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RECENT DEVELOPMENTS IN INDUCTION LOOP TECHNOLOGY

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WHAT IS AN INDUCTION LOOP?

An alternating current flowing through a wire (usually in the form of a loop) will produce a corresponding alternating magnetic field. If this field intersects another loop of wire an alternating current can be induced in this second loop, varying in sympathy with the first current. In this way information in the form of speech or music may be transferred without direct electrical connection, the basis of transformer theory. In fact, an induction loop system can be regarded as a very 'leaky' form of transformer.

Theoretically the alternating current could be one of a wide range of frequencies but induction loop systems are generally divided into two categories, those at audio frequencies (up to 20kHz) and those using a modulated carrier at higher frequencies. The two categories reflect both regulatory and technical considerations. Generally the high frequency systems are described as 'RF' loops and provide multi-channel facilities for specialised applications where cost is of relatively minor importance. The audio-frequency loops have one great advantage over the RF types, their signals can be picked up by standard prescription hearing-aids.

This paper concentrates on AF loop installations, which essentially consist of a specialised amplifier driving a multi-turn loop of wire with audio signals from the low-impedance output of the amplifier (typical loop resistances being 2-12 Ohms). Alternating magnetic signals generated by the loop can be received by hearing aids or other loop receivers (induction loop headset, pocket receiver, etc) that contain a pick-up coil. The chief advantages for the hearing impaired are improved clarity due to the absence of room resonances, no audible distractions from audience noise and no equipment required except the wearers own aid.

Induction loops have been installed for many years using conventional amplifiers, a few giving acceptable results, the majority being unsuitable because of insufficient field strength or causing interference with other communications systems due to excess field strength. A standard for loop parameters was required and, after many years campaigning by interested organisations (notably the Royal National Institute for the Deaf), the British Standards Institution produced BS 6083: part 4: 1981. This standard defines the frequency response of the system (100Hz - 5kHz +/- 3dB ref. 1kHz), the average field strength (0.1 A/m in the area covered by the loop) and the peak field strength (+12dB above the average level).

At present, a licence costing twelve pounds, fifty pence lasting for 5 years must be obtained from the Department of Trade and Industry for every induction loop installation.

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WHERE IS IT USED?

Induction loop systems are in use in many churches, handicapped schools and hospitals. Organisations for the deaf have been promoting better facilities for hearing-aid users in all public places and so recent years have seen an increasing number of systems being installed in theatres, cinemas, meeting halls, shopping malls, banks and booking offices.

WHAT MAKES AN INDUCTION LOOP DIFFERENT FROM CONVENTIONAL AUDIO AMPLIFIERS?

Common problems with loop systems driven by conventional audio amplifiers include high noise and hum levels, poor field strength, distortion due to clipping of the amplifier on signal peaks and faithful reproduction of large changes in input signal level.

To limit interference from unwanted sounds BS 6083: part 4: 1981 specifies a frequency response with -3dB points of 100Hz and 5kHz, with reference to 1kHz, removing 50Hz supply hum and other low-frequency interference together with high-frequency noise and distortion products. Bandpass filtering is usually applied early in the signal path to prevent out-of-band signals from causing spurious reactions in the following level-sensitive circuits (see Fig 1).

Large changes in input level are most uncomfortable for a hearing-aid user if the amplifier system does not provide automatic gain control. To maintain a relatively constant output level the signal is sampled and rectified to charge a long time-constant (30 seconds) resistor/capacitor network, the voltage across which controls the gain of a voltage controlled amplifier (VCA). In this way a change of microphone user from a strong talker to a quiet talker or a change of music sources from a lightly modulated to a heavily modulated tape programme will not cause wild changes in field strength.

The maximum current, and therefore power, drive required from the amplifier is dependent on the peak signal level to be handled. If a peak signal of +12dB above the average signal level (the maximum defined in BS 6083) is expected then the amplifier must produce four times the average current and sixteen times the power. With a large installation demanding 65 watts for average signals, the maximum power required might exceed 1kW if clipping of signal peaks is to be avoided. A limit of +6dB is provided in most induction loop amplifiers as a good compromise between audio fidelity and maximum amplifier capability thus limiting the maximum current to twice the average. The cost of the amplifier therefore is also kept to a reasonable level.

Limiting the maximum level is achieved by rectification of the signal and the use of a short time-constant (1 second) to respond to short-term signal peaks (fig 1). The voltage derived in this way controls the VCA in a similar manner to the automatic gain control circuit.

Unlike a conventional public-address system the induction loop system has no loudspeakers and so a failure due to loop disconnection (for example) may go undetected for some time unless hearing-aid users complain. It is essential that the loop amplifier designer includes a visual indication of signal input and of loop drive which will enable the system engineer to verify correct system operation or to identify the signal source, amplifier or loop as the cause of a failure.

PLANNING AN INDUCTION LOOP SYSTEM

The first step in planning an induction loop installation is to use a loop receiver to check if the proposed area of coverage is suitable, as many otherwise good installations have been marred by an excessive background level of magnetic interference from motors, dimmers, discharge lamps and ac supply wiring. A survey of the proposed route for the loop wire is necessary to establish the actual loop dimensions, its height above (or below) the listeners receiver and any extra wire required to go around doors and windows.

Using the dimensions noted during the survey an approximation of the loop shape should be made to one of the following shapes; a) a circle, b) a square, c) a 'short' rectangle (long side less than one-and-a-half times the short side) and d) a 'long' rectangle (long side more than one-and-a-half times the short side). From these idealised shapes the average current requirement can be found.

A circular loop (fig 2) produces a magnetic field measured in Amps/metre which is a ratio of the current in the loop to the diameter of the loop (formula 1). Rearranging the formula for a 0.1 A/m field strength in terms of the loop current gives formula 2.

However, circular loops are the exception rather than rule. Square loops (fig 3) are more common and the formula for their field strengths and current required for 0.1 A/m field strength are given in formulae 3 and 4 respectively.

Rectangular loops are divided into two groups for the purpose of establishing the required loop current, 'short' and 'long' loops, a short rectangle being defined as having long sides not more than one-and-a-half times the length of the shorter sides and a long rectangle having long sides of more than one-and-a-half times the shorter sides. A short rectangle (fig 4) is approximated to a square loop of the same area and its current requirement established by means of formulae 5 and 6 respectively.

Away from the ends of a long rectangular loop (fig 5) the two long sides are the major contributors to the field, the ends being too far away. The field strength can then be calculated as approximately half that due to a square loop of the same width (formula 7) which can be simplified in terms of current as shown in formula 8. The field strength will rise by up to 3dB near the ends of the loop but this increase will not cause a noticeable increase in signal level in most receivers.

Using more than one turn of wire in the loop can have a number of advantages. Each doubling of the number of turns doubles the field strength or, more usefully, halves the current requirement (quarter the power) for a given field strength. The formula previously referred to may be modified to take this into account by dividing the resulting current by the number of turns used. Installation costs need not increase significantly as multi-core calbing may be used, wiring the conductors in series to achieve a multi-turn loop. A single turn loop will probably have a very low resistance presenting a serious mis-match to the amplifier output impedance, whilst a multi-turn loop can be designed to present an appropriate load to the amplifier.

Single turn loops will generally have a low inductance and will therefore present a low inductive reactance to the amplifier compared to the dc resistance of the loop at the frequencies used. However, loops of 3 or more turns can have significant inductances at the top frequency of 5kHz and should therefore be avoided if the full permitted frequency range is required. Most loop amplifier designs include a high-frequency tone control to compensate for loss of signal due to loop inductance (fig 1).

The calculations have assumed that the receiver is in the same plane as the loop, but it can be advantageous to site the loop along a skirting-board, above a false ceiling or even under the floor. The greater the displacement of the loop from the receiver, the greater the loop current required to maintain the field strength at the receiver (fig 6), and is dependent on the ratio of the loop displacement to the length of the shortest side of the loop. A loop displacement can also help 'even-out' the rather uneven field found at the edge of a zero displacement loop due to a 90 degree field rotation at the wire as shown in figs 6 a), b) and c). The following table shows how much the calculated average current or power must be increased to compensate for loop displacement and demonstrates how displacement/width ratios of more than 0.5 demand unrealistically high powers from the amplifier in all except the smallest loop installations.

d/w	Multiply i by.....	Multiply P by......
0.1	1.1	1.21
0.2	1.2	1.44
0.3	1.5	2.25
0.4	1.85	3.43
0.5	2.5	6.25
0.6	3.2	10.24
0.7	4.15	17.22
0.8	5.35	28.62
0.9	6.8	46.24
1.0	8.5	72.25

So far, the calculations have been dealing with average signal levels but the amplifier will be expected toi produce peak signals 6dB higher (for example). So any average current requirement must be multiplied by two (power by four) to determine the minimum capacity of the amplifier.

The physical dimensions of the loop noted during the survey should now be used to find the total length of wire used. From this the total dc resistance can be obtained for different wire diameters and a suitable size found which closely matches the amplifier output impedance (usually around 4 Ohms). As already mentioned, the inductive reactance of the loop may be ignored in most cases.

From the loop resistance and peak current requirements the loop power dissipation can be calculated using Ohms Law (formula 9). Due to hidden structural ferrous metalwork some installations may absorb a small amount of power from the magnetic field and so amplifier capacity should be chosen to allow for an extra ten percent above the calculated power to be available.

It is important that the system is checked with the loop wire in approximately its final position before installation, as mistakes may be difficult to rectify if the loop wire has been embedded in plasterwork, for example. Paticular attention should be paid to weak spots in the field due to structural metals and interference from electrical and magnetic sources.

Once installed, the amplifier inputs should be adjusted to drive the automatic gain circuit fully and the amplifier drive adjusted to provide a field strength of 0.1 A/m over the main area of coverage as measured on a Field Strength Meter.

Lastly, it should be noted that the installation will be useless unless used. So signs informing potential users of the existance of the loop should be prominently displayed and, if the building is a public auditorium, a note made in the published programme.

WHAT'S MADE IN BRITAIN?

Very few British companies are currently producing induction loop amplifiers, but Millbank Electronics Group Limited, a leading British communications equipment manufacturer has introduced two models of a 100 Watt amplifier, a 'slave' unit for existing PA installations and a mixer/amplifier to provide complete loop facilities in new installations. They produce up to 5 Amps in loops of 2 to 12 Ohms resistance. It is designed to meet BS 6083: part 4: 1981 in all respects but also features electronic amplifier protection against loop short-circuits or other faulty loads. The design takes advantage of high-efficiency electronics to keep costs, power consumption and heat generation to a minimum.

FORMULA 1 : H = i/d Where H = Field strength (Amps/metre)
i = Average loop current (Amps)
d = Diameter of loop (metres)

FORMULA 2 : If H = 0.1 A/m, rearranging for i gives;
i = 0.10*d

FORMULA 3 : H = (2*sqrt (2) /pi)*(i/w)
Where w = length of one side (metres)
pi = 3.1415927

FORMULA 4 : Rearranging for i, (H = 01. A/m);
i = w/9 (approximately)

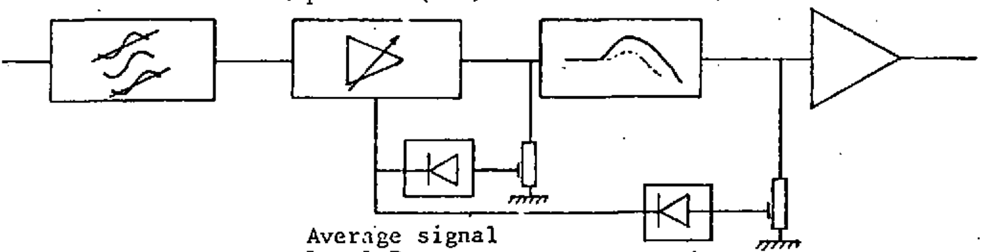
FORMULA 5 : Equivalent side length = sqrt (l*w)
Where l = length of longest side (metres)

FORMULA 6 : Rearranging for i, (H = 0.1 A/m);
i = (sqrt (l*w))/9

FORMULA 7 : H = (2*sqrt (2) /pi) * (i/w)/2
Where w = length of shorter side

FORMULA 8 : i = 2w/9

FORMULA 9 : P = I*I*R Where I = Peak current required by loop
R = Total resistance of loop



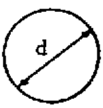


Fig.2

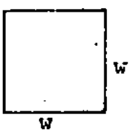


Fig.3

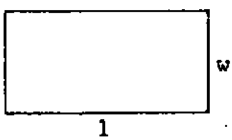


Fig. 4

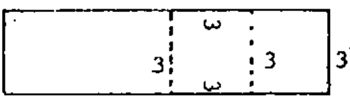
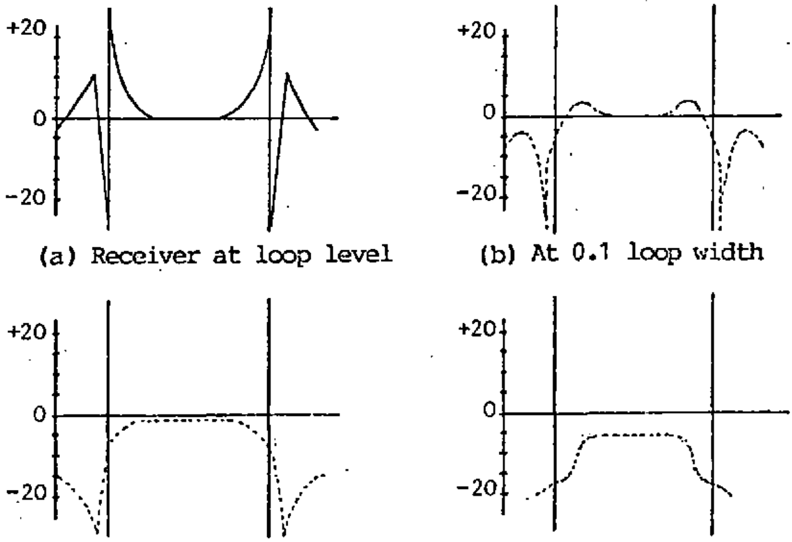


Fig. 5



(a) Receiver at loop level

(b) At 0.1 loop width

(c) At 0.2 loop width

(d) At 0.4 loop width

Fig. 6