PEAK UNLIMITER

AUDIO DYNAMIC RANGE PROCESSOR

Increases system gain when passing peaks that may have been limited during the original recording process

BY JOHN SUTTON

LIVE music can easily have a dynamic range exceeding that of current analog recording and playback systems. To "fit" onto an analog tape or disc, this dynamic range must be reduced. Generally, this is accomplished by manipulating the system gain as the signal passes through, making the loud passages softer and the soft passages louder. *Compression* is moderate application of this technique throughout the dynamic range. *Peak limiting* cuts gain radically if the signal exceeds a determined level.

Although this approach works, it sacrifices some of the realism in the reproduction of the program material. But not all of the 30 or so dB of dynamic range subtracted by the compression and limiting process is irretrievably lost. It can be restored by electrical processing complementary to what was done in recording. Most often, the exact nature of the original processing is unknown, making the complementary nature of the restorative action a hit-and-miss proposition. Expansion (the inverse of compression) that is not correct is often unsatisfactory, but the ear is more tolerant of errors in peak unlimiting.

The Peak Unlimiter described in this article "stretches out" what's left of the original peaks to enhance dynamic range. It is low in cost and easy to build and use.

Peak Unlimiting VS. Expansion. Peak unlimiting differs from expansion in that it need not change the system gain as radically to accomplish what it does. This means that attack and release times can generally be faster than in a linear expander without causing audible side effects such as "pumping and breathing." As shown in Figures 1A and 1B, linear expansion may use as much as 20 dB of gain change, while peak unlimiting uses 7.5 dB.

Another advantage of peak unlimiting is that it allows the processor to control each channel independently. Were such an arrangement used in a linear expander, the stereo image of the program material would suffer greatly. Common gain control avoids this, but causes another problem. The effect of synchronized gain change is quite noticeable in music that favors one channel, especially with low-frequency material. To the ear, this may result in an annoying "swishing"sound that we would like to avoid.

The Peak Unlimiter makes independent gain control work in its favor. Since we're interested in processing short-term peaks with a modest change in gain, attack and release times can be optimized. Audible signal degradation is thereby minimized.

About the Circuit. The Peak Unlimiter, shown schematically in Fig. 2, is designed around two quad BiFET operational amplifiers. The first, *IC1*, performs the actual signal processing, and the other, *IC2*, forms the heart of a gain-change indicator that is common to both audio channels. The signal-processing stages of both channels are identical, so further reference will be made only to the left channel.

Potentiometers *R1A* and *R2* couple a portion of the input signal to capacitor *C1*, which passes ac but blocks any dc level. The signal is applied to the noninverting inputs of *IC1A* and *IC1B* by means of *R4* and *R8*. Diode *D1* rectifies the output of *IC1A*, and capacitor *C2* filters the pulsating dc into a smooth level. This dc level is applied to the gate of FET *Q1* via *R9*

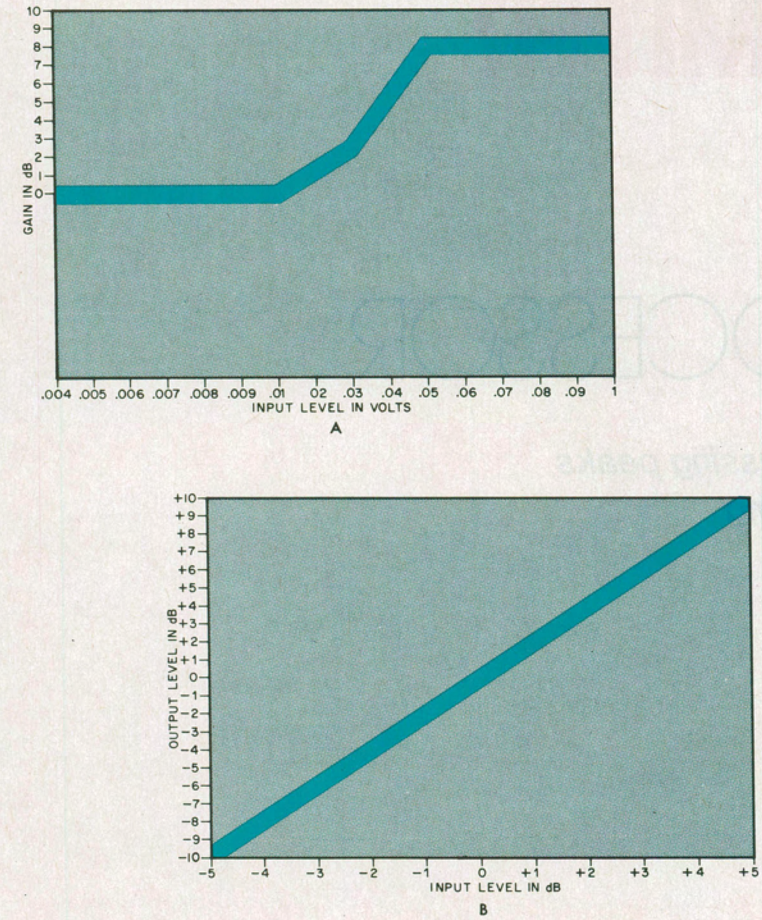


Fig. 1. Peak unlimiting (A) shows a 7.5-dB change, while linear expansion (B) shows a 20-dB variation.

when switch *S1* is in its open position. The time constant associated with this rectifier/filter network has been chosen for optimum project performance. Diode *D1*, a 1N82 germanium type, was carefully chosen for the required dynamic characteristics. Substitution of another diode type may degrade performance.

The drain of *Q1* is connected to the inverting input and feedback resistor of *IC1B*. Its source is grounded. The channel (drain-to-source) resistance of the FET depends on the dc level applied between its gate and source, which in turn depends on the amplitude of the input signal. A large input-signal amplitude results in a large gate-to-source control voltage and, hence, less channel resistance and greater gain. When *S1* is closed, the channel resistance of *Q1* and the gain of stage *IC1B* are constant. No peak unlimiting occurs when the switch is closed.

The output of *IC1B* is routed to jack *J3* by coupling capacitor *C3* and to the input of voltage follower *IC2A*. Diodes *D3* and *D4* rectify and feed the output of *IC2A* to the inverting and noninverting inputs of differential dc amplifier *IC2B*. Similarly, the output of *IC2C* (the voltage follower in the right-channel portion of the circuit) is rectified and applied to the inputs of *IC2B* by means of *D5* and *D6*. Tricolor emitter *LED1*, which consists of a red LED and a green LED connected back to back and housed in a single package is driven by the output of *IC2B* via current limiter *R23*.

The indicator circuit alerts the user to changes in gain. If the differential dc input voltage is negative, the red section of *LED1* becomes forward biased. In operation, faint red flickers indicate that gain changes of approximately 1.9 dB are taking place. If the differential dc input voltage is positive, the green emitter in *LED1* becomes forward biased. When this happens and the LED flashes green, a gain change of approximately 7.5 dB is taking place.

As is the case with *D1* (and *D2*), the diodes selected for use as *D3* (and D5) and *D4* (and *D6*) have been specified for their dynamic characteristics. Silicon diode *D4* has a higher conduction threshold than *D3*. This makes possible the desired visual indication of gain changes, because the red section of *LED1* will be firing at lower levels than the green section, which is forward biased only during relatively large changes in gain.

The power supply, shown schematically in Fig. 3, is of fairly conventional design. Transformer *T1* has a fuse-protected primary and a grounded secondary center tap. The outputs of full-wave bridge rectifier *D7* through *D10* are filtered by *C8* and *C10*. Regulators *IC3* and *IC4* generate stable +15- and −15-volt outputs for the rest of the circuit. Capacitors *C9* and *C11* improve the transient response of the IC regulators and ensure low effective power-supply impedances.

Construction. Printed-circuit assembly techniques are recommended in building the Peak Unlimiter. A full-size etching-and drilling-guide for a suitable pc board appears in Fig. 4, and the complementary component-placement guide appears in Fig. 5. Alternative construction techniques such as point-to-point or wrapped-wire assembly can be employed, but care should be taken to avoid ground loops and circuit instability. The use of IC sockets or Molex Soldercons is highly recommended. To ensure close tracking between channels, match *Q1* and *Q2* for their *actual* values of key parameters—I_{DSS}, V_{GSS}, and g_m.

Observe the polarities and pin basings of electrolytic and tantalum capacitors and of semiconductors. Note particularly that the pin basings of regulators *IC3* and *IC4* differ. The use of a radiation (hum) shield for *T1* is recommended. One can be fashioned by cutting a piece of sheet tin to fit and wrapping it around the body of the transformer. Trimmer potentiometers *R2* and *R11* are not mounted on the pc board: they can be soldered directly to the lugs of dual potentiometer *R1*. Use shielded cable for connections between the input jacks and the dual potentiometer, between the trimmer potentiometers and the circuit board, and between the pc board and the output jacks. Finally, house the project in a metal enclosure.

Initial Adjustment. Patch the Peak Unlimiter into your stereo system at some line-level point, such as a tape-monitor loop, or between the preamplifier outputs and the power-amplifier inputs. The only prelimina-

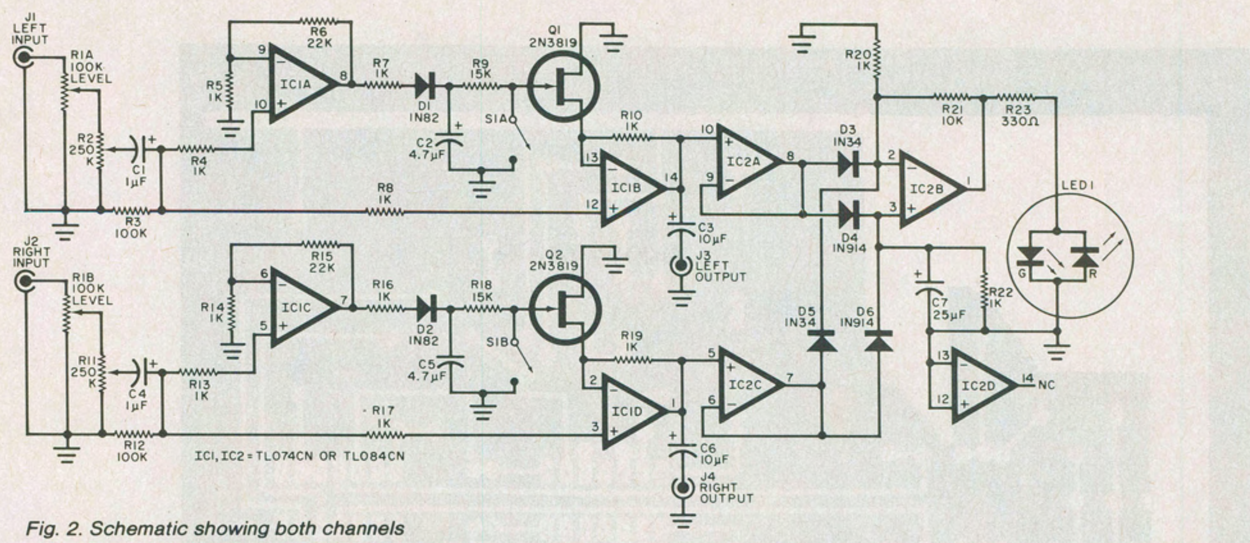


Fig. 2. Schematic showing both channels of the Peak Unlimiter circuit and LED indicator.

PARTS LIST

C1,C4—1-μF, 35-V tantalum capacitor
C2,C5—4.7-μF, 25-V, radial-lead aluminum electrolytic
C3,C6—10-μF, 16-V, axial-lead aluminum electrolytic
C7—25-μF, 25-V, axial-lead aluminum electrolytic
C8,C9,C10,C11—1000-μF, radial-lead aluminum electrolytic
D1,D2—1N82 germanium signal diode (see text)
D3,D5—1N34 germanium signal diode (see text)
D4,D6—1N914 silicon switching diode (see text)
D7,D8,D9,D10—1N4002 rectifier
F1—¼-ampere fast-blow fuse
IC1,IC2—TL074CN or TL084CN quad Bi-FET operational amplifier
IC3—LM340T-15 +15-volt regulator
IC4—LM320T-15 −15-volt regulator
J1,J2,J3,J4—RCA phono jack
LED1—Tricolor light-emitting diode (Radio Shack 276-035 or equivalent)
Q1,Q2—2N3819 n-channel FET (see text)
The following, unless otherwise specified, are ¼-watt, 5% tolerance, carbon-composition fixed resistors.
R1—100-kΩ, linear-taper dual potentiometer
R2,R11—250-kΩ, linear-taper trimmer potentiometer
R3,R12—100 kΩ
R4,R5, R7, R8, R10, R13, R14, R16, R17, R19, R20, R22—1 kΩ
R6,R15—22 kΩ
R9,R18—15 kΩ
R21—10 kΩ
R23—330 Ω
S1—Dpst miniature toggle switch
T1—35-V, 65-mA, center-tapped transformer (Triad F-227X or equivalent)
Misc.—Suitable enclosure, printed-circuit or perforated board, standoffs, IC sockets or Molex Soldercons, LED mounting collar, terminal strips, line cord, shielded cable, hookup wire, control knob, suitable hardware, solder, etc.
Note—The following is available from XEN, Box 2, Scranton, PA 18504: a complete kit of parts (not including enclosure), No. X-1980, for $59.00 post-paid in the United States. Also available separately are *Q1* and *Q2*, No. XMP-3819, for $5.00 a matched pair; etched and drilled printed-circuit board, No. X-1980-PCB, for $11.00; both postpaid in the U.S. Pennsylvania residents, add state sales tax. Allow four to six weeks for delivery. Add 2 weeks for personal check to clear.

ry adjustments that must be made are of trimmer potentiometers *R2* and *R11*. Close switch *S1* so that the peak unlimiting is defeated. Place the MODE switch of the preamplifier in its MONO position, rotate the control knob of the preamplifier's BALANCE potentiometer to its fully left position, and adjust the control knob of the project's front-panel LEVEL control (*R1*) so that the wipers of the dual potentiometer are at the midpoint of their travel. Adjust trimmer potentiometer *R2* so that the signal level at jack *J3* equals that at *J1*. This can be done aurally, by monitoring the loudspeaker output while alternately routing the drive signal through and around the Peak Unlimiter.

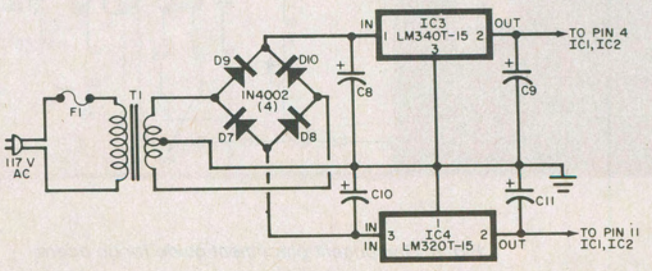
A more precise adjustment can be made if you have access to a signal generator and an oscilloscope. Connect the signal generator to a line-level input of the preamplifier and the probe of the oscilloscope to *J1*. Adjust the generator's output-level control for a 1-volt p-p signal at *J1*. The output frequency of the generator is not critical, but should be approximately 1000 Hz. Then shift the scope probe to *J3* and adjust *R2* for a 1-volt p-p output level.

Next, connect a pair of stereo headphones using clip leads to the "hot" sides of output jacks *J3* and *J4*. Do not make any connection to the common (shell) lead of the headphones. With the stereo preamplifier still providing a monaural drive signal, adjust *R11* for an output null. If an oscilloscope is being used, connect its probe(s) to the project outputs and set the scope to read differential voltage. Then adjust *R11* for an output null. Note that both channels of the project must be driven by the same signal to make valid adjustments of the trimmer potentiometers.

Now disconnect the clip leads or scope probe(s) and install the cover.

(Continued overleaf)

Fig.3. Power supply provides regulated bipolar 15 volts for op-amp power.



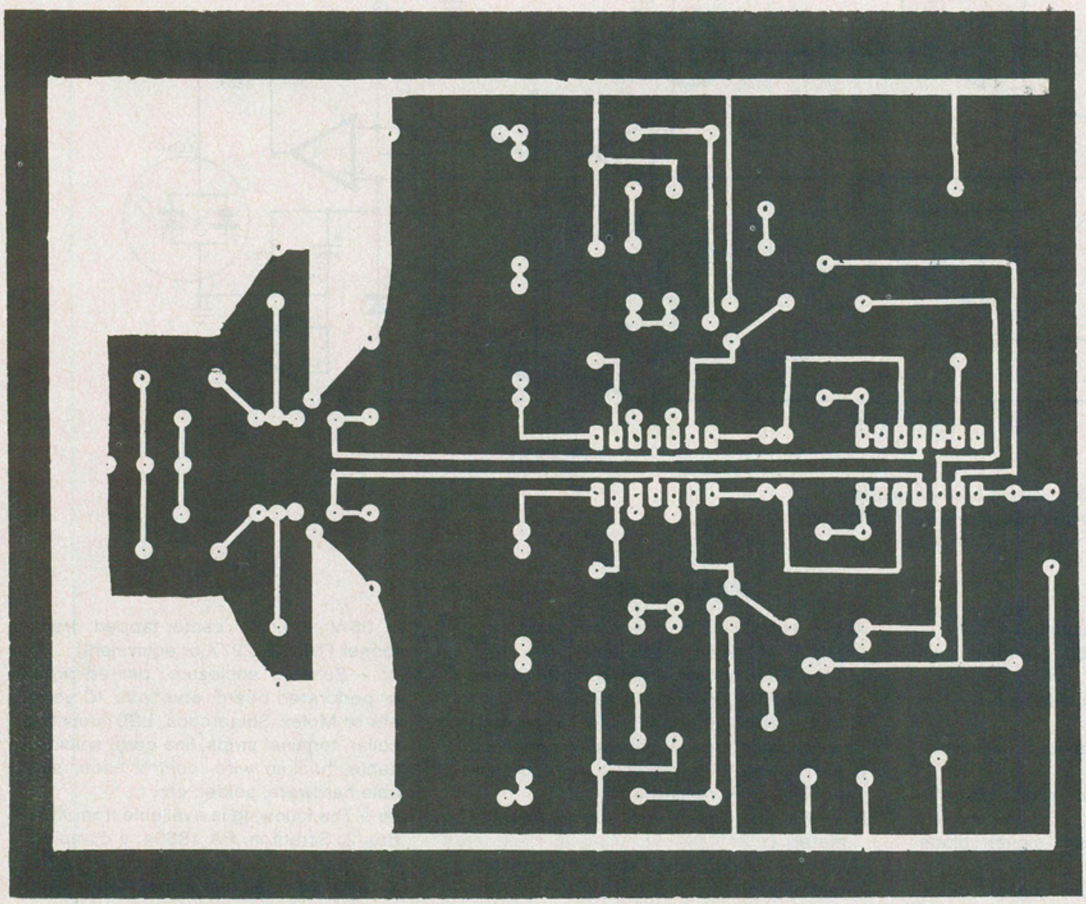


Fig. 4. Etching and drilling guide for pc board.

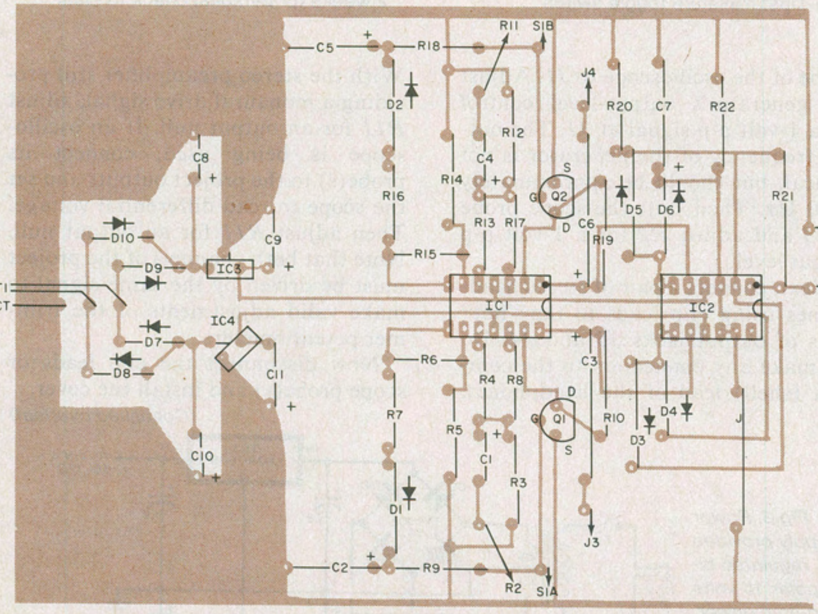


Fig. 5. Component-placement guide for pc board.

Using the Peak Unlimiter. Route audio signals through the project, and monitor the loudspeaker outputs and indicator *LED1*. The author recommends that LEVEL control R1 be adjusted so that, with *S1* in its open position, *LED1* glows red most of the time (except in the absence of input signals) and flashes green on the loudest signal peaks. This recommendation is somewhat arbitrary, however, and your ears should be the final judge. Opening and closing *S1* will allow you to make quick comparision between the processed and unprocessed signal. You might find that the nature of the program material dictates which setting gives the most pleasing results.

An apparent improvement in the program material's signal-to-noise ratio will be realized because of a masking effect introduced by the Peak Unlimiter. Keep in mind that signal peaks are accentuated by several dB, so some caution should be observed, at least at first. If the audio system does not have sufficient headroom, amplifier clipping and damage to the loudspeakers may occur. ◇