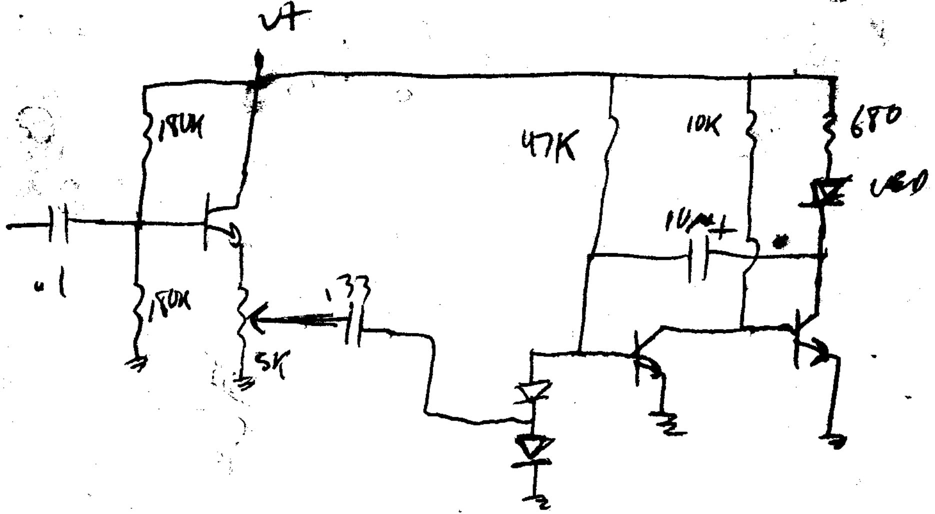
Overload with pulse stretcher



36

overmodulation indicator

J. Tabel

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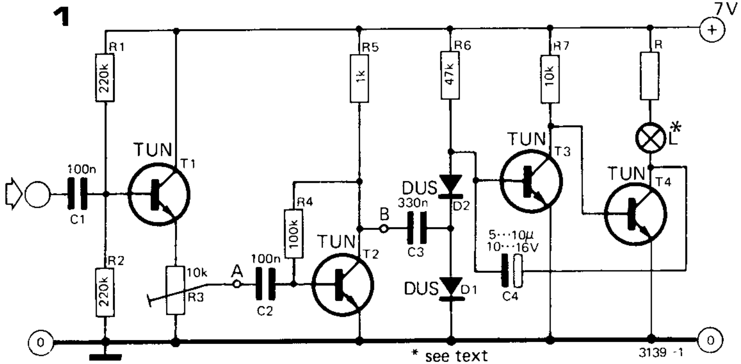

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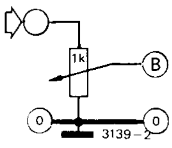


During recording on tape, it is necessary to ensure that the signal voltage at some point does not exceed a predetermined level. A similar situation can occur with (pre-)amplifiers and measuring instruments.

In such cases a meter-type indication is not the only possibility – and indeed it is invariably not the best. An overmodulation indicator that lights a lamp is cheaper – and gives a more distinct warning. The accompanying circuit is designed for this purpose.

Transistor T1 is an emitter follower, providing a high input impedance (about 100 kΩ) to minimize the load on the signal source. The trimmer R3 sets the voltage at which the lamp will just light up (overmodulation level).

The circuit around T2 is a x 100 amplifier which enables the threshold to be set as low as 5 mV. When this high sensitivity is not needed, i.e. when the threshold is 0.5 volt or higher, the stage can be omitted. The points A and B are then bridged. If the high input impedance is also unnecessary, as for instance when a loudspeaker-connection is being monitored, it is obviously permissible to omit the input stage also. Figure 2 shows how the input is made to point B in this case.

The circuit following point B is the indicator proper. The current through R6 normally 'bottoms' T3, so that T4 is cut off. Alternating signal voltage at point B however, rectified by the action of D1, D2, C3 and C4, will cause a negative drive to be applied to T3 base. When this AC voltage exceeds about 0.5 volts, T3 will no longer be bottomed, so that T4 will start to conduct. 'Monoflop' action via C4 will now ensure that even short signal peaks are clearly indicated by the lamp.

When selecting the type of lamp, one should note that the maximum available current is about 100 mA. With a supply voltage of 7 V as shown, the lamp should be a 6 ... 7 volt type. If circumstances dictate, a resistor can be inserted in series with the lamp. Given the supply voltage (V_B), the lamp voltage (V_L) and the lamp current (I_L) in amps, the series resistor (R) value required is:

$$R = \frac{V_B - V_L}{I_L}$$

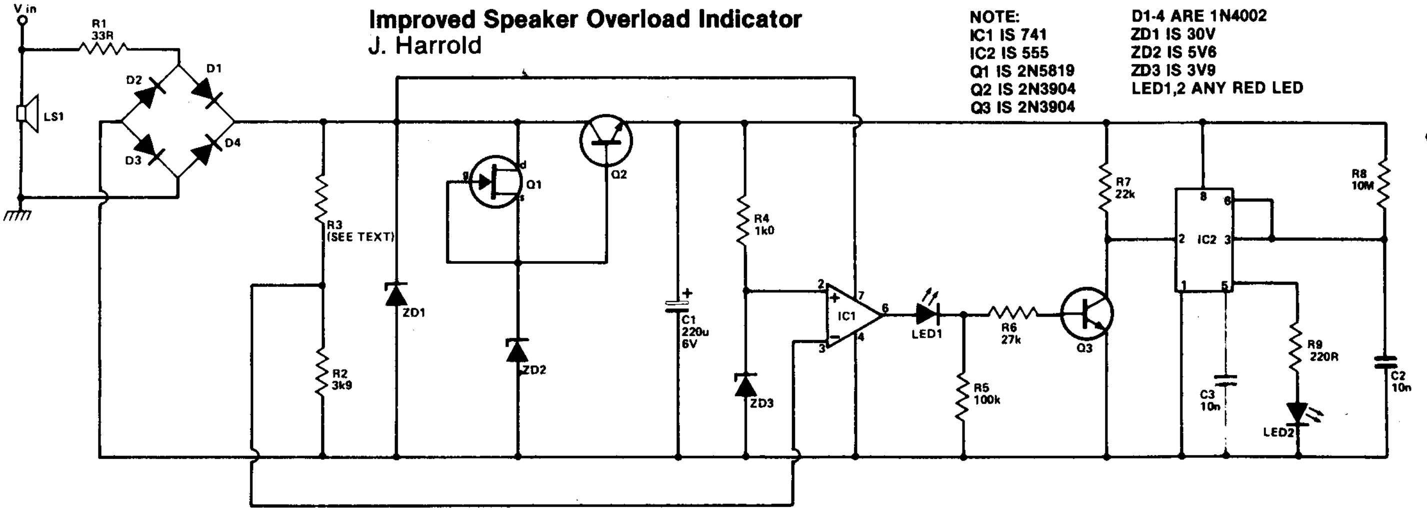
To take an example, suppose that a 6 volt 50 mA (= 0.05 A) lamp is to be used on a 9 volt supply:

$$R = \frac{9 - 6}{0.05} = 60\ \Omega,$$

for which the nearest lower standard value of 56 Ω would be taken.

Improved Speaker Overload Indicator

J. Harrold



NOTE:
IC1 IS 741
IC2 IS 555
Q1 IS 2N5819
Q2 IS 2N3904
Q3 IS 2N3904

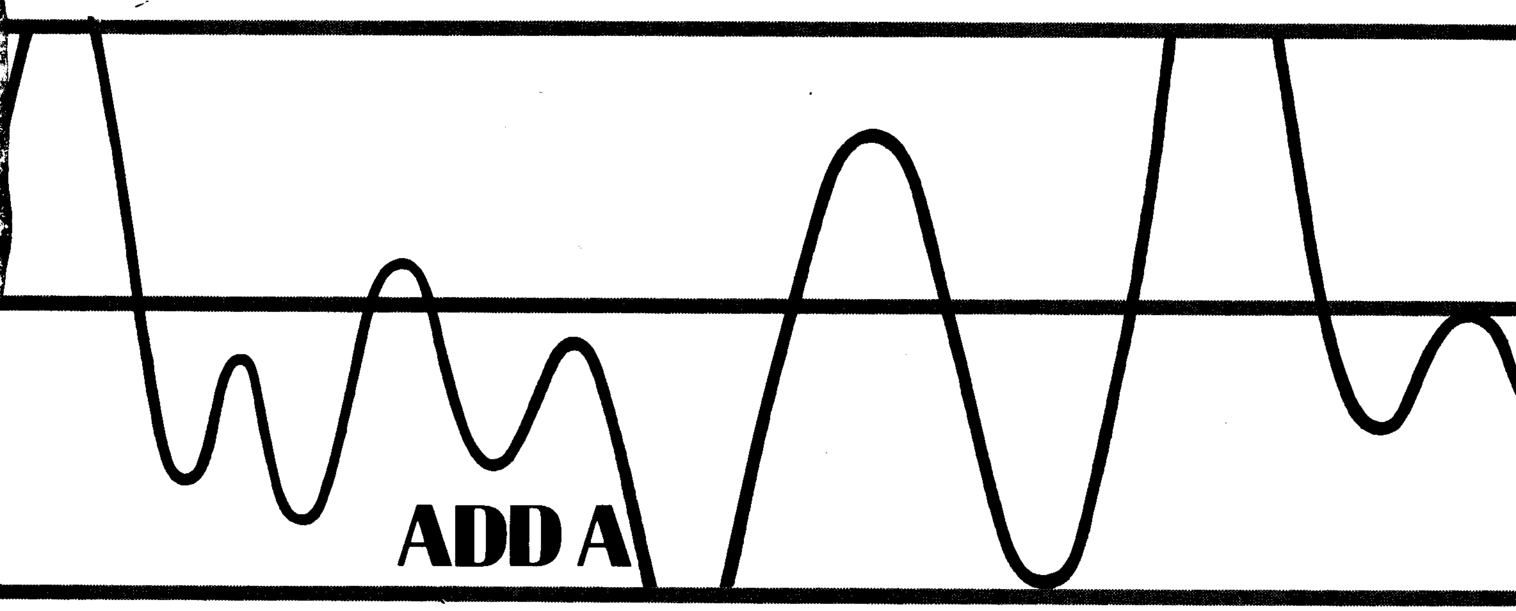
D1-4 ARE 1N4002
ZD1 IS 30V
ZD2 IS 5V6
ZD3 IS 3V9
LED1,2 ANY RED LED

This circuit is based on a design by J.P. Macaulay. This one offers an improvement in performance, which is low cost and does not introduce an external DC power supply.

The voltage at the speaker output terminals is rectified and then passed to potential divider R2, R3. ZD1 provides 'last ditch' protection for Q1 and IC1 (this method is not suitable if indication of overloads of greater than 50 W is required). Q1 is used as a voltage variable resistor and with ZD2, series pass transistor Q2 and C1, provides a regulated supply. This supply improves the stability of the 3V9 reference potential at the inverting input of IC1 and also provides a stable supply for IC2 and its timing components R8, C2. C1 cannot be placed between 0V and the collector of Q2 as this would have an adverse filtering effect on high frequency signals. When the voltage across R2 is less than 3V9, the output from comparator IC1 is low (about 1V5) and this voltage is dropped across forward biased red LED 1 (or alternatively any three silicon diodes in series). Q3 is off and the trigger (pin 2) of IC2 is high. When the voltage across R2 exceeds 3V9, IC1 output goes high and Q3 is turned on, lowering the voltage at IC2 pin 2, triggering the monostable and lighting LED 2 for a period dependent on R8, C2 (about 100 mS with given values). C2 must be a low leakage type (not ceramic).

$$R3 = (\sqrt{2PR} - 3.9)\ \text{kilohms},$$

where P is the power output and R is the speaker impedance.



ADD A CLIPPING INDICATOR TO YOUR AUDIO AMPLIFIER

To protect speakers, this simple circuit senses power supply voltages and flashes a warning LED just before the onset of clipping

BY NORMAN PARRON

THE CONSEQUENCES of overdriving an audio power amplifier can range from the unpleasant (ragged, distorted sound) to the catastrophic (burnt, black remains of tweeters and supertweeters). It's obvious, therefore, that the audiophile will want to avoid this condition. The project presented here, an Amplifier Clipping Indicator, will help him do just that. It continually senses both the audio output of the amplifier and the power supply voltages, and flashes a warning LED if the output signal voltage approaches either power supply rail. The user can then reduce the drive level so that the LED stops flashing.

Readily available, inexpensive components comprise the Amplifier Clipping Indicator. Many of them will be found in an experimenter's "junk box." A stereo version can be built in just a few hours, making the Amplifier Clipping Indicator an enjoyable weekend project. The modest amount of power the circuit requires can be tapped from the power amplifier's supply or furnished by a small supply built especially for this purpose.

What Is Clipping? When an audio amplifier is overdriven, it "clips" the input signal. The process is shown graphically in Fig. 1. A power amplifier is driven by a sinusoidal input signal having maximum positive and negative amplitudes of $+V_{IN}$ and $-V_{IN}$, respectively (Fig. 1A). The amplifier generates an output signal that is (ideally) an exact replica of the input except for its increased amplitude.

Because the amplifier must reproduce ac waveforms, it employs a bipolar dc power supply. This means that the most positive voltage it can produce at the output terminals is $+V_{CC}$, and the most negative voltage is $-V_{CC}$. If the amplifier's gain control is adjusted so that the output signal approaches the limits imposed by the power supply, a waveform like that shown in Fig. 1B is generated. It can be seen that the maximum positive and negative swings of the output voltage, $+V_{OUT}$ and $-V_{OUT}$, are somewhat less than the absolute limits of $+V_{CC}$ and $-V_{CC}$.

Adjusting the control for more gain causes the amplifier to attempt to exceed the constraints of the power supply. The result is a clipped waveform like that shown in Fig. 1C. Spectral analysis of such a waveform indicates the presence of high-order harmonic distortion products during the interval that clipping takes place. If the output signal is clipped less than 1% of the time, the effect is usually inaudible. As the duration of clipping approaches 10%, the usual consequence is audible, "raspy" distortion. A severely clipped signal (more than 10% of the time) contains a considerable amount of high-frequency energy. This energy poses a significant threat to midrange and high-frequency drivers because it is directed to them by the crossover network and they are usually capable of dissipating far less power than bass drivers.

Although the example that has been discussed used sinusoidal signals, an audio amplifier usually processes musical signals that are much more complex. It is characteristic of most recorded music that the average signal level is low. However, musical program material does contain a significant number of short-lived, high-level transients. An amplifier might be called upon to deliver one watt of output power on an average basis, but accurate reproduction of a bass percussion transient can require fifty to one-hundred times that power level for a brief instant.

All is well if the amplifier has enough voltage and current reserves to pass the transient unclipped. However, if the amplifier cannot do so, the dynamic range of the recording will be compressed and audible distortion products introduced. This, coupled with the fact that perceived loudness is a function of average (as opposed to peak) power, explains the trend toward power output capabilities that were unheard of in audio amplifiers a relatively short time ago. So-called "super-power" amplifiers allow the audiophile to listen to program material at realistic levels without clipping high-level transients, even if inefficient speakers are used.

About the Circuit. The Amplifier Clipping Indicator is shown schematically in Fig. 2. Each channel of amplification in a sound system will require a separate indicator circuit. The most common application for the project is in a stereo system, so component numbers for two channels are shown. Those for the right channel are given in parentheses. The discussion that follows pertains to only one channel, designated the left channel of a stereo pair. Everything that will be said, however, applies equally to as many channels as are needed because the indicator circuit is identical for each.

Output signals from the audio amplifier are applied to an 11:1 voltage attenuator (*R1R3*). Similarly, the positive and negative supply voltages, $+V_{CC}$ and $-V_{CC}$, are applied to attenuators *R5R7* and *R9R11*. The voltage dividers associated with the power-supply outputs, however, employ trimmer potentiometers and have variable attenuation factors. Those portions of the input voltages passed by the attenuators are applied to two 741 operational amplifiers (*IC1A* and *IC1B*) employed as voltage comparators.

Assume that the trimmer potentiometers have been adjusted to attenuate the power supply voltages slightly more than the fixed divider attenuates the audio signal. If the amplifier is being driven by an audio signal, but not to the point of clipping, its output voltage will be smaller in magnitude than either the positive or negative supply voltage. This means that the voltage applied to the noninverting input of *IC1A* is never more positive than that applied to the inverting input, and the output of the comparator remains at −12 volts. Similarly, the voltage applied to the inverting input of *IC1B* remains positive with respect to that present at the noninverting input, keeping the output of *IC1B* at −12 volts.

Diodes *D1* and *D3* form an OR gate whose output goes to +12 volts when either of the comparator outputs does. In the absence of clipping, both *D1* and *D3* are reverse-biased, which keeps transistor *Q1* cut off. Monostable multi vibrator *IC3* remains untriggered and its output (pin 3) is at ground potential. This keeps *D7*, which together with *D5* forms a second diode OR gate, in a nonconducting state. The output of the *D1D3* OR gate is applied to the *D5* input of the second gate. Both inputs are low, so *Q3*

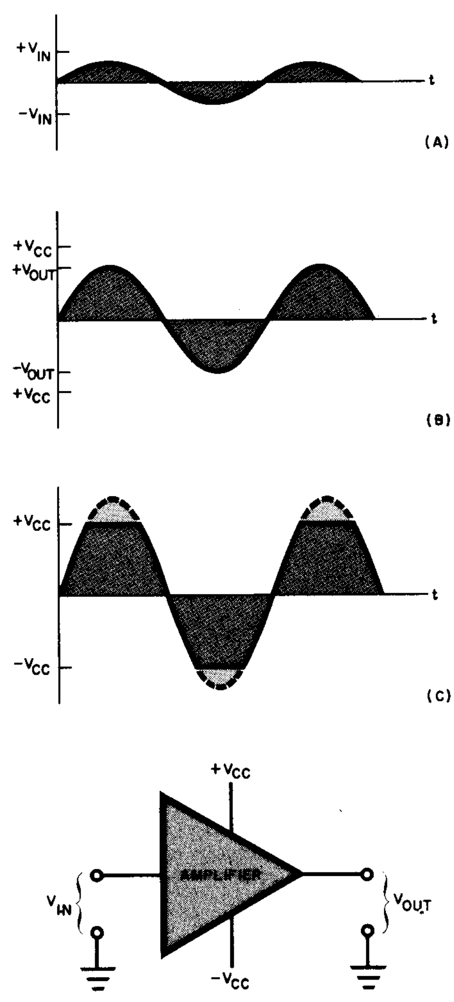


Fig. 1. If input amplitude (A) or gain of amplifier is not excessive, output is not clipped (B). Increasing one or both causes amplifier to clip the output (C).

receives no base drive and the clipping indicator LED (*LED1*) remains dark.

Now let's assume that the audio amplifier is driven into clipping. The audio output voltage reaches the positive or negative supply voltage (or both) and is clipped like the one shown in Fig. 1C. When the positive portion of the audio waveform applied to the noninverting input of *IC1A* becomes more positive than the voltage at the inverting input, the output of the comparator goes to +12 volts, this forward-biases *D1* and *D5*, and provides base drive for *Q1* and *Q3*. A similar thing happens when the negative portion of the audio waveform is clipped. The voltage applied to the inverting input of *IC1B* becomes more negative than the voltage at the noninverting input, so the output of this comparator switches to a +12-volt level. This forward biases *D3* and *D5*, providing base drive for *Q1* and *Q3*.

When *Q3* is supplied with base current, it turns on and the clipping indicator LED glows. However, the clipping interval can be so short that the eye will not readily detect the brief flash of the LED. That's why *Q1*, *IC3*, and their associated components have been included. Together they function as a pulse-stretching circuit. Here's how.

When the output of either comparator goes high, *Q1* receives base current and its collector drops to ground potential. A negative pulse is passed by *C1* to pin 2 of *IC3*, triggering this monostable multivibrator. The output of the timer IC (pin 3) goes high for an interval determined by the time constant of *R19C5*. For the values given, the width of the output pulse is about 0.25 second. This output pulse is OR'ed with the output of gate *D1D3* and applied to resistor *R21*. Transistor *Q3* receives base drive and sinks current for *LED1*, causing the clipping indicator LED to glow.

The pulse-stretcher turns the LED on for one quarter of a second even if the clipping interval is much shorter. A subsequent trigger pulse received while the monostable is timing will not retrigger it. However, one received immediately after a timing cycle will cause the process to be repeated. If the clipping interval is longer than the width of the output pulse (which can be extended to any desired interval by increasing the value of *R19* or *C5* or both), the OR'ing action of *D5* and *D7* will keep *Q3* in a conducting state. Therefore, the clipping indicator LED will continue to glow even after the output of the monostable has returned to its ground state. It will glow until the audio amplifier recovers from the clipping condition.

The project requires a bipolar power supply of ±12 volts dc. These operating voltages can usually be tapped from the audio amplifier's power supply. Zener diodes and series current-limiting resistors can be used to drop the amplifier's $+V_{CC}$ and $-V_{CC}$ supply voltages to the desired values. Alternatively, a small line-powered supply can be built into the project's enclosure. Current demand is relatively modest—a few milliamperes for the −12-volt supply and about 50 mA from the positive rail.

Because dynamic voltage comparison is the method employed to sense clipping, this project enjoys a significant advantage over such power-monitoring devices as peak-reading meters and strings of LEDs. A peak-reading meter only indicates that the audio output has reached a given level. It will not necessarily indicate that clipping is taking place. For the sake of illustration, let's consider what happens to an amplifier with an unregulated power supply when it is driven by an audio signal with many high-level transients.

Suppose that our amplifier can deliver 75 watts per channel of continuous power to 8-ohm loads and has an IHF dynamic headroom of 2.04 dB. This means that it can deliver 120 watts of output power into 8 ohms for brief intervals. Consequently, the power supply voltages under full load are +34.6 volts and −34.6 volts. When the demand on the power supply is light, the available voltages are +43.8 and −43.8 volts.

If the supply's filter capacitors have charged up to these higher voltages and a short-lived, high-level transient arrives at the amplifier's audio input, the output stage can momentarily generate an 87.6-volt peak-to-peak waveform without clipping it. However, driving the amplifier this hard causes the voltages across the filter capacitors to decrease. If the amplifier is called upon to reproduce a second high-level transient before the filter capacitors have had an opportunity to recharge sufficiently, clipping will result.

It can thus be seen that a peak-reading audio power meter will not *necessarily* indicate that the amplifier is clipping. In our example, the lowest possible power supply voltages are +34.6 and −34.6 volts, so we can safely say that any audio output signal with a peak power of up to 75 watts as indicated on the peak-reading monitor will not be clipped. Above that power level, however, the meter reading alone will not tell us whether clipping is taking place. By contrast, a flash of the indicator LED in this project warns of the onset of clipping, a warning which takes into account the dynamics of the amplifier's power supply.

Construction. Either printed circuit or perforated board can be used in the assembly of the Amplifier Clipping Indicator. In any event, the use of IC sockets is recommended. Be sure to use the minimum amount of heat and solder consistent with the formation of good solder joints. Also, observe the polarities and pin basings of semiconductors and electrolytic capacitors.

After the project's circuit board has been completed, connect it to *BTS1* and the indicator LED(s) with suitable lengths of hookup wire. Then secure the board to the project enclosure with standoffs and machine hardware. Mount *BTS1* on the rear panel of the enclosure

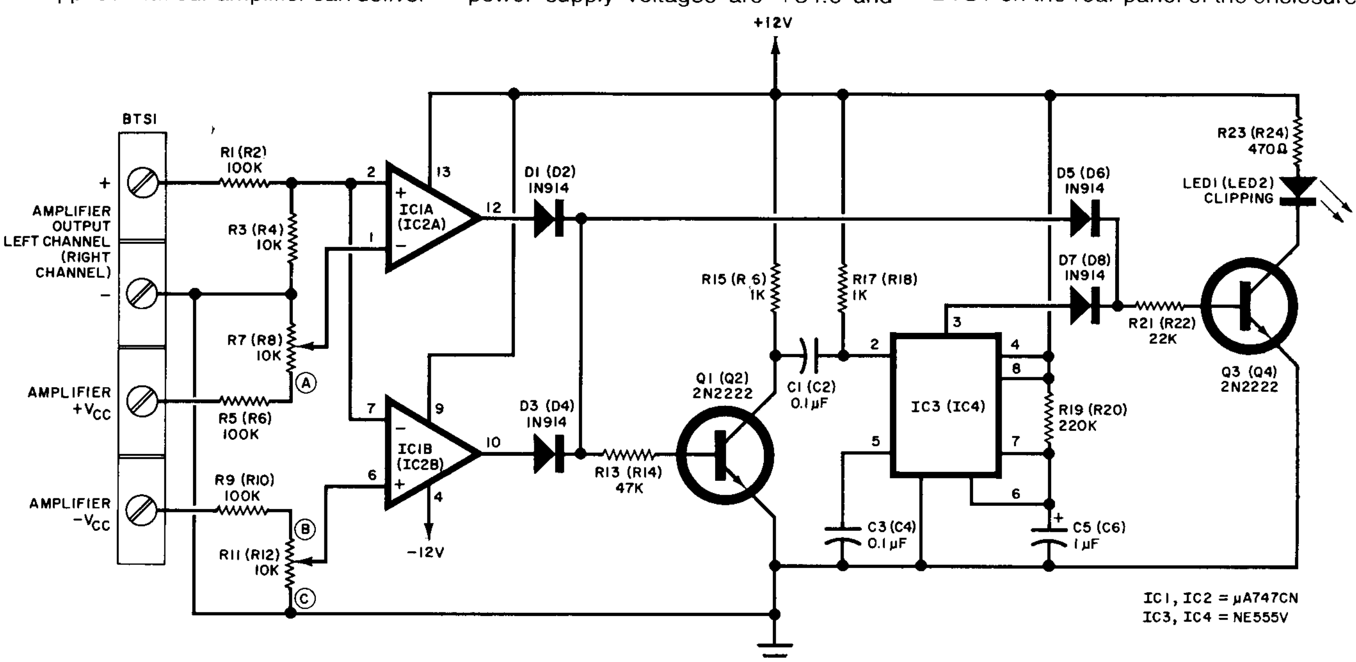


Fig. 2. Schematic of the clipping indicator circuit for one channel.

PARTS LIST

BTS1—Four-position (Six-position) barrier terminal strip
C1 through C4—0.1-µF disc ceramic
C5,C6—1-µF tantalum
D1 through D8—1N914
IC1, IC2—µA747CN dual operational amplifier
IC3,IC4—NE555V timer
LED1,LED2—Light emitting diode
Q1 through Q4—2N2222
The following are ¼-watt, 5% tolerance carbon composition fixed resistors unless otherwise specified.
R1,R2,R5,R6,R9,R10—100,000 ohms
R3,R4—10,000 ohms
R7,R8,R11,R12—10,000-ohm, linear-taper trimmer potentiometer
R13,R14—47,000 ohms
R15,R16,R17,R18—1000 ohms
R19,R20—220,000 ohms
R21,R22—22,000 ohms
R23,R24—470-ohms, ½-watt, 10% tolerance
Misc.—Suitable enclosure, printed circuit or perforated board, bipolar 12-volt power supply, IC sockets or Molex Soldercons, LED mounting collars, machine hardware, hookup wire, solder, etc.

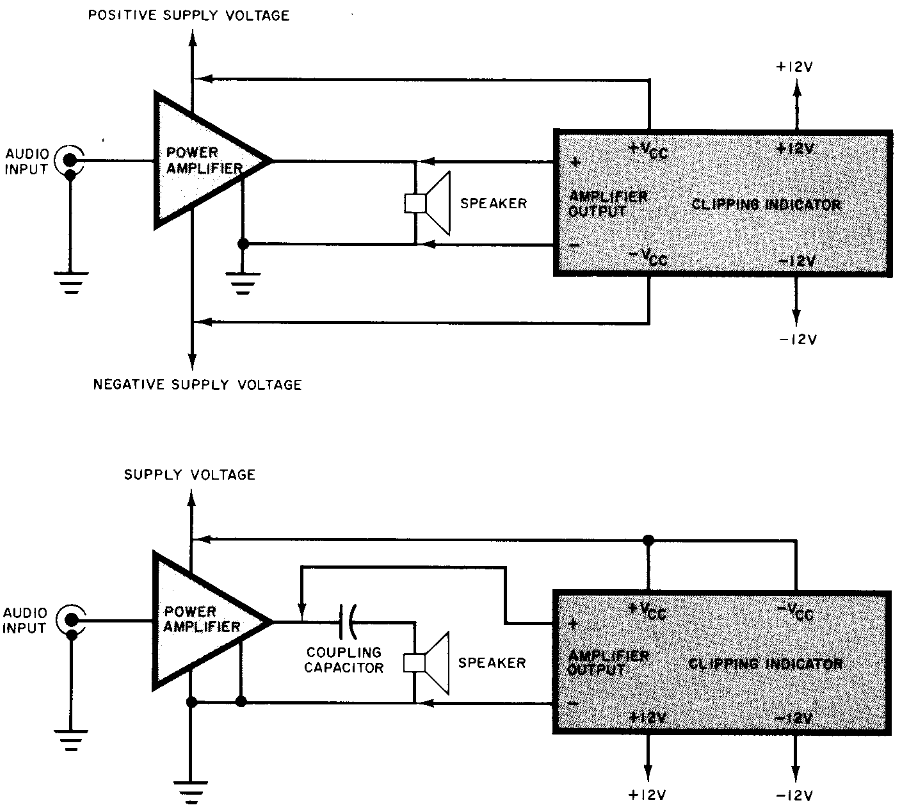


Fig. 3. Diagram showing details of interconnection for amplifiers with bipolar (A) and single-ended (B) power supplies

with machine hardware and the indicator LED(s) on the front panel with rubber grommets or mounting collars made especially for this purpose. As mentioned earlier, operating power for the project can be obtained from a small supply included inside the enclosure or tapped from the amplifier itself if a bipolar dc supply is employed. If the latter approach is taken, the required zener diodes and series resistors will easily fit inside the project enclosure.

Another possible approach, if there is room in the amplifier chassis, is to mount the entire project inside the amplifier and locate the indicator LEDs on the front panel. If this is done, *BTS1* can be eliminated and the connections to the speaker outputs and $+V_{CC}$ and $-V_{CC}$ hard-wired.

Note that the circuit as shown will function properly with audio amplifiers having supply voltages of up to ±60 volts (or +80 or −80 volts in the case of an amplifier with a single-ended supply). That bipolar voltage corresponds to a clipping power of 225 watts into 8 ohms. The project is therefore useable with the vast majority of audio amplifiers commercially available. If you have an amplifier employing greater supply voltages, the circuit can be suitably modified simply by increasing the attenuation factors of the input voltage dividers (increasing the values of *R1*, *R5*, and *R9*).

Interconnection and Adjustment. If your audio amplifier employs a bipolar dc power supply (most do), connect the $+V_{CC}$ and $-V_{CC}$ terminals of *BTS1* to the power supply outputs inside the amplifier. (Note that making these connections will, in most cases void the warranty on your amplifier.) Also, connect the AMPLIFIER OUTPUT terminals of *BTS1* to the amplifier's speaker output terminals in agreement with the polarities indicated in Fig. 2. These connections can be made with standard "zip-cord" or speaker wire. Refer to Fig. 3A for details.

Slightly different connections should be made if your audio amplifier employs a single-ended power supply and a coupling capacitor or transformer between the final amplifying devices and the speaker output terminals. The required connections are as follows: connect the $+V_{CC}$ *and* $-V_{CC}$ terminals of *BTS1* to the "hot" side of the power supply output; and connect the "hot" AMPLIFIER OUTPUT terminal of *BTS1* to the "hot" side of the amplifier output *before* the output coupling (dc blocking) capacitor or transformer. Refer to Fig. 3B.

The circuit's trimmer potentiometers can now be adjusted. Referring to Fig. 2, note the points near *R7* and *R11* designated *A*, *B*, and *C*. If your audio amplifier has a bipolar power supply, adjust the wiper of *R7* so that it is at position *A* and the wiper of *R11* so that it is at position *B*. If your amplifier's power supply is single-ended, adjust the wiper of *R7* so that it is at position *A* and the wiper of *R11* so that it is at position *C*.

Two pieces of test equipment are needed to adjust the trimmer potentiometers properly. The first is a sine-wave generator whose output is of sufficient amplitude to drive the audio amplifier into clipping. (One volt peak-to-peak of drive signal is usually more than adequate.) The second item can be either an oscilloscope or a multimeter, but the former is preferred. We will first describe the procedure to be followed if an oscilloscope is available and then that to be employed if one is not.

Connect a patch cord between the output of the signal generator and the input of the audio amplifier. Then connect the probe running from the oscilloscope's vertical amplifier input to the audio output of the power amplifier. Apply power to the project, signal generator and audio amplifier. Then adjust the amplitude of the generator's output, the gain of the audio amplifier, and the various oscilloscope controls for a stable, sinusoidal trace. The output of the audio amplifier should not be connected to a speaker.

Increase either the gain of the amplifier or the amplitude of the generator output until the oscilloscope trace just begins to reveal clipping of the waveform. Then decrease either the amplifier gain or signal output so that the amplitude of the waveform decreases a few volts below each clipping limit. (This provides a small safety margin so that the indicator LED will start to flash just before clipping actually begins.)

Without disturbing the amplifier, generator, or oscilloscope control settings, adjust trimmer *R7* until the LED starts to flash on positive signal peaks. Make a pencil mark on the circuit board denoting the correct position of the wiper and then return the control to its original setting. Next, adjust *R11* so that the indicator LED starts to flash on negative signal peaks. Once the correct setting of *R11* has been found, don't disturb it. Return to *R7* and adjust its wiper so that it corresponds to the position marked on the circuit board. Decrease the amplitude of the generator output or the gain of the amplifier, noting that the indicator LED will be extinguished. If you have built more than one Amplifier Clipping Indicator, say, for use with a stereo or four-channel audio amplifier, repeat the procedure just described for each.

Those who do not have acess to an oscilloscope can use a VTVM, VOM, or similar multimeter to adjust the project. First, the power supply limitations of the amplifier with which the project will be used must be determined. Connect the signal generator to the amplifier as described above and adjust the generator for a 60-Hz output. Connect the amplifier's speaker output to an 8-ohm load (a resistor is best) and apply a moderate amount of drive to the amplifier input. With the power supply loaded, measure its output voltage(s). Increase the gain of the amplifier or the amplitude of the drive signal and note whether the power supply voltages decrease. If they do, measure the *minimum* values.

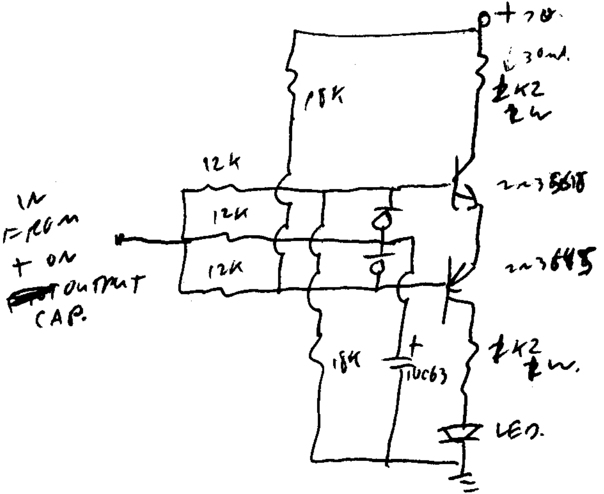
Having performed these measurements, determine the peak-to-peak voltage swing that the output can generate. For example, if the minimum voltages that a bipolar power supply generates under maximum drive conditions are +30 and −30 volts, the continuous peak-to-peak signal that the amplifier can pass at the onset of clipping is 60 volts p-p. Next, calculate the rms output voltage using the equation $V_{rms} = V_{p\text{-}p}/2.828$. For our example, the rms output voltage is 21.2 volts.

Connect the multimeter probes across the 8-ohm load and adjust the amplifier's gain or the amplitude of the input signal so that the calculated rms voltage is indicated by the meter. Then decrease the gain or the drive signal so that the meter reading is a few volts below the calculated value. (This provides the safety margin previously discussed.) Now adjust the trimmer potentiometers in the same manner described in the procedure employing the oscilloscope. Repeat the procedure for the circuit associated with each additional channel of amplification (if any).

Use. The Amplifier Clipping Indicator is now ready for use. With it, you'll be able to adjust drive level and/or amplifier gain so that your amplifier will never go into heavy clipping. Keep in mind that the indicator LED will begin to flash slightly before the the onset of clipping. If the LED starts to blink, back off on the drive level or gain control. Your high-frequency drivers will be glad you did! ◇

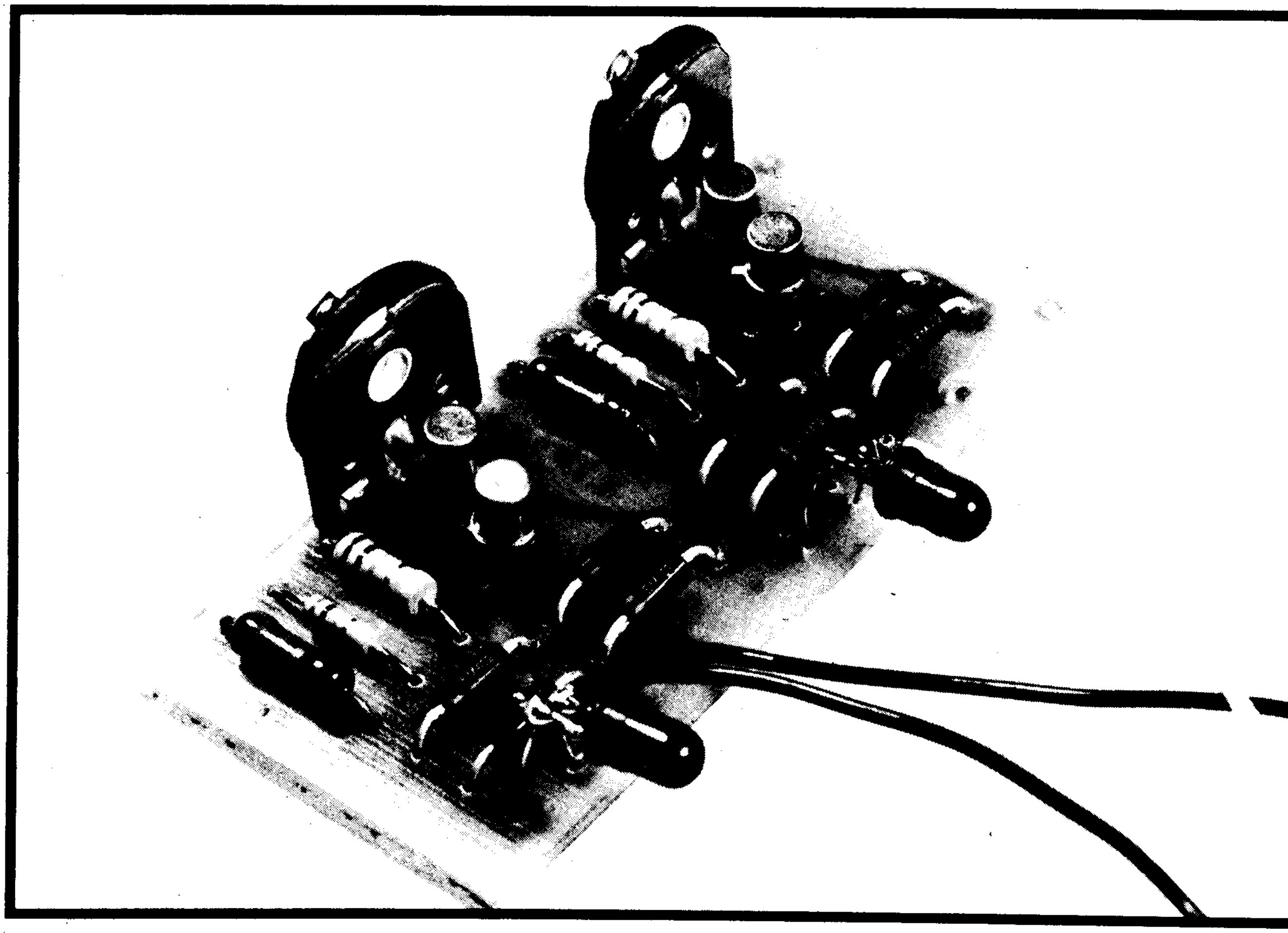
$R = \frac{70}{.03} = 70+33 = 2K2$

FOR SINGLE SUPPLY AMPS



CLIP INDICATORS.

Automatically calibrates to amp output.



eti project

THE OVER-LED

Is your power amplifier clipping? This simple monitor lets you know.

MANY people are aware of distortion when they turn up the volume control on their hi-fi equipment – but are usually unaware of the cause.

Nine times out of ten this distortion is caused by 'clipping'. That is, the amplifier does not have enough reserve power to handle the peak music transients at the required volume.

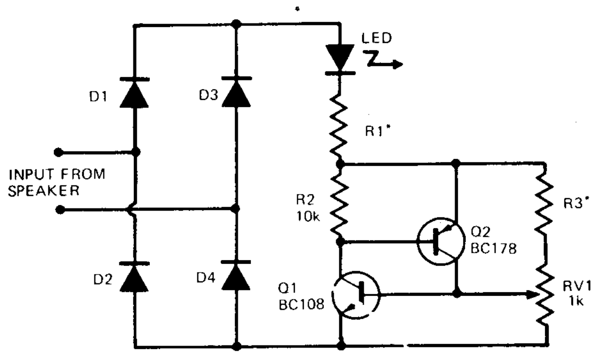
During such peaks, the amplifier is driven into an overload condition and as a result the music peaks are 'clipped'. This results in harsh sounding reproduction.

This simple device, which may be built into your existing amplifier, or separately located, flashes a warning light if the power level at which clipping occurs is exceeded.

Two completely independent circuits are provided so that each channel of a stereo system may be monitored separately.

TABLE 1

	SPEAKER IMPEDANCE					
RMS watts per channel	4Ω R1	4Ω R3	8Ω R1	8Ω R3	16Ω R1	16Ω R3
5	68	5.6k	82	8.2k	120	12k
10	82	8.2k	120	10k	180	18k
15	100	10k	150	15k	220	22k
20	120	12k	180	18k	240	24k
25	150	15k	220	22k	270	27k
35	180	18k	240	24k	330	33k
50	220	22k	270	27k	390	39k
75	240	24k	330	33k	470	47k
100	270	27k	390	39k	560	56k



*SEE TABLE 1 FOR VALUES

ONE CHANNEL ONLY SHOWN

Fig. 1. Circuit diagram of overload detector. One channel only shown.

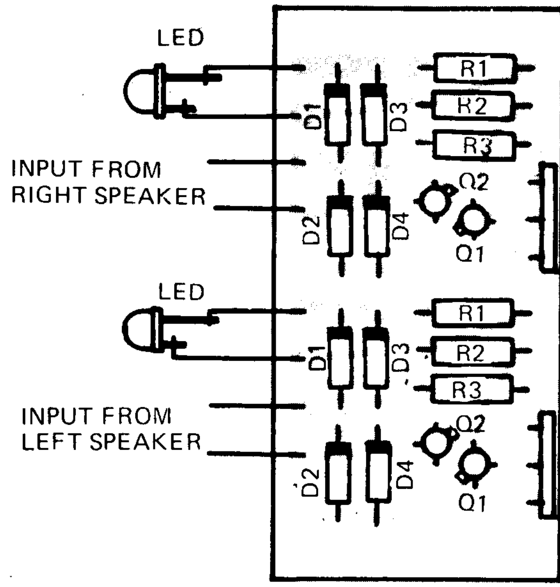


Fig. 2. Component overlay.

HOW IT WORKS

The output of each power-amplifier channel is monitored at the speaker terminals. The output is bridge rectified by D1-D4 so that both positive and negative transients may be detected.

Transistors Q1 and Q2 (together) are equivalent to a sensitive gate SCR (silicon controlled rectifier). If the voltage at the base of Q2 is more than about 0.6 volts above its emitter, Q1 and Q2 will each turn hard on and latch on, until the current through them drops to zero.

When transistors, Q1 and Q2 are on, the current flowing through them also flows through the LED causing it to illuminate. Resistor R1 limits the peak current through the LED to about 100 mA. The range of calibration potentiometer RV1 is set by resistor R3. The values of R1 and R3 are provided in Table 1 for various amplifier power ratings and speaker impedances. These values are not critical. If your amplifier has a power rating other than that specified, the nearest values will do.

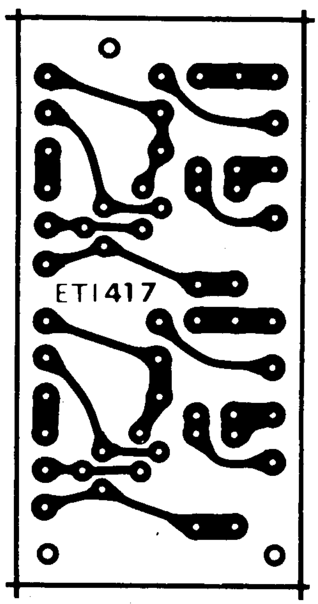
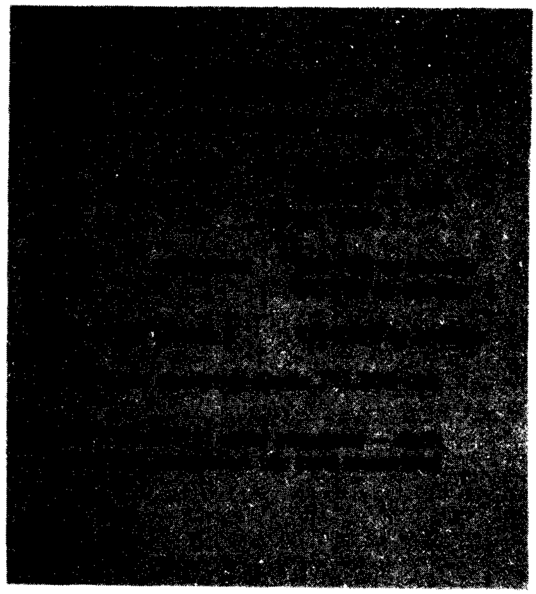


Fig. 3. Printed circuit board (full size).



CONSTRUCTION

Mount all components on to the printed circuit board in accordance with the component overlay. Make sure that all diodes are correctly orientated, in particular the LED's. The LED's will not be damaged by reverse polarity but will not operate in that mode.

Whether the unit is mounted inside the amplifier or external to it in a small box will be a matter for the individual constructor. The printed circuit board may be mounted in any suitable position within the amplifier and leads extended to front-panel mounted LEDs if required.

Polarity of the leads to the amplifier output terminals is immaterial but make sure that the leads of separate channels are not mixed. This is best avoided by twisting each pair of leads to each channel.

CALIBRATION

There are several ways of calibrating the unit.

By far the best way is to connect an audio oscillator to the input of the amplifier (both channels driven at the same time), then, with the amplifier volume control at a low setting, adjust the oscillator to provide a 1 kHz sine-wave.

Set both trim potentiometers (RV1) so that their wipers are nearest R3.

Now increase the amplifier volume until clipping occurs. This is very easily identified as a sudden harshness of tone. Do not leave the volume control at this setting for more than a second or two, as apart from the pounding you are giving to your ears, some amplifiers will not tolerate a sine-wave input at clipping level for extended periods without damage.

Once the clipping point has been established, turn the volume down again, and then quickly turn up to the clipping point momentarily, meanwhile adjusting the trimming potentiometers RV1 until a point is reached where the light emitting diodes just come on.

Repeat the procedure a few times — finally arriving at a setting at which the LED's come on just before the clipping point.

If you do not have access to an oscillator, the device can be set by playing a test record that contains a sine-wave tone — or failing this — by playing a record of a solo instrument such as a flute. A recording of the human voice is also very effective. In such cases the same calibration procedure described above should be followed. ●