Designing professional audio mixers for every scenario

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Introduction

Many people enjoy listening to music. Whether they're listening to recordings or live performances, the experience has almost certainly benefited from a mix engineer's skilled use of a professional audio mixer.

Mixing is the art of combining multiple audio sources to produce something that sounds great. If you've ever heard a recording of Robert Johnson from the 1930s, it was just a guy singing with his guitar, captured with one microphone. That's it; there was nothing really to mix. But if you listen to a recording of a band today, with drums, guitars, bass, more cowbell, vocals, etc., someone mixed it all together before you heard it. The same goes for live music performed by ensembles, where multiple musicians' performances have to be combined in real time in an ear-pleasing manner.

The tool of a mix engineer's trade is the mixer, or mixing console as seen in **Figure 1.** Mixing in the recording studio is often done on a PC of some kind (with a Digital Audio Workstation (DAW) and mixer-esque control surface), but live music is typically mixed on a physical mixer. Behind any great-sounding band is a talented mix engineer; behind (in front of, actually) any talented mix engineer is a mixer. And behind that mixer is a team of design engineers who have many factors to consider when developing a family of mixers.

What does a mixer do?

Consider a basic power trio—a Motörhead tribute band playing at a backyard biergarten. Fundamentally, the mixer needs to be able to:

***Figure 1**. Digital mixing console in use at live event*

- Accept a few audio sources and manage the input gain (trim) for each. This example would include a lead vocal, guitar cab, bass cab, kick drum, snare drum, two overhead mics, and one line-in (someone's portable music player) for intro music.
- Apply equalization for each source.
- Control the output volume for each source.
- Control panning (the left-to-right balance) for each source.
- Sum all of these sources into a master stereo output and send that resulting mix somewhere, such as an amplifier in a PA system.

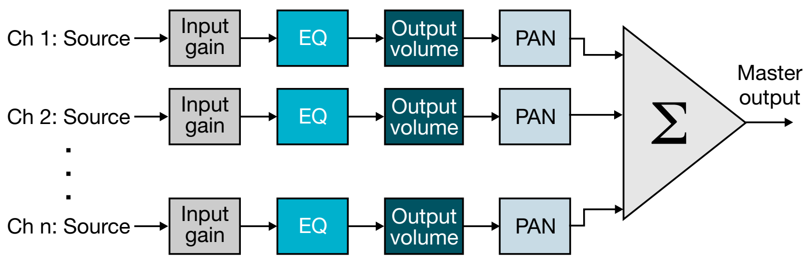

***Figure 2**. Basic audio mixer signal flow*

The requirements shown above and in **Figure 2** are about as basic as it gets for a mixer: there's a relatively low channel count and no effects needed. For smaller-scale scenarios, a basic analog mixer might be sufficient. Once the mixer's job gets more complex, though—with more musicians, a fancier venue, more varied sources (both analog and digital) or the need for effects—then it makes more sense to use a digital mixer.

Feeding the machine – I/O, part 1: input

Design engineers have to decide what market segment they're targeting: mix engineers working small events? Those working huge venues? Something in between? The first thing to consider is the number of input channels. Mixers scale; there's a mixer for just about every scenario, from a power trio to a band like Chicago, which likely requires at least 20 channels to handle the five vocalists, horn section and all the other instrumentalists.

Another key question for design engineers concerns the kinds of audio sources that need to be accommodated. Many of the sources will probably be analog mics. Any instruments going directly into the mixing board via a direct-input (DI) box will be analog sources. Needless to say, digital boards will need to incorporate analog-to-digital converters (ADCs), like the PCM1864 and PCM4204 ADCs from TI, in order to work with analog sources.

In many cases, the mixer will have to handle digital sources. For example, the band might use a laptop's S/PDIF output to send backing tracks directly into the board, eliminating the need for an additional analog-to-digital conversion.

It may be desirable for a mixer to be able to handle portable media. This is particularly important if the band's outro music is stored on a USB stick or on an SD card, or if music is played from a mobile phone via *Bluetooth*®. Or perhaps the performer is a cutting-edge electronic artist that has a live band, as well as someone playing a güiro solo from a remote location via Ethernet. While some of these situations are fairly (OK, very) rare, they do happen, and almost certainly call for digital mixers.

Sound sculpting: audio processing and effects

It's very common for a mix engineer to use varying degrees of effects for live performances. In some basic scenarios, just having compression available might be enough, but having more effects available is a good thing. Most digital consoles feature compression, and often include reverb, delay and other effects; this is a more cost-effective solution than buying additional outboard gear.

Though not strictly considered an effect, equalization can also be performed via digital processing. A typical analog mixer might have a knob for bass, a knob for mid (high and low mid, if you're lucky) and a knob for treble. A digital mixer could have a parametric equalizer for each channel, with selectable center frequencies and Q factor for each band. If the mixer is doing all of this digitally, then things like panning, input and output (I/O) gain are also implemented digitally.

Then there's the audio quality to consider. Each jump in bit depth correlates to lower quantization noise, which leads to a higher signal-to-noise ratio (SNR). Sample rate is also an important consideration: 96-kHz consoles are common now. A higher bit depth means more bits per sample, and a higher sample rate means more samples per a given period of time. More bits times more samples times more channels equals lots more data to process, and it adds up quickly. If the design engineer wants to create a digital console with a lot of I/O, complex signal processing and signal routing, they'll need to invest heavily in computational power.

Most mixer manufacturers don't want to sell one mixer; they want to sell a family of mixers with a range of specifications. Developing a line of mixers, each with a totally different hardware design and different CPUs (and therefore different software development efforts) can become really expensive. Using a family of software-compatible system on chips (SoCs) across a family of mixers will save manufacturers and engineering teams a lot of time—and cost—in product development.

There are no do-overs in live music: ease of use

A mixing console with a modest feature set can be controlled adequately with a handful of knobs, but that won't cut it for a more complex product. Adding the physical controls needed to adjust a multiband equalizer and even a handful of effects to each channel strip would result in a gargantuan mixer (similar to the one shown in **Figure 3a**), and it would be very difficult to make adjustments on the fly. A display of some sort is very practical for fuller-featured mixers (**Figure 3b**), especially if it's a touchscreen. It's fine to adjust an equalizer with a few knobs, as we've done for decades, but each effect has its own set of parameters to manage, and being able to quickly page through the settings for each effect is very important. These features require an SoC with the right video capabilities, as well as the right interfaces to support a touch controller.

You may have noticed that the band usually sounds best if you're sitting right by the mixing desk. That's because the mix engineer is crafting the mix for that position. That's the sweet spot, and it's the best seat in the house. What can the mix engineer do to make the sound great throughout the venue? He can't haul the console to several spots and fool with the mix, but he can walk around the venue with a tablet and make adjustments remotely from a few different locations. This requires the appropriate wireless interface and software running on the mixer. These features come at a cost, but they benefit the mix engineer (and the audience) greatly.

The grand finale – I/O, part 2: output

We've almost reached the end of the signal path. The band is playing and the mix is pumping out of the master stereo bus straight into the venue's PA

***Figure 3**. Example of a traditional mixer (a); example of a touchscreen mixer (b).*

system. For the power trio's guitarist and bassist, maybe that's enough, but they don't have very powerful amps and the drummer can't hear them very well. Fortunately, their little mixer allows for a monitor mix separate from the main stereo mix going to the PA system. The audience may need to hear everything, but the drummer may just want to hear bass and lead vocals.

Mixing a larger ensemble often has more complicated monitoring requirements. On top of the drummer's needs, there may be multiple singers wearing in-ear monitors, each wanting to hear different instruments in their mix. Maybe there are no amps or wedges onstage and the whole band is wearing in-ear monitors. That isn't a problem if the mixer has the right routing capabilities and enough auxiliary busses. The mix engineer may just be looking at how many aux sends and output jacks are available, but the design engineer needs to be conscious of the I/O capabilities of the potential audio SoCs.

Some bands like to send a sub-mix to an external USB hard drive or using a built-in SD card slot; this way they can record the show and critique it later. If the audio SoC can write directly to USB or an SD card, that's even better. The mix engineer may want to daisy-chain multiple mixers in order to achieve a higher channel count, or broadcast the performance to a remote studio via Ethernet-based systems such as Dante or audio video bridging (AVB). In that case, an audio SoC with a network interface that can connect directly to an Ethernet PHY would provide a BOM cost reduction.

Keep in mind that although we've been talking a lot about the digital aspects of a digital mixer, the very end of the signal chain is analog. Most PA systems still have amplifiers that expect an analog source. That means that if anyone wants to actually hear the music, the mixer will need digital-to-analog converters (DACs), like TI's PCM1795 and PCM1753 DACs, in its master output path. That covers the big speakers, but what about the really small speakers that fit over the mix engineer's ears? If he wants to audition his mix on headphones, that's also going to require a DAC (and a headphone amp).

The right tools for the right jobs: TI's processor family

The mix engineer at the biergarten is really good at her job, and thanks to her, the crowd can hear every note of our power trio's raucous rendition of "Ace of Spades." Part of her job is knowing how to pick the right tool for the job. The design engineer made a very similar assessment when spec'ing the mixing console: "What kind of gigs should this mixer support? What are my processing needs? Which processor(s) would best serve that set of requirements?"

Texas Instruments (TI) offers a broad range of digital signal processor (DSP)-based and DSP-plus-Arm®-based processors, many of which are already in the best mixers on the market. The C6000™ processor family, with its combination of processing horsepower and diverse peripheral sets, is an especially good fit for audio mixer architectures.

With respect to I/O, TI processors cover a range of requirements. Many C6000 devices feature the multichannel audio serial port (McASP), which is an audio-centric time-division multiplexed (TDM) interface (note that I^2S is a specific case of 2-slot TDM). The 66AK2G12 SoC, for instance, features three McASP ports and a total of 32 McASP I/O pins, allowing up to 64 channels' worth of I^2S data (more when using multislot TDM). Each McASP port features independent receiver and transmitter clocking, allowing for fully asynchronous operation.

Several C6000 processors also support PCIe (Peripheral Component Interconnect Express), and most have onboard USB and SD card interfaces, as well as Ethernet controllers. Additionally, the 66AK2G12 SoC has a hardware ASRC (asynchronous sample rate converter) supporting up to 16 channels and six input and output clock zones; this can be a useful feature for Ethernet-based sources where data comes in as packets, with no reference clock. The band itself can even be an Ethernet-based source, with instruments and mics onstage plugged into a Dante-enabled I/O rack that will then pipe everything to the mixer through a single network cable.

Mix engineers will always have their pick of mixers that can satisfy their channel count, and design engineers know that their product must stand out from the pack based on its processing capabilities, which have to cover everything from effects to signal routing. TI's C6000 family scales in this respect, with a variety of floating-point processors ranging from the C67x DSP series at 300 MHz to multicore devices such as the C667x DSP, which supports up to eight DSP cores running at up to 1.25 GHz each.

A manufacturer may produce several different mixers with a range of processing needs (perhaps requiring different audio SoCs), and their engineering team shouldn't have to write new software for each product. TI's Processor SDK is a unified and free software platform that runs on most C6000 processors and supports both the TI real-time operating system (RTOS) and Linux® (many C6000 processors also have Arm cores, where Linux is often preferable). The benefit is potentially huge: if a manufacturer builds a few mixers with C67x devices and some with C66x-based processors, they'll be able to run Processor SDK on all of them, meaning that they can run the same baseline audio software on all of their products and spend their efforts on algorithm differentiation rather than on porting exercises.

Anyone who has mixed a concert or seen a mix engineer at work knows that live music is a volatile beast, often requiring quick adjustments that you only get one chance to make. Ease of use is essential in such a situation, and having an intuitive display and control interface is the way to go. Many C6000 devices have integrated Arm cores, allowing for flexible user interface (UI) creation as well as built-in display capabilities, with 3D graphics engines and support for a variety of video formats. All of these devices have a variety of serial control interfaces (I^2C, SPI, UART) for connecting to physical controls such as buttons, sliders and touchscreen controllers.

The best seat in the house

A great mixer fits into a sweet spot of I/O capability, processing power and ease of use. That sweet spot will vary depending on the jobs that the mix engineer will need to perform with that mixer. Design engineers understand this, and start by assessing which sweet spot(s) they're trying to address. Having a range of software-compatible processors at their disposal is a huge benefit, because there truly are all manner of musical scenarios out there. Luckily, TI's processors scale, right along with mixers and gigs.

Related websites

- Learn more about TI DSPs for audio.
- Discover more details about TI's high-fidelity ADCs and DACs.

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