

HUM

MAINS hum in the output from an amplifier can be very objectionable, and is sometimes difficult to track down or eliminate. One thing that often helps is recognition of the "type" of hum. The reader may have noticed that there are different qualities of hum, as well as a difference in loudness, although they are all basically "50 cycle."

Heaters

A true 50 cycle hum, which is a very deep note by itself, is seldom loud enough to be objectionable. The most common source is valve heaters. If the hum is due to unbalanced earthing of the heaters (if the heaters are not earthed at all they cause a hum that is higher pitched or "ticky") then a humdinger across the heater supply, with the slider to earth, will provide means of adjusting out the residual 50 cycle hum. If the hum is due to magnetic induction inside the earlier stages of a high gain amplifier, demagnetising the valves in a large demagnetiser, such as watchmakers use for demagnetising watches, may remove the hum. But this process may have to be repeated whenever the valves are changed, so the most satisfactory solution where an amplifier has enough gain to cause this particular trouble is to run the first stage heaters from a rectified and smoothed d.c. supply.

H.T. Smoothing

A hum that is often mistaken for 50 cycles is really chiefly 100 cycles, and is often caused by insufficient smoothing on the h.t. supply, particularly to the early stages. If this is the cause, provision of extra decoupling for the early stages is the simplest remedy; but before making drastic alterations to include this, it should be "lashed on" to see whether it proves a remedy.

Insufficient smoothing on the h.t. supply can cause another trouble, not recognisable as hum. This occurs where practically unsmoothed h.t. is used to supply the anodes of push-pull valves. Due to the push-pull action, no hum is heard, because the two hum voltages cancel. (Adequate smoothing may prevent hum being caused in earlier stages.) But because of the large hum voltage on both anodes of the output valves, the gain of the valves is modulated at hum frequency, usually 100 cycles. The result on music or speech is that the reproduction sounds "chopped" or "dithery." This will probably be

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most noticeable at low levels, but it will certainly not be more noticeable at high levels, as is the effect of intermodulation or parasitic oscillation, which otherwise sounds somewhat similar.

Hum Pick-up

The foregoing forms of hum are caused by fairly obvious means. Now follow those forms that are more difficult to track down, due to various forms of pick-up.

(1) MAGNETIC

Where an input transformer is used, or an inter-valve transformer between the earlier stages, this component can pick up a magnetic hum field from either the mains transformer or the main smoothing choke. Such hum gives a deep note, almost pure 50 or 100 cycle.

To track it down, it is best to earth the core (and case, if metal) of the suspected transformer, removing it from the chassis, keeping the connections intact. Then rotate it gently in different directions as far as the leads will allow. If the hum is caused by magnetic induction in the transformer core, this movement will vary the hum level. If the magnetic field causing the induction is strong, it will be difficult to find a position where the hum can be eliminated, and probably even more difficult to contrive a fixing for the transformer in the required position!

Input and intervalve transformers for high gain applications are usually mounted in Mumetal cases to provide screening against magnetic hum pick-up. This does not completely prevent pick-up, so it may still be necessary to pay attention to the mounting position.

Layout is a great help. The input stage should be kept as far as possible from the supply end of the chassis, where the mains transformer and smoothing choke are—if they are on the same chassis. Aluminium chassis are better than steel ones for this purpose. Another useful aid in an equipment where the voltage amplifier is on a separate chassis from the output section, is to use mains transformer and chokes that work at low a.c. flux density. Some manufacturers specialise in components for this purpose. It is not practical to work supply components for power stages at low flux density, so if the whole amplifier is on the same chassis, the alternative is to mount the supply components—mains transformer, chokes and capacitors—on a separate chassis, which can be kept at a satisfactory distance from the input end of the main chassis.

(2) INDUCTIVE

Other forms of hum pick-up occur in the wiring of the amplifier. There are two types of pick-up that can cause trouble, and the hum picked up differs in character so that with a little experience it is not difficult to recognise the type, and hence go more directly to the cause. One type is called electromagnetic, or inductive, pick-up, and produces a deep hum similar in character to the others dealt with so far. It is caused by the wiring forming a loop somewhere through which a

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hum field can induce a voltage in the circuit, which gets amplified along with the signal voltages. This type of pick-up is particularly likely in low impedance circuits, such as the primary of a step-up input transformer; but it can also occur in high impedance circuits, especially where there is high gain.

To avoid this hum, the leads from the primary of the input transformer should be twisted all the way from the transformer winding to the input lead itself. Other leads that can cause trouble of this kind are the anode decoupling and screen decoupling circuits. Leads from capacitors used for this purpose in early stages of a high gain amplifier should be twisted together, and the earth return made as close to the "hot" terminating point as possible. Poor earth return arrangement can also cause hum for a different reason dealt with later.

(3) CAPACITIVE

The other type of pick-up is called electrostatic or capacitive, and produces a "ticky" hum as a rule. It is due to stray capacitance coupling from places where there are a.c. hum voltages to signal wiring, usually at high impedance, but not necessarily.

Complete screening of the amplifier prevents this kind of pick-up inside the amplifier, as well as ensuring stability. But this kind of

hum can still get picked up. If the amplifier is not earthed, a ticky hum may appear; a connection to a good earth will cure it.

If an input lead is not screened, or the screening not connected to amplifier chassis, capacitance transfer may take place through the input transformer, even though the input is low impedance. If screened lead is not available, earthing one side of the low impedance input is a good second best.

As with magnetic, so also with electric, it is possible to reduce the effect by cutting down the field at its source. Reduction of the magnetic field is achieved by working at lower flux density in mains transformer and chokes. One source of static field is the sharp current pulses that charge the reservoir capacitor, producing peaks of voltage round the supply circuit, and even back through the mains. A suitable resistor connected in series with the reservoir capacitor (see Figure 24) will reduce this effect, and at the same time lengthen the rectifier's life.

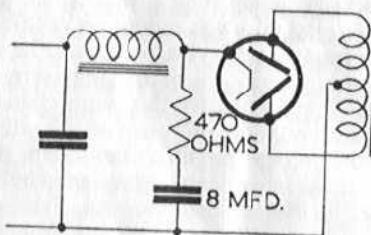


FIG. 24. A RESISTOR IN SERIES WITH THE RESERVOIR CAPACITOR, REDUCES RADIATION OF "TICKY" HUM.
Values shown are to give a rough guide only.

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(4) EARTHING

Another form of pick-up is caused by incorrect earthing. This form can be very puzzling until understood. Often an amplifier that performs quite satisfactorily on test develops a severe hum when installed. Returned to test, the hum has disappeared. The commonest cause of this trouble is the method of earthing.

There must be only one earth path. All earth connections should be kept separate from the chassis, to which connection is made at just one point, preferably at the input. Connection to an installation earth should be made at this point *only*. There may also be an earth connection through three-core mains lead. If so, one or other earth connection must be removed, leaving only one good earth.

In all mains installations there are capacitance currents to earth, and these currents cause small voltages in the earth connections themselves. If the amplifying equipment is connected to two different "earth" points in the building from two different places in its own earth wiring, then the small difference in voltage at hum frequency between the different installation earths will send a small current through the amplifier earth line. This current will cause voltages along the earth line that will be injected into earlier stages of the amplifier.

The usual effect in a good equipment is: no earth—slight "ticky" hum; one earth—O.K.; two earths—deep hum. If there are earth leakages in the amplifier itself—say from one side of the mains—then anything may happen in the way of hum. It will often be found that reversing the mains plug connections will give less hum one way round than the other. This is particularly the case with a.c./d.c. amplifiers.

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SCREENING

HERE are three basic kinds of screen, and the requirements for each to be effective differ considerably. It is helpful to understand how each kind does its job, so that screens may be constructed or used intelligently to get the best results.

Magnetic

A magnetic screen is made of magnetic material, such as steel or Mumetal, and its purpose is to "capture" the magnetic field and lead it round the object to be screened, usually a transformer, without affecting it magnetically. Magnetic screens for input and interstage transformers are usually made of Mumetal. An important feature for their satisfactory working is that any lids or joints in the screen should be a good close fit, so as to provide good magnetic "contact." Figure 25 shows (a) the way a magnetic field is led round the screened space by

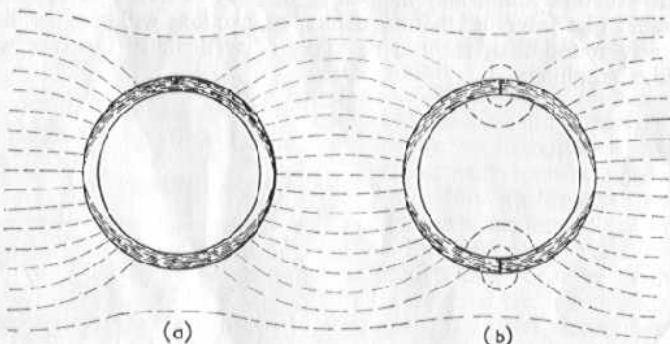


FIG. 25. EFFECT OF MAGNETIC SCREEN ON INTERFERING FIELD.

the magnetic screen ; and (b) how a poor joint allows some of the field to appear inside.

Mumetal has to be heat treated after drilling, filing, or any other work on it, so unless the reader has facilities for getting this treatment done (*Telcon Metals*, the manufacturers of Mumetal, have their own

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process), he should see that any Mumetal case he uses has all the necessary holes, etc., already, so he need not work on it further.

Mumetal is not successful as a screen against very strong fields, because it saturates at a fairly low flux density. For this reason it is sometimes an advantage for the mains transformer, and perhaps the smoothing choke as well, to be mounted in steel cases. Some types are finished in steel cases as routine. The steel case round the mains transformer or choke ensures that the field outside the case is small enough for the Mumetal case round the input transformer to deal with satisfactorily.

Electromagnetic

Electromagnetic screening keeps a magnetic field out by the famous principle of "electromagnetic induction." The variations in the magnetic field cause currents to flow in the low resistance material of which the screen is made, and these currents create a magnetic field in opposition to the original, so that there are no magnetic field fluctuations penetrating the screen. Figure 26 shows (a) the relation between the component fields and current at one instant during an

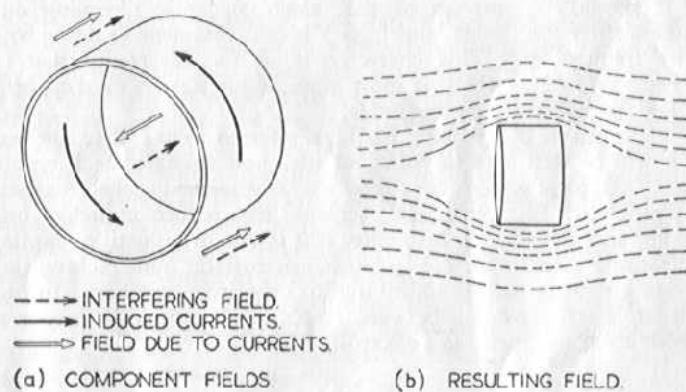


FIG. 26. EFFECT OF ELECTROMAGNETIC SCREEN ON INTERFERING FIELD.

alternating cycle ; and (b) the resulting field, due to combination of the components as shown at (a).

So electromagnetic screens are made of copper or aluminium. With these it is important that any lids or joints should make good electrical contact. There must be no gaps of any kind in the screen. Sheet tinned iron will *not* do for an electromagnetic screen, because an electromagnetic screen must not be of magnetic material.

Electrostatic

Electrostatic screening keeps electric fields out (or in). It is essential for an electrostatic screen to be well earthed. This is not essential for the other two types for their own purpose; but by seeing that they are earthed, the one screen may serve a double purpose. For an electrostatic screen it is not essential that lids or joints should make good contact all round, and the screen need not be continuous, it can have holes in it (e.g., for ventilation), without destroying its electrostatic screening properties. (Some valve screens are an example of this.) Sheet tinned iron (such as a cocoa tin) will serve for electrostatic screening provided there is no electromagnetic effect to be dealt with as well.

Applications

The reader should never look upon any screen as being perfect. Whatever type is used, it only reduces the effect by a certain amount. If the correct type of screen is used, the amount is usually adequate, and so effective that it appears to remove the trouble completely. But if the field requiring screening is too strong, any screen becomes inadequate, and further steps must be taken.

It should be emphasised that electromagnetic screening only excludes *alternating* fields, and in fact is more efficient in doing so at higher frequencies. This characteristic is the reverse of that for magnetic screening, which is most efficient for steady, or d.c., fields and low frequency alternating fields.

The purpose of screening has been referred to in earlier chapters, but it will be well here to point out the applications of each type of screen. Magnetic screens are almost exclusively used against magnetic hum pick-up. Electromagnetic screens help reduce inductive hum pick-up, and also remedy instability if it is due to inductive coupling. Electrostatic screens are used against electrostatic hum pick-up, and provide a remedy for instability due to capacitive coupling. In high gain amplifiers, screening between stages to prevent instability must be both electromagnetic and electrostatic.

NOISE

Two kinds of noise will be dealt with in this chapter: that known as valve hiss, and various other noises in the form of crackles and bangs.

Valve Hiss

Valve hiss is quite a normal form of noise, and cannot be eliminated altogether from high gain amplifiers. However, there are ways of keeping it to a minimum. In the first place, whatever noise the first stage develops will always be present if the volume control is in the grid circuit of the first stage, because the amplifier itself is always working "flat-out." By having the volume control *after* the first or second valve, the noise due to the early stages will be turned down when volume is turned down.

It should be mentioned that the volume control should not be put too late in the amplifier either, for another reason. Suppose different types of microphone are to be used, or the same one used alternatively for long range pick-up or close speaking, then widely different settings of the volume control will be needed. If the amplifier has enough gain to cope with the weakest microphone, or long range pick-up, then it will have plenty in reserve for the stronger microphone or close talking. If the volume control is, say, just before the output stage, as it is turned well down for the latter job, so the previous stage will be overloading and distorting, before the output from the volume control is high enough to give full output.

Valve hiss is proportional to anode current for a given type of valve. At low levels, in the early stages, little gain will be lost by working the valve at lower anode voltage and current; but it will cause considerably less noise. The anode voltage can be dropped by providing extra stages of decoupling which will also be advantageous in reducing hum in the h.t. supply.

Crackles and Bangs

These are another sort of noise, and are not normal. They can be due to defective valves, but are far more often due to faulty joints in the wiring—dry joints. These are caused by poor soldering, and the remedy is to use greater care in cleaning the lead and contact point to be soldered, and in the use of soldering flux and the iron. A good resin cored solder, with no separate flux, is recommended, *after* care has been taken to see that the parts to be joined are cleaned. Both

parts should be tinned before being brought together. After this the two parts should be brought together, a good mechanical joint made (by bending over, or inserting through a hole or slot, if provided), and the iron together with enough solder applied to the joint for just long enough for the solder to flow all round the joint. Do not use too much solder to make a large "blob," or too little, so that the joint is not adequately filled with solder.

Other contacts beside soldered ones can be the cause of crackles and bangs, and often are. The sliding contacts of volume controls and switch contacts are frequent offenders. Cleaning the contacts will at least provide a temporary remedy. Dust from the resistance track may collect on a volume control slider. Removing the cover, blowing away the dust, and replacing the cover, often gives a new lease of life to an old control. Noise can also be due to a break or breaks in the track itself, for which the only cure is a new control. Switch contacts can be cleaned from time to time, but a good switch should not require much attention, especially if it is enclosed so that dust cannot reach the contacts. In a well-designed switch, the contacts are self-cleaning in operation, and good contact pressure ensures good contact.

INTERMODULATION

INTERMODULATION means that low frequencies in the signal modulate high frequencies in the same signal, in the same way as a broadcast carrier frequency is modulated by the audio frequencies in the programme. The result is that the intensity of the high frequencies goes up and down during each cycle of the low frequency causing the modulation. The effect is that reproduction goes "dithery" or "chopped up" when a loud low frequency signal appears.

Intermodulation, in sufficient degree to cause aurally noticeable effect, seldom occurs in amplifiers, provided they are free from other forms of distortion; but it quite frequently occurs noticeably in pick-ups, loudspeakers, and occasionally in microphones.

Most pick-ups are of the magnetic type, using an armature that moves between two pole pieces. The output from the pick-up depends upon the changing magnetic field due to this movement. To gain sensitivity, the pick-up is designed so that small movement caused by the needle in the groove of the record produces as much change in magnetic field as possible. But the bigger the change, the more curved does the characteristic become, and so relative movements due to low frequencies modulate the intensity of the electrical output at high frequencies being reproduced at the same time. It is a general principle for magnetic type (or variable reluctance, as they are technically called) pick-ups, that improved freedom from distortion requires lower sensitivity, or lower output. Another cause of intermodulation is non-linear behaviour of the control used for centring the armature. This is usually made of rubber or some substitute, which may perish with age, causing distortion not present when the pick-up was new. Because of non-linear behaviour of the crystal, many piezo crystal pick-ups cause intermodulation at high levels. The modern moving coil or ribbon pick-ups eliminate intermodulation, but have the disadvantage of extremely low output, or sensitivity. The light-weight pick-ups reduce intermodulation to a very low order, and have a reasonable output, although much less than that of the older types.

Loudspeakers can cause intermodulation for two reasons: (1) Uneven magnetic field in the air gap, over the distance through which the coil moves; and (2) uneven control force from the centring spider. Distortion due to (1) is not easy to check. Distortion due to (2) can be detected by careful feeling of the action of the diaphragm. As the cone is moved back and forth with the fingers, the pressure

against the fingers, pushing it from its central position, should steadily increase in both directions. Sometimes the spider develops an "oil-can" action, so that it avoids the centre position, travelling past it quickly; sometimes it is not as bad as that, but there is central zone of movement practically without any opposition due to the spider, and beyond this movement the spider suddenly begins to show greater opposition to further movement. Either of these cases produce considerable modulation distortion. Careful refitting of the spider can often improve such a speaker.

Intermodulation distortion is not easy to track down without special equipment, since it can originate almost anywhere in the chain. Any measurement to detect it relies on the use of equipment known to be free of it. The method used to check loudspeakers for intermodulation distortion consists of feeding in two fairly high frequencies at the same time from an amplifier known to be free of distortion, coupled to two pure tone audio signal generators. Distortion in the speaker shows up by an extra note of lower frequency, equal to the difference of the other two, although this frequency is not applied to the speech coil. Having checked that the distortion is due to the loudspeaker, it remains to see how it is caused; but since the reader may not possess either the facility to check for distortion in this way, or the means of altering the loudspeaker, no more will be said here.

MATCHING

HERE are two places in an amplifier where matching is important—the input and the output. The general idea of output matching is well known, but often only partly understood. The requirement of input matching is often not realised at all.

The formula for turns ratio in matching is well known,

$$\frac{Z_1^2}{Z_2^2} = \frac{T_1}{T_2} \text{ or } \frac{Z_1}{Z_2} = \sqrt{\frac{T_1}{T_2}}$$

The abac shown in Figure 27 on pages 32/33 is provided to facilitate this calculation. As an example of its use, to match 15 Ohms to 6,000 Ohms requires a ratio of 20/1.

Measuring Transformer Ratio

It is easy to find which windings of a transformer are the high and low number of turns respectively, by measuring their resistances with an ohm-meter. But the ratio of winding resistances does not necessarily give any indication of turns ratio, so if the ratio of a transformer is not known, another method must be used. The simplest is a check with input from the mains. A voltage should be connected to the high turns side, taking care that the voltage is not too high for the purpose of the transformer. Then the voltage is measured on both sides, and the ratio calculated directly from the voltages.

Input Matching

At the input end of the amplifier, the microphone or pick-up should have a transformer of the correct ratio to get best results. Use of too high a step-up ratio will result in loss of quality, although there may be greater gain; while use of too low a ratio will merely lose gain—there will be no deterioration in quality. However, too much loss of gain may mean that an amplifier, that otherwise would have sufficient gain, has not. This will appear from the examples that follow. The abac of Figure 27 may be used to find a good ratio for any specified microphone or pick-up impedance. If the impedance is matched to less than 50,000 Ohms, useful gain will be lost; but quality becomes poor if an attempt is made to match to over 200,000 Ohms. The best plan is to find a standard ratio that matches somewhere between these figures.

For example, a certain moving coil microphone has an impedance of 50 Ohms. A ratio of 40/1 will match it to 80,000 Ohms, or one of 50/1 to 125,000 Ohms, either of which would be reasonably suitable,