizer and channel fader, depending on the position of the PRE/POST switch. The AUX 3 and AUX 4 controls are permanently connected to the post-EQ/fader signal. The outputs of the AUX 3-4 controls can be switched as a pair to either the AUX 3-4 or AUX 5-6 busses, allowing the controls to do double duty.

Auxiliary returns are normally additional inputs to the main left/right bus, but they can often be switched to other busses. All of the Mackie auxiliary returns (with the exception of the PPM mixers) come in pairs since most of the things you'd connect to those inputs – effect processors or synthesizers – have stereo outputs.

The AUX RETURN jacks have normalling contacts like the Insert jacks, but they're used in a different and clever way. Normalling the two jacks together allows you to send a mono signal, via an AUX RETURN, to both channels of the stereo bus.

Notice the connections between the two Aux Return 4 jacks.



The Left input jack, in addition to being connected to its buffer amplifier, is connected to the switch contacts of the Right input jack. In patchbay lingo, we'd say that the left and right jacks are half normalled.

A mono signal plugged into the Left jack (only) gets connected, through the Right jack's switch contacts, to the right input as well. This splits the mono signal so that, to the RETURN inputs, it looks like a stereo source.

When connecting a stereo source to the AUX RETURNs, inserting a plug into the Right jack breaks the normalled connection between the jacks, feeding the left and right amplifiers independently.

Auxiliary returns on the 1604 have some specialized routings that we'll describe in detail in the section on controls, but as an exercise, follow them through the block diagram and see where they go. You'll discover that with the press of a button, you can add reverb from Aux Return 1 or 2 to a stage monitor or headphone cue fed from Aux Send 1 or 2.

Directly Outa Here!

The DIRECT OUTPUT is a copy of the signal taken from the same point that feeds the post-fader auxiliary sends, therefore anything that you connect to the DIRECT jack will be affected by the fader and EQ controls. Note that a direct output isn't always taken from this point in the signal path. It's one of the things that differ between models (even between Mackie models). It's easy to tell, though, by looking at your mixer's block diagram.

Determining the source of your mixer's direct outputs is a good exercise in reading a block diagram. We stated that signal flow conventionally goes input-to-output from left to right on a block diagram, but a good way to figure out the source of an output is to start with the output end and work backwards. Exercise your block diagram reading skills to see what affects the signal from your mixer's DIRECT OUTPUT jacks.

The Long Road from In to Out

The block diagram is one good way of getting an overview of a console. Another way is to take each building block, each control, each input, and each output and study it individually. That's where we'll go next.

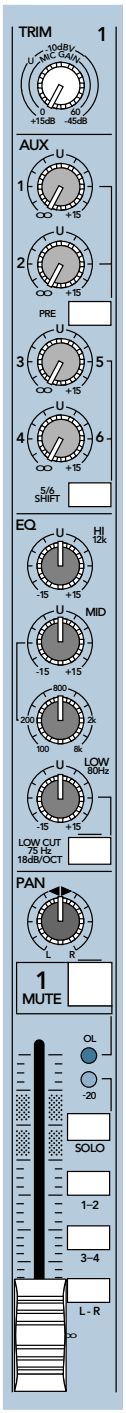
After this brief introduction, when reading about a particular section or function of your mixer, you should be able to turn to the block diagram and see where that part fits into the big picture.

Being able to follow a signal as it flows from input to output really helps when you know something's going in and it's not coming out where you expect it – and that happens to even the most experienced engineers at times.

Now that you've looked at the map, let's hit the road, Jack. On to the hardware:

Strolling Down The (Channel) Strip

The vertical column of knobs, buttons and circuitry associated with each input channel of the mixer is called a channel strip or module.



On older consoles, it was truly an independent and removable module. Maintenance was easy, but it's expensive to build a console with so many removable parts. At Mackie, we've chosen to construct our mixers with all of the channel strips in a single unit, or a large module comprised of several channels. The familiar term channel strip or module tends to hang around, however, since regardless of actual construction, it just looks like a module.

The Amplifier - The Mixer's Basic Building Block

You can't read about a mixer for very long without encountering the term gain. An amplifier is the building block that supplies that gain. Gain is the amount a signal is amplified. It's always a ratio (10 times or 100 times).

In audio, it is almost always expressed in decibels (dB):

$$Gain = \frac{VoltageOut}{VoltageIn}$$

$$Gain(dB) = 20\log\frac{VoltageOut}{VoltageIn}$$

An amplifier that boosts a 1 millivolt (0.001 volt) microphone signal up to the mixer's internal operating level of 0.775 volt has a voltage gain of 775, or about 58 dB. (Use your scientific calculator or dig up a dusty old math book.) A handy rule of thumb is that doubling the gain adds 6 dB, while cutting it in half is the same as subtracting 6 dB.

Some amplifiers have a gain of 1 or unity (no amplification), but serve to isolate one circuit from another, or to match impedance. A unity gain amplifier is often called a buffer.

The Mic Preamp

The first thing that a microphone signal encounters when entering the console is an amplifier with up to 60 dB of gain, adjustable with the TRIM control. It's called the preamplifier since it's the first amplifier in the chain. The preamp is a hard worker. It must amplify the mic signal from a quiet dulcimer or a loud kick drum, doing both without adding a lot of noise or distortion. This requires that it work well, providing as much as 60 dB of gain or as little as none (unity gain).

A line-level input typically has a gain range of –20 (that's 20 dB of attenuation) to +20 dB. On a Mackie mixer, line inputs pass through the preamplifier stage, but are first attenuated to bring the line level signal down to the working range of the TRIM control.

When the gain is properly adjusted with the TRIM control, peaks as much as 20 dB above the average level can be amplified without distortion. Too much gain and loud peaks can distort, while too little gain and the preamp's internal noise will be amplified farther on in the chain. Just right is . . . just right.

Pots – Let's Do The Twist

A potentiometer, or pot for short, is a variable resistor that divides a voltage in relation to the position of a contact sliding along a resistive element. Most potentiometers are round, and the resistance changes when you rotate a knob. The linear faders used as main level controls on most Mackie mixers are potentiometers built with the resistive element in a straight line. Equalizer controls are pots, too – they adjust the gain at specific frequencies.

PAN Controls

All stereo and multi-bus mixers have a Pan control in the channel strip. The pan (short for "panoramic") control consists of two volume controls ganged together to a single knob, operating on the same signal. With the knob turned fully in one direction, the signal going into one of the potentiometers comes out at full volume, while the signal through the other is completely off. Between the extremes, the signal is divided between two outputs, which ultimately end up at the left and right speakers. The difference in volume level of the signal between the two speakers creates a "phantom image" of the sound source, located in the space between the speakers.

Groups and Subgroups

In a basic stereo mixer, the pan controls route the input channels to a pair of busses that feed the main outputs. The eight busses we speak of when we refer to an 8-Bus console are called group (or sometimes subgroup) busses. In a multi-bus console like the Mackie 1604-VLZ PRO, switches connect the panned outputs to selected pairs of subgroup busses or the main stereo busses. In the studio, subgroup busses are often connected to the inputs of multitrack recorders.

The Mackie 8-Bus, SR, and 1642-VLZ PRO mixers provide multiple output jacks for each subgroup bus for convenient connection to multitrack recorder tracks. See the Applications section for the whole scoop.

Most multi-bus consoles also have switches to route the group busses to the main stereo bus. Group outputs then become true subgroups, and the group faders become submasters. A submaster fader simultaneously adjusts the level of all the sources assigned to that subgroup, retaining the balance that you've established for those sources.

If you assign the background vocal tracks to a pair of subgroups, which are in turn assigned to the main stereo mix, you can balance, pan, and EQ the tracks, and then adjust the background vocal level in the mix using the subgroup faders rather than a whole handful of individual channel faders.

Auxiliaries

Aux busses are typically used to create mixes on AUX SENDs (outputs) that don't go directly to a recorder or speakers, but are still important to the mixing process. Common applications are to send signals to an effects processor, or to create a custom monitor mix for a performer.

Tape Monitoring for Multitrack Recording

OK, we know you're probably hip to the latest hard disk technology and hope you never see rusty plastic ribbon again, but the term "tape" is just so comfortable You can record on anything you want using your Mackie – honest!

The thing that most distinguishes a multitrack recording console from other mixers is its tape monitoring facilities. With a simple stereo mixer, you mix a group of microphones or other sound sources so that they blend well, perhaps add some EQ and reverb, and send the mix to a stereo (2-track) recorder or PA system. What you mix is what you get.

In multitrack recording, instruments and voices are recorded on their own tracks, often one at a time, as the song moves through the production process. Not until all the tracks have been recorded do we "print" the final stereo mix.

When recording new tracks, you need to hear the previously recorded tracks so that you can make sure the new parts fit. You're always mixing, at least roughly, while you're tracking. A multitrack recording console has to be able to do both jobs at once.

It's desirable to record each track as "hot" as possible in order to achieve the best signal-to-noise ratio when using an analog recorder, or preserve low level resolution when recording digitally. This means that tracks will all be recorded at approximately equal volume, even though that's not how you want them to sound in the final mix. While laying the tracks, however, you must to be able to construct a mix that's musical enough so as not to distract the talent, the producer, or the engineer.

A multitrack recording console has a special section dedicated to monitoring during the tracking phase of the project. At all times, you can conveniently hear a mix (or, using AUX busses, more than one mix) of the multitrack recorder outputs. This allows us to record at optimum levels while monitoring tracks at any level we choose, temporarily boosting a track, muting a track, or, when overdubbing, listening to what we're sending to the recorder.

Multitrack consoles have a set of dedicated tape return inputs, one for each recorder track. These are routed to the monitor section when tracking, but are also often available as additional inputs during mixdown.

There are two different architectures used in the design of a multitrack console, both related to the form that the monitor mixing section takes. These are called "split" (or "side-by-side") and "in-line" monitoring. Split monitoring is sometimes known as "British style" (not to be confused with "British EQ") because it evolved from the first multitrack consoles designed by British studios. In-line monitoring is sometimes called "American style" because it was developed by an early US console manufacturer.

The Mackie 8-Bus is an in-line design. While Mackie doesn't make a split console, in the Applications section, we'll show you how to set up a 4-bus mixer for split multitrack monitoring.

A split console has a distinct group of controls dedicated to multitrack monitoring during the tracking phase. The monitoring section is clearly recognizable as a separate mixer with, at minimum, level and pan controls for each track, sometimes minimal EQ and an AUX send or two, but rarely the full set of channel strip controls.

While a split console may have 36 or more input channels, its monitor section is almost always smaller, typically 16 or 24 inputs, corresponding to the number of tracks on the recorder with which it was designed to work. A 48-channel monitor section on a split console, while not unheard of, is pretty unwieldy.

Expansion to more tracks, unless you planned ahead (remember when you said "8 tracks is all I'll ever need"?) often ultimately involves console replacement when the recorder is upgraded.

An in-line console, like a split console design, provides a separate mix (often called Mix-B as it is on the Mackie 8-Bus) for the recorder returns. Unlike the split console though, all of the controls and circuitry associated with the monitor section are located within the channel strip.

The in-line design has two big advantages over the split console:

- First, without the separate section of the work surface dedicated solely to monitor controls, it can be physically smaller for the same number of inputs and outputs.
- Second, since every input channel has a set of tape return mixing controls included, you are able to monitor and mix as many recorder tracks as you have input channels.

Today, most multitrack consoles are the in-line style – they're less expensive to build and usually will live through a couple of recorder upgrades before you outgrow them.

Regardless of the architecture, the monitor mix ends up going to the main left-right busses. That's what you normally listen to in the control room when tracking, and it also feeds the stereo mixdown recorder – handy for recording rough mixes while working.

With today's modular digital multitrack recorders, multitrack hard disk recorders, and almost indefinitely expandable digital audio workstations, adding more recorder tracks isn't the huge investment that it used to be. It's often as simple as borrowing another recorder from a band member and hooking it up. With a split console, even if you have enough channels to mix all the extra tracks you hauled in for the project, you might have to kludge some additional monitor inputs when tracking. With an in-line console, if you have enough inputs to mix your tracks, you'll have enough inputs to monitor them.

Now that you've had the ten dollar tour, let's move on to specifics about Mackie mixers. In the next section, we'll look at all the input and output connections, then follow with details on what the controls do.

Notes