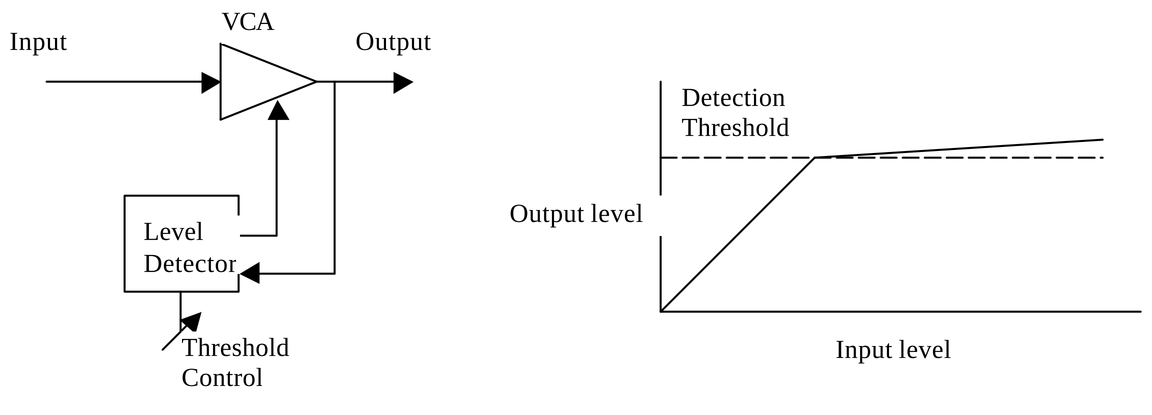
Yamaha Professional Audio Products

Explanation of Limiter circuit in EMX series mixers

Recent models of Yamaha's EMX-series powered mixers incorporate circuitry that attenuates or "limits" the signal level presented to the internal power amplifier stages under certain conditions. A front panel LED provides a visual indication that this limiting action is currently being applied to the signal. The fact that the term "LIMITER" appears on the front panels of the various products and their respective Owner's and Service Manuals, can often lead customers, accustomed to using conventional limiter products, to complain about the audible effects of the EMX internal limiter.

What is a limiter?

Quite simply, a limiter circuit does what its name suggests – it limits the amplitude of an audio signal at its output to some pre-determined maximum level. It is frequently used to prevent damage to loudspeakers in live stage applications by reducing the effects of large signal transients from microphones and amplified musical instruments. Figure 1(a) shows the basic configuration of a conventional limiter. The input signal is applied to a Voltage Controlled Amplifier (VCA) whose gain (or more correctly, its attenuation) is controlled by a level detection circuit. The detection circuit compares the level of the VCA's output signal with a preset threshold voltage (that is usually adjustable), and acts to reduce the VCA's gain when the output level exceeds the threshold. It is important to note that as long as the output signal level remains below the threshold, the VCA's gain is held constant and the signal through the limiter is unaffected. The graph of Figure 1(b) illustrates this.



(a) Basic limiter (b) Signal input/output relationship

Figure 1

Difference between basic and EMX limiters

In the basic limiter, the threshold level is either fixed or is adjustable. In either case, this threshold represents a signal level at the limiter's output that is *below* that required to overload the power amplifier. In the EMX limiter however, the fixed threshold level is in fact *at* the clipping level of the subsequent power amplifier stage and the limiter acts to reduce the ill-effects of a sustained high level input signal that would otherwise severely clip the power amplifier. It is this action – the fact that limiting is initiated at the power amplifier's clipping point – that can result in unusual audible side effects. The block diagram of the EMX limiter configuration is shown in Figure 2.

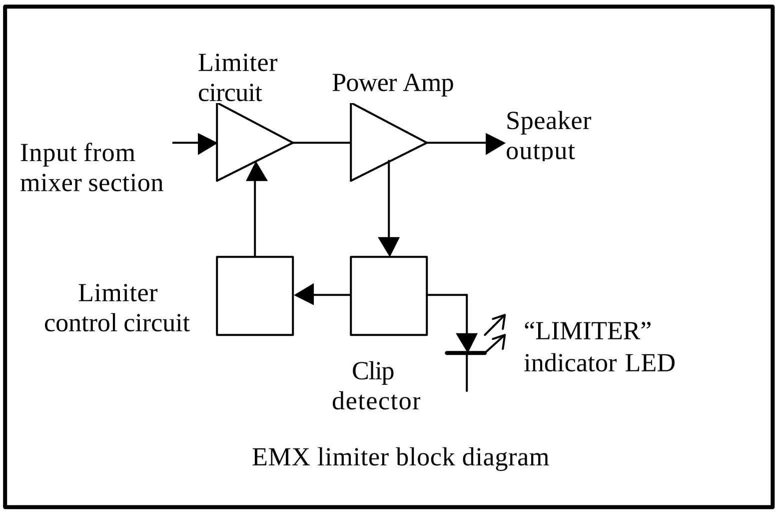


Figure 2

If it were not for the inclusion of the limiter circuitry in the EMX models, the "LIMITER" LED would otherwise have simply been labelled "CLIP" or "PEAK", as it is on other Yamaha Professional power amplifiers. Most users are well aware of the damage to loudspeakers that a clipping amplifier can cause and so operate their amplifiers only up to a level at which signal transients occasionally illuminate the "CLIP" LED, if at all.

Users of conventional limiter products usually find comfort in the constant illumination of the product's "limit" LED under signal limit conditions, feeling quite rightly that the product, audibly and visually, is "doing its job". It's understandable then, that these users tend to operate their EMX mixers in the same way. However, as has already been described, the EMX "LIMITER" LED indicates actual power amplifier clipping. There are two audible effects of this system that users may find "unusual". To explain these effects, it is necessary to analyse the circuitry used.

<u>EMX limiter circuit analysis</u>

Figure 3 shows the actual limiter circuitry that precedes the "Monitor Power Amp" section of the EMX640 Powered Mixer, one of the first products to provide this feature. Relating the elements of Figure 2 to actual circuit components, the input signal passes through limiter transistors Q201 to Q204 and op-amp IC101 to the subsequent power amp. The limiter control circuit consists of op-amp IC102, transistor Q225 and their associated passive components. Q208 is the clip detection transistor.

In more detail, Q201 to Q204 form two differential pairs – Q201/Q202 forming the PNP "upper" pair and Q203/Q204, the NPN "bottom" pair. Resistors R203 and R204 supply their respective differential pairs with the necessary operating current. The input signal is fed to the emitters of both differential pairs by resistors R201 and R202. The bases of Q201 and Q203 are connected together and held at ground potential by R205. The bases of Q202 and Q204, which are also connected together, can be regarded as the "control input" of the limiter stage, and are fed from the output of IC102. Depending on the voltage at IC102's output, the limiter stage will vary the signal level available to the power amplifier.

Let's suppose for the moment that IC102's output is at zero volts. Since the bases of Q201 to Q204 are all now at zero volts, both differential pairs are consequently "balanced" and the transistors in each pair will share their available emitter current equally. One transistor (Q201 or Q204) in each pair returns this current through its collector terminal directly to ground. The remaining transistors (Q202 and Q203) have their collectors wired together, so that Q203 "sinks" any current "sourced" by Q202. With no input signal,

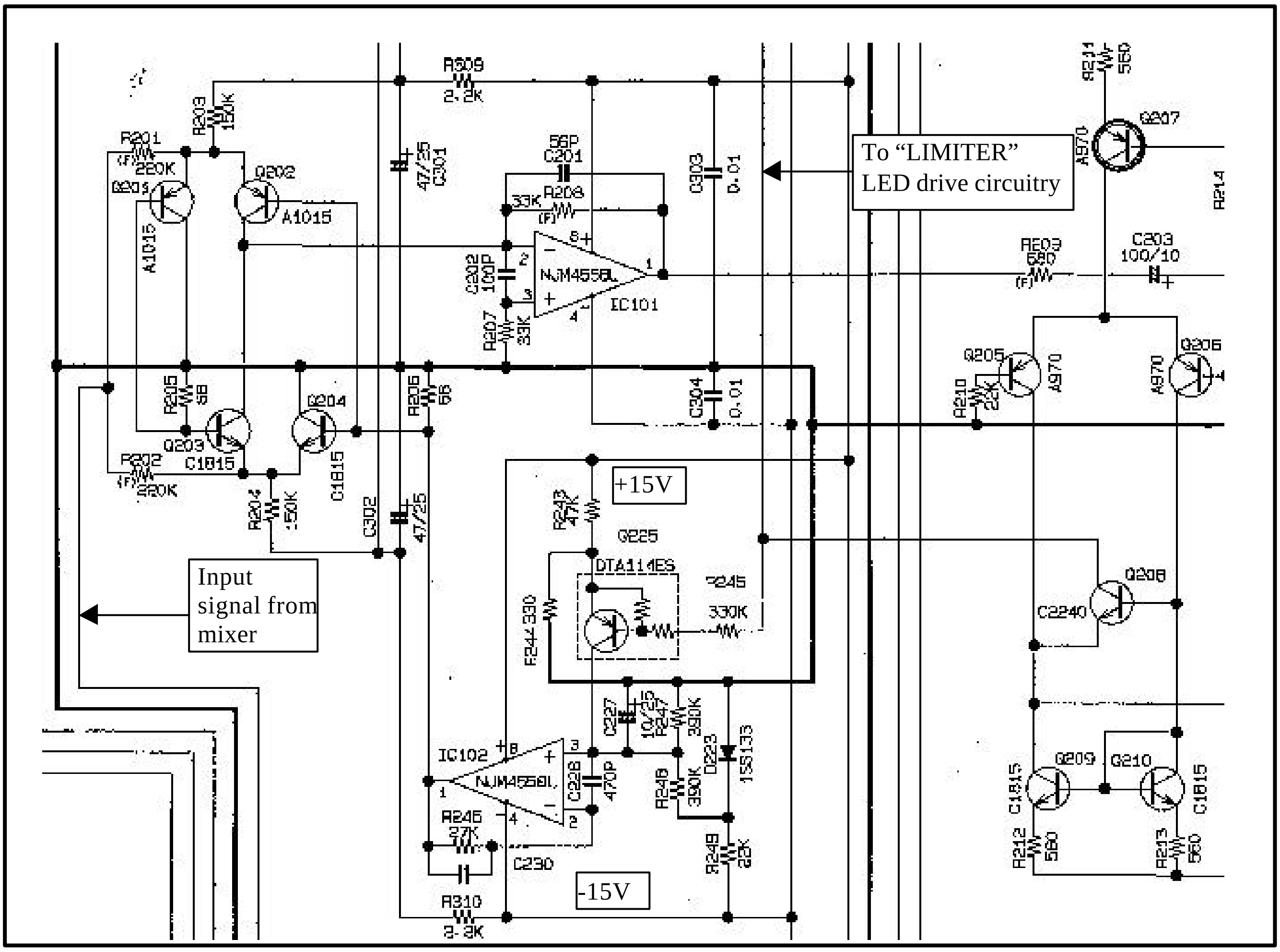


Figure 3

these currents are balanced, so none flows into the virtual-earth input pin 2 of IC101, and its output is zero. A positive-going input signal increases the bias on Q201/Q202 and decreases the bias on Q203/Q204. The larger collector current out of Q202 relative to that into Q203, flows into IC101, is inverted, and appears as a negative-going signal at IC101’s output pin 1. A negative-going input signal has, of course, the opposite effect.

The control voltage (IC102’s output) needs to be only slightly above or below zero to have a major effect on the limiter’s action. When IC102’s output is negative (as it would normally be under non-limiting conditions), Q202 is biased on harder than its partner Q201 is. Also, Q204 is biased *off*, which turns Q203 on harder. This means that less of the input signal is shunted to ground by Q201/Q204 and more is allowed to pass through Q202/Q203. Consequently, a higher signal level appears at IC101's output. A positive output from IC102 has the opposite effect to all this, resulting in a lower signal level at IC101’s output.

The passive components around IC102 and Q225 determine the attack and decay characteristics of the control voltage applied to the limiter. Diode D223 and resistor R249 in conjunction with the voltage divider R247/R248 develop a bias voltage of about minus 0.32 volts, which is filtered by capacitor C227 and applied to the non-inverting input pin 3 of IC102, connected as a unity-gain buffer. Under non-clipping conditions, transistors Q208 and Q225 are both off (as is the “LIMITER” LED, whose drive circuitry is not shown here), so they have no effect on this voltage. Since the buffered output of IC102 is minus 0.32 volts, the limiter has minimal attenuation effect on the audio signal level passing through it.

When the power amplifier clips, the collector of Q208 swings hard negative, which turns on Q225. This transistor acts as a switch that charges C227 from its (presently) negative voltage to the positive voltage at the junction of R243 and R244 (about 0.1 volts). The limiter now acts to reduce the signal level at its output. How quickly the limiter reacts depends on the values of R243 and R244. With the signal level to the power amplifier now reduced in level, clipping ceases and the Q208/Q225 combination switches off. C227 now discharges through R247/R248, restoring “normal” conditions (minimal signal attenuation through the limiter).

Subjective performance limitations

If the high input signal level that initiated limiter action in response to power amplifier clipping is still present when the limiter releases, clipping will re-occur and the whole cycle described above will repeat itself. Since time constants are involved, the user may hear “breathing” effects on the signal as the limiter cycles between the two states. The user may misinterpret this as a fault condition, which it obviously is not.

Another, more subtle effect may be audible under conditions where the input signal contains frequently occurring transients. In a “normal” amplifier running typical music signals, clipped transients may not necessarily be audible if they are of sufficiently short time duration. The subjective level of the overall music signal can be higher under these conditions because of the increase in *average* power that the amplifier is producing. However, once initiated by a clipped transient, the limiter stage of the EMX mixer/amplifier reduces the *overall* music level, which prevents clipping of any further transients that occur before the limiter time constants have restored the normal gain characteristics of the system. The average power delivered by the power amplifier is consequently lower and it may not “sound” as powerful as a conventional amplifier system of similar power output specification.

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