A TRANSISTOR CAR RADIO WITH PUSH-BUTTON TUNING

by D. PASMA *) and G. SPAKMAN *).

Two important characteristics desirable in car radios are small dimensions and ease of operation. As regards the first point, the transistor made a considerable advance possible. This article describes one of the most recently developed sets (type N5X04T), which is entirely equipped with transistors. The receiver is tuned to the principal stations by push-buttons; the mechanism employed and the measures taken to ensure accurate tuning are discussed at some length.

Differences between car radios and other receivers

Certain characteristics are required of car radios which are not so rigorously imposed, if at all, on portable sets or domestic receivers. We shall begin with a brief review of these characteristics.

The first point to be considered is the mechanical construction. Although a car radio should be small enough for it to be mounted in or under the dashboard of a normal car, it should be sufficiently sturdy to withstand the shocks and vibrations to which it is constantly subjected in a moving vehicle.

To screen the set against electrical interference from the engine, it must be completely enclosed in a metal housing, and this in its turn calls for special measures to ensure adequate heat removal. Further-

*) Radio, Television and Record-playing Apparatus Division, Philips, Eindhoven.
aerials used on cars, the signal strength is in many cases not much more than 10 \mu V, and reasonable reception at such a low aerial voltage should still be possible. For example, at a modulation depth of 30\%, a power of at least 0.5 W should be available at the output. This fairly high power is necessary in a car in view of the fairly noisy conditions usually present. For this reason, too, the maximum output should be fairly high; at the present time it is usual to be able to supply 5 or 6 W to the loudspeaker without appreciable distortion.

Since considerable variations in signal strength occur when the car is in motion, a very effective automatic gain control is necessary. In this respect, too, the demands are no lower than those made on a high-quality domestic receiver.

Some of the above-mentioned requirements also apply to other transportable receivers. Small size, for example, is always important. Since in most cases, however, a smaller output is sufficient, the power taken from the source and hence the heat generated are considerably lower. This makes it easier to solve the problems of heat dissipation arising from the reduced dimensions.

In some respects the demands made on the receiver part of mobile VHF equipment resemble those applicable to a car radio. Such equipment does not, however, like the car radio, have a continuously variable tuning frequency, but operates on various fixed frequency bands. This considerably simplifies certain problems of circuitry. On the other hand, a mobile VHF unit, as professional equipment, has to meet even more rigorous demands in mechanical respects than a car radio.

Development of the car radio

The building of car radios was started as long ago as in the thirties. These sets were designed for reception in the long and medium wavebands. The first receivers were "straight sets", i.e. they had no frequency changer, but a switch was very soon made to superheterodyne receivers.

The valves and other components then available were rather bulky, and the early sets, with built-in loudspeaker, had a volume of 8.5 litres. Sets of this size necessarily had to be fitted outside the reach of the driver; usually they were fitted to the bulkhead (fire wall) between engine space and car interior. The driver operated the set by Bowden cables from a control box 1). With the development of smaller valves and components, the size of subsequent series of car radios was gradually reduced, a trend which was helped by not building-in the loudspeaker. Nevertheless, the sets were still too big to be mounted near the driver, and the use of Bowden cables still remained necessary. Because of the drawbacks attached to these cables (stiff running, backlash), efforts continued to be made to reduce the dimensions sufficiently to enable the set to be mounted in the dashboard. These efforts reached fruition in 1945, with the aid of a new range of small valves 2).

The new set (type NX570V) consisted of two parts. One part, which could be mounted in the dashboard, contained the receiver proper; the power pack and the loudspeaker were contained in a separate box which could be fitted to a suitable point on the bulkhead. The two parts were connected by a multicore screened cable.

The volumes of the two parts were 1.6 l and 4.7 l respectively, giving a total of 6.3 litres. In this respect, then, not much progress had yet been made. An important advance, however, was that the manual controls were now on the receiver itself, thus dispensing with the need for Bowden cables.

A measure that contributed a great deal to the further reduction of volume was the change from tuning by means of ganged variable capacitors to permeability tuning, using inductors in which the position of the ferrite core can be varied. This considerably reduces the size of the tuned circuits. A further advantage of permeability-tuned inductors is that they are much less sensitive than capacitors, with their large vanes, to mechanical vibrations, and thus cause less microphony. Yet another advantage of these inductors is that, given a well designed mechanical system, they are much more readily adaptable to push-button tuning. We shall return to this point presently. Finally, it is worth mentioning that using a capacitive aerial and a tuning circuit having a constant capacitance and a variable inductance, the voltage multiplication Q is virtually independent of the tuning frequency. (This means that the sensitivity of the receiver is much less dependent on the tuning frequency.)

In the earlier sets the power pack accounted for a substantial part of the total volume. To obtain the anode voltage for the valves from the car battery, use was made of a vibrator. This converted the battery voltage into an alternating voltage, which was stepped up and rectified to produce the required DC supply of about 220 V 3). Rectification was

---


3) J. Kuperus, On the construction of vibrators for radio sets, Philips tech Rev. 6, 342-346, 1941, and also the article in reference 1).
effected either by using a separate contact on the vibrator or a rectifying valve. Since the unit also contained a transformer, together with smoothing capacitors and choke, it always took up a fair amount of space. The obvious line of development was towards a receiver in which the battery voltage could be used directly for feeding the valves. It was possible to make valves that could operate on an anode voltage of about 6 V, with the exception, however, of the output valve; no valve could deliver a power of 2 to 5 W on such a low voltage as this. For this reason the construction of such a receiver only became possible after the advent of the transistor. One of the first transistors capable of delivering a sufficiently high power (type OC 16) was used in the output stage of a car radio, the other stages of which were equipped with valves for low-voltage operation. The output stage contained one OC 16 transistor, or two of them in push-pull. In these sets, called “hybrid receivers”, or VT (valve-transistor) receivers, which were first sold in 1957, a vibrator was thus no longer needed. Since this made it possible at the same time to dispense with the transformer and smoothing components (choke and capacitors) a considerable reduction in volume was achieved. The radio-frequency and intermediate-frequency circuits were contained in a housing of 1.3 l volume, which could be mounted in the dashboard, whilst the audio-frequency section was mounted, without the loudspeaker, in a separate housing of only 0.9 l. The volume was thus 2.2 l. Owing to various sizes of loudspeaker being used, the total volume varied 3 and 4.2 l. This considerable size reduction was possible despite the fact that the set could deliver 6 W, while only 2 W could be obtained from the earlier car radios. Although substantial space saving was achieved by eliminating the vibrator, transformer, rectifier and smoothing components, the gain was to some extent offset by the need to introduce extra suppressor filters into the supply lines. The likelihood of ignition interference was considerably greater now that the valves were directly connected to the battery.

An intractable problem in the development of VT sets was the design of an effective automatic gain control. The main difficulty was that at the low anode voltage of 6 V, even a very low negative grid bias reduced the anode current of the valves to zero. As a result, severe distortion occurred when the sets came into the proximity of strong transmitters. Although this trouble could be avoided by careful design, the normal spread in the data of the valves and other components made it impossible to guarantee the absence of this undesirable effect in all sets. The difficulty described is much less serious at an anode voltage of 12 V. In countries where the great majority of cars are equipped with 12 V batteries, these VT sets are therefore still being made.

The mechanical and electrical construction of the first VT sets was identical with that of other receivers; the components, for example, were interconnected in the conventional way by copper wire. In such very compact units there was a considerable risk of short-circuits, and in fact these occurred repeatedly after installation in the vehicle. This difficulty was overcome by the use of printed wiring in car radio receivers, which not only substantially reduced the risk of wiring faults, but also allowed a further reduction of dimensions.

When transistors were sufficiently far advanced to enable them to be used for radio-frequency and intermediate-frequency amplification, it became possible to build receivers which operated entirely on transistors. All-transistor car radios are now also being made, which are both smaller and consume less current. The entire set (excluding the loudspeaker) can now be contained in a housing of 1.7 litres, the dimensions of which allow it to be mounted in the dashboard. A receiver of this kind (type No. N5X04T) will be described in this article.

The circuit

The set is designed for reception in the long-wave and medium-wave bands. It is equipped with ten transistors and three germanium diodes, the various functions of which are illustrated in figs 1 and 2. These figures show the basic circuits, omitting non-essential parts. We shall consider some particulars of these circuits.

Fig. 1 represents the radio-frequency, intermediate-frequency and detector sections. I is the radio-frequency stage, which uses a transistor (TrI) of the type OC 170. K1 and K2 are the two RF tuning circuits, using permeability-tuned inductors. The way in which the RF tuning circuits and the oscillator circuit are switched over from the long-wave to the medium-wave band is not shown in this diagram. The aerial is connected to a capacitative tapping of K1. The aerial lead incorporates a choke, L1, for suppressing ignition interference from the engine. To enable the set to be connected to aerials of different sizes, a variable capacitor C1 is included in the screened aerial lead (see also fig. 5b).

The RF stage I is followed by the self-oscillating
Fig. 1. Simplified diagram of the radio-frequency, intermediate-frequency and detector circuits of the N5X04T car radio. Among the parts omitted are the circuit elements required for switching from the medium-wave to the long-wave band. The symbols +, — and ± indicate that the relevant points are connected to the positive or negative supply cable or to a voltage divider between these cables. The various parts of the diagram that may be regarded more or less as separate units are surrounded by dot-dash rectangles. I RF stage. II mixer II, which has a transistor (Tr2) of the type OC 44. K5 is the oscillator circuit, which is tuned, like K1 and K2, by varying the position of a ferrox-cube core in the inductors. A tuned transformer, consisting of the tuned circuits K5 and K9, forms the first intermediate-frequency band filter.

The mixer is followed by two intermediate-frequency stages III and IV, containing transistors Tr3 and Tr4 of the type OC 45. The second and third IF band filters are formed respectively by circuits K6, K7 and K8, K9. The inductors of the two primary circuits K6 and K7 are provided with a few extra turns (shown at the bottom of the coils) which are connected via capacitors to the input end of the relevant transistors. This largely eliminates the feedback in the transistors. (This technique is known as neutralization.)

The detector stage V is a normal diode detector using a germanium diode D1 of the type OA 79. The potentiometer R1 is the volume control, and potentiometer R2 with capacitor C2 form the tone control.

The parts of the circuit denoted by VI, VII and VIII form the automatic gain control.

Fig. 2. Simplified diagram of the audio-frequency section. IX emitter-follower stage. X and XI audio-frequency amplifier stages. X11 output stage. LS loudspeaker. P negative-feedback network. S1 speech/music switch. If the set is operated from a 6 V battery, optimum matching between the transistors Tr6, Tr79 and the loudspeaker is obtained by using only part of the primary of transformer T3. For this purpose switches S1 and S2 are used (shown here in the position for 12 V). If the set is connected to a 12 V battery, switch S2 is used to introduce a resistor into the common emitter lead of Tr6 and Tr19; this resistor is short-circuited in the case of a 6 V supply.
The automatic gain control works as follows. The signal voltage on the primary of the last intermediate-frequency transformer, $K_9$, is rectified by the diode $D_4$ (type OA 79) and the rectified signal is fed via a filter to the base of the first IF transistor $T_{75}$. Consequently, if the signal strength increases the emitter-collector current and the gain of $T_{75}$ decrease. The change in the voltage across the emitter resistance $R_5$ of $T_{75}$ now controls, through the intermediary of transistor $T_{76}$, the gain of the radio-frequency transistor $T_{77}$. To allow the reception of very strong signals (e.g. 1 V or higher) without overloading the IF amplifier, a diode $D_4$ (also of type OA 79) is connected between the emitter of $T_{77}$ and the top of the resistor $R_4$ in the collector lead of $T_{77}$. During the reception of small signals the emitter of $T_{77}$ is at a negative potential with respect to the top of $R_4$. As a result $D_4$ is cut off. Large signals, however, make this diode conduct, chiefly because of the drop in the voltage across $R_4$. Between the base and the emitter of $T_{77}$ there now appears a positive voltage of about 1 V, cutting off this transistor completely and allowing the very strong aerial signal to reach the mixer transistor $T_{75}$ only via internal capacitances, thus undergoing a strong attenuation.

Fig. 2 shows a simplified circuit diagram of the audio-frequency section. The first audio-frequency stage, $IX$, consists of a transistor $T_{89}$ of the type OC 75, in the common-collector (emitter-follower) configuration. This stage provides no voltage amplification; its presence in the circuit is to enable a crystal pick-up (of an "Automignon" record-player) to be connected to the terminals $G$ (see fig. 1). As a crystal pick-up has a high internal resistance and thus calls for a large load resistance, it was necessary to give the first audio-frequency stage a large input resistance. One means to this end is to use a transistor in the common-collector connection, the input resistance of which is much higher than that of transistors in other arrangements. A consequence of this high input resistance is that the detector stage $V$ also has a high input resistance. This made it possible to connect the detector in parallel with the last IF circuit $K_{11}$, and no tap on the coil of $K_{11}$ was necessary for this connection.

Stages $X$ and $XI$ are audio-frequency amplifiers. The coupling between $IX$ and $X$ is effected by the two capacitors $C_2$ and $C_1$ in series. The capacitor with the lower capacitance, $C_2$, can be bypassed by the switch $S_1$. When $S_1$ is open the low notes are not so strongly reproduced, which is an advantage for the reception of speech (speech/music switch). Transistors $T_{77}$ and $T_{78}$ are types OC 71 and OC 79 respectively. The latter transistor is coupled via a transformer $T_1$ to the push-pull output stage $XII$. This contains two transistors of type OC 26 ($T_{79}$ and $T_{710}$). The loudspeaker $LS$ is connected across the output transformer $T_2$. If required, two loudspeakers can be connected in parallel. To ensure proper matching in that case, a tap is provided on the secondary of $T_2$. Negative feedback is provided between stage $XI$ and stage $XII$ via the network $P$ in the figure. The output stage can deliver a power of 6 W, at which the distortion is 10%.

The diagram in fig. 3 again simplified, represents the power supply circuit. The battery is connected to the terminals $a$ and $b$. The choke $L_2$ and $L_3$, together with capacitors $C_4$ and $C_6$, form the interference-suppressor filters. The on/off switch $S_6$ is combined in the conventional way with the volume control $R_1$ (see fig. 1).

To adapt the set for operation on a 6 V or 12 V battery, according to requirements, various connections have to be changed. The switches used for the purpose are $S_2$, $S_3$, $S_4$, $S_7$ and $S_8$ in figs 2 and 3;
Construction

The problems involved in the construction of a car radio are not only concerned with the efforts to reduce dimensions, mentioned at the outset. Small dimensions are also important in portable receivers, but in their case the construction is simplified in as much as the manual controls and the tuning dial can be disposed if necessary on different sides of the set. Since a car radio has to be mounted in the dashboard, the controls and dial all have to be on the same side, and indeed on one of the smallest sides in view of the relatively small space available on the dashboard. An added difficulty is that it should be possible to operate the set wearing fairly thick gloves, and therefore the controls should not be too small. The receiver type N5X04T measures 180 × 174 × 54 mm. The space thus available for a tuning dial and the controls was 54 × 180 mm. This side also had to accommodate the means of securing the set in the dashboard, to which we shall return presently.

The receiver can be tuned by means of five push-buttons, which select three stations in the medium-wave band and two in the long-wave band. A control knob is provided for tuning to other stations in the normal way. The facility for tuning to a station by pressing a push-button is of considerable importance in a car radio, since it means that the driver’s attention is not so distracted as when tuning by ear with a knob. If he knows the sequence of the five stations to which the push-buttons are preset, he can operate the set by touch alone.

The construction of the set was substantially influenced by the choice of push-button tuning. We have already mentioned that permeability-tuned inductors are preferable for this purpose to variable capacitors. The rectilinear movement of the inductor cores in the tuning process, and the small mass of the moving parts, make it easier in this case to design a simple and accurately functioning tuning system than if conventional variable capacitors were to be used.

In a receiver without push-button tuning, the RF tuning section is not tied to a particular part of the housing. The mechanical coupling between the tuning control, the variable inductors and the dial cursor can almost invariably be satisfactorily effected by a system of cords or other coupling elements, particularly since there need be no fixed relation between the tuned frequency and the position of the tuning control: the station is after all tuned in by ear. In the case of push-button tuning, however, such a mechanism is unsuitable owing to the considerable precision required to adjust the tuning device by means of each push-button. The motion of the push-buttons must be transmitted as directly as possible to the ferrite cores. The inductors should therefore be brought forward as much as practicable, roughly in the middle of the set, so that they form a single assembly together with the push-buttons. To achieve the desired compactness the remainder of the circuit should be grouped around this assembly so as to waste as little space as possible. Fig. 4 illustrates how this is done in the receiver under discussion. F is the front plate of the set (seen from

---

**Fig. 4.** Sketch showing the lay-out of the principal parts of the N5X04T car radio. F front plate. U dial. A1 to A3 printed-wiring panels. B cooling plate. H chassis plate. L inductors. Tr9 one of the two output transistors. R1 volume control. R9 tone control.
Fig. 5. The receiver with the housing removed.

a) Right way up. Panel $A_4$ is raised to allow access to the components beneath it.

b) Upside down. In the foreground can be seen the variable capacitor $C_1$ in the aerial lead (see fig. 1), enabling the set to be matched to aerials of different capacitance. The letters denoting various components correspond to those used in figs 1 to 4.
the rear), on the outside of which is the dial $U$. Immediately behind are the inductors $L$ of the radio-frequency and oscillator circuits. The five plates marked $A_1$ to $A_5$ are printed-wiring panels $^4$). On these panels are mounted most of the smaller components, such as resistors and capacitors. Panel $A_4$ carries most of the components of the radio-frequency section, panels $A_2$ and $A_3$ carry the intermediate-frequency and detector components, and $A_4$ and $A_5$ carry the audio-frequency circuits, with the exception of some heavy components like the transformers $T_1$ and $T_2$ (see fig. 2). The latter are mounted directly on the metal chassis.

Although much less heat is generated in transistor sets than in receivers fitted with valves, in this case it was nevertheless necessary to pay attention to cooling. The most heat is generated in the two output transistors, $T_{9}$ and $T_{10}$; these are therefore fixed to the aluminium plate, $B$, which forms the back cover of the set. This plate is provided with cooling ribs and the transistors are mounted on the outside, so that they are in fact outside the actual set. (In fig. 4 only one of the output transistors is visible; see also fig. 5.)

Opposite panel $A_3$ are the volume control $R_1$ and the tone control $R_2$ (see also fig. 1), which are operated with the aid of two concentric shafts, and thus take up little space on the front plate. The on/off switch ($S_5$, see fig. 3) is as usual coupled to $R_1$. Mounted on the other side of the front plate is the mechanism (not visible in fig. 4) for tuning to stations that cannot be selected with the push-buttons, and also the speech/music switch ($S_1$ in fig. 2). The operating shafts for the tuning control and $S_1$ are also concentric. The part of the set to the left of the compartment marked $H$ in fig. 4 contains the power supply components (fig. 3).

The connection points for the printed-wiring panels are mostly arranged around the periphery, enabling each panel to be easily disconnected and replaced if necessary. Panel $A_4$ is connected by means of flexible wires, and is held in place between lugs. It can thus be pulled up, as shown in fig. 5a, without breaking any of the connections, thus allowing easy access to the components beneath it.

Various other measures have been taken to ensure ready access to the majority of components. The chassis is so designed that after disconnecting only one lead and removing two screws, the rear section can be turned through 90° with respect to the front section. It can be fixed in that position with two screws.

Fig. 6 shows a receiver opened up in this way, which is not only useful for making repairs but is also used in assembly.

![Fig. 6. For assembly or repair work, the rear portion of the receiver can be turned through 90° with respect to the front part. $C_v$ and $C_p$ are reversible plugs for adapting the set to batteries of different voltage (6 V or 12 V) and different polarity. $A_1$, $A_2$, $A_3$ are printed-wiring panels.](image)

### The tuning mechanism

We shall now consider in more detail the mechanism of tuning by means of the five push-buttons. Each push-button ensures that the ferrite cores in the inductors of both RF circuits and in the oscillator circuit are moved into pre-set positions.

The mechanism employed is shown in a very simplified form in fig. 7. The cradle $N$ pivots around the line $AA'$ and is coupled to the bar $J_1$. The movement of this bar is transmitted by rods $T$ to the ferrite cores in the inductors $L$. Only one of the five push-buttons, $D$, is represented in the drawing. Mounted on the push rod $E$ of this button is a semi-circular segment $S$. When the button is depressed, the cradle $N$ takes up the position corresponding to the position of the segment, and this in turn brings the bar $J_1$ into the position corresponding to the tuning of the receiver to a

---

Fig. 7. Simplified sketch of tuning mechanism. D push-button. E push rod. S segment. 
N cradle which turns about the line $AA'$. $W_1$ worm. $W_2$ wormwheel. K tuning knob. 
$J_1$, $J_2$ and $J_3$ moving bars. T tie-rods. L inductors. I indicator block.

In this way, then, a station once tuned in with the tuning control $K$ can repeatedly be obtained by depressing one of the push-buttons. The push-buttons also operate the waveband switch. The sliding contacts of this switch are mounted on a strip of insulating material which is connected to the sliding bar $J_2$ shown in fig. 7. The latter is provided with notches, one of which ($Z$) can be seen in the figure. Whenever a button is depressed, the chamfered end of the relevant rod $E$ pushes against the bevelled edge of one of these notches, causing $J_2$ to take up one of the two extreme positions, and thus setting the waveband switch to one of the two wavebands. The notches in $J_2$ are so arranged that the long-wave band is switched in with two of the push-buttons and the medium-wave band with the three others.

Another sliding bar $J_3$ is moved at the same time as $J_2$; this serves to disconnect the friction clutch between the wormwheel and the cradle shaft when one of the push-buttons is depressed. (We shall return to this point later.)

The use of a sliding switch instead of the conventional rotary type made it possible to place the contacts immediately under the inductors, thus giving short connections and a very convenient layout.

When the receiver is tuned either by push-button or tuning control, the station indicator must move along the dial. Its movement must be perpendicular to that of the sliding bar $J_1$. The most obvious method of coupling the tuning mechanism to the cursor...
is to use a cord passing over pulleys. A cord drive system, however, could not be used here because the friction involved would detract from the high precision required of the tuning mechanism. The simple linkage mechanism adopted, and shown in fig. 8, caused much less friction.

The link $H_1$ pivots about a fixed point $I$ and carries at end 3 a spindle which rests in a slot in the bar $J_1$ (see fig. 7). The end 2 is hinged to a strip $H_2$, which can slide in a slot in a fixed plate $Q$ (The spring 4 keeps $H_2$ pressed against one side of this slot.) The other end of $H_2$ carries the cursor $H_9$, which is easily detachable. $U$ denotes the position of the dial. It can easily be shown that the pivoting of $H_1$ (caused by the spindle 3 following the movement of $J_1$) results in a practically linear movement of $H_9$; with the dimensions of the components used in this set, the maximum deviation from a straight line is only 0.3 mm. The cursor thus travels straight along the dial with sufficient accuracy.

**Tuning precision**

As mentioned in the foregoing, a very high degree of precision is required of the tuning mechanism. Some figures will illustrate this. In the inductors used in the N5X04T set the total variation of the self-inductance is achieved by displacing the ferrite core 15 mm. This is sufficient to cover a frequency range of 1100 kc/s in the medium waveband. If we now specify that, when one of the push-buttons is depressed, the set should be tuned to the required station with a deviation of no more than 0.5 kc/s, then the average precision with which the cores must be displaced is $(0.5/1100) \times 15 \text{ mm} \approx 7 \mu\text{m}$. This maximum permissible deviation is the sum of the deviations that may be due to misalignment of the segments $S$ (see fig. 7) and the play in, and deformation of, the drive system. The components of this system must therefore be light and very rigid, and springs must be used to ensure that any play in the connections has no effect on the adjustment of the cores. Once the segment $S$ has been fixed in position, any movement in relation to the push rod $E$ must be prevented by very rigid clamping. The construction used for this purpose is illustrated in fig. 9. The push rod, which was shown in fig. 7 for simplicity as a single rod, consists in reality of two parts capable of moving relative to one another, and denoted by $E_1$ and $E_2$ in fig. 9. The part $E_2$, which carries the push-button $D$, can slide in a bushing $I$ which is attached to $E_2$. The segment $S$ is pivoted on the screw 5. Fig. 9 represents the situation in which $S$ can move freely. When $E_1$ is now moved to the right in relation to $E_2$, a leaf spring 2 presses a hardened steel ball 4 to the right and causes a leaf spring 3 to clamp the edge of the segment $S$. Very considerable leverage is exerted by 3 as a result of its special profile. The force with which $S$ is clamped is roughly 40 kg, which is sufficient to prevent any slip in the segment, even in frequent use.

To prevent displacement of the segment $S$ in the pivoting point, the hole through which the screw 5 protrudes is not round but slightly V-shaped (see fig. 10). This ensures that there is no play at this position when the segment $S$ is pressed against the cradle $N$ (see fig. 7).
The precision with which the cradle returns to the same position when one of the push-buttons is depressed depends, among other things, on the torque required to move this component with the bar $J_3$, the tuning cores and the cursor mechanism. This torque is determined to a large extent by the friction clutch by means of which the cradle shaft $A'$ is connected to the wormwheel $W_2$ (see fig. 7). Apart from increasing the torque necessary to turn the cradle when the wormwheel is stationary, the friction clutch also causes the cradle to rebound slightly whenever a push-button is depressed, largely because the depression of the button produces slight torsion in the cradle. There may even be some rebound in the friction clutch itself. The consequence is an additional error in the reproducibility of the push-button tuning.

Operation of the tuning control $K$ may also cause some rebound in the friction clutch, primarily due to vibrations to which the set is subjected after the tuning.

The degree of precision required in the alignment of the cradle appears from the following figures. The angle through which the cradle can turn is roughly $40^\circ$. In the medium-wave band this corresponds to a frequency coverage of 1100 kc/s. If we specify 0.2 kc/s as the maximum permissible detuning due to rebound, then the maximum angle over which the cradle may rebound is $(0.2/1100) \times 40^\circ = 26^\circ$.

To minimize the chance of cradle rebound, a mechanism is used by means of which, whenever a push-button is depressed, the friction clutch between the wormwheel and the cradle shaft is put out of operation. For ease of illustration, this mechanism was omitted in fig. 7, but is drawn separately in fig. 11, together with the friction clutch in cross-section. The wormwheel $W_2$ can be turned on the shaft $A'$ of the cradle $N$; fixed to the same shaft is a diaphragm $M$ of beryllium copper, which is pressed into a tapered recess in the wormwheel by a retainer 1. The pressure is applied by the spring 4 via a lever 3 and a screw 2. When one of the push-buttons is depressed, the sliding bar $J_3$ moves to the right (see fig. 7), as a result of which the lever 3 also moves to the right against the action of the spring 4. The pressure of the retainer 1 on the diaphragm $M$ is then removed, thereby disconnecting the coupling between the wormwheel $W_2$ and the shaft $A'$. When the push-button is released, the coupling is again restored by the spring 4.

Another factor influencing the precision of the tuning mechanism is that, when a push-button is depressed, the cradle is not only turned, but slightly bent. The bending produced by the force $F_d$ exerted by a push-button is illustrated in fig. 12, exaggerated...
for the sake of clarity. The effect disappears when the push-button is released. Since the wormwheel \( W_2 \), which meshes with the stationary worm \( W_1 \), also moves upon the bending and rebound of the cradle, the resultant displacement of wormwheel and cradle may cause an impermissible tuning error if suitable measures are not taken to prevent it. To give some idea of the amount of bending permissible, it may be mentioned that a displacement \( f \) of the wormwheel over a distance of 5 \( \mu \)m can cause a detuning of 0.6 kc/s.

The wormwheel displacement produced by a given degree of bending is less the smaller is the distance \( a \) between the centre of the right-hand ball bearing and the centre of the wormwheel. Among the measures therefore taken to reduce this distance to as little as 3 mm was to mount the right ball-bearing on the outside of the chassis and to provide the left-hand side of the cradle with a ball thrust bearing, in which the ball \( I \) is forced outwards by a leaf spring 2. The cradle was also given such a profile as to make it very rigid. These and similar measures made it possible to reduce the detuning in question to a permissible value.

The receiver housing

In designing the receiver housing, two important factors had to be taken into account. Firstly, the housing had to prevent the penetration of electrical interference from the engine. Secondly, provision had to be made for opening and closing the set quickly and easily. These requirements would be incompatible if one were to build a metal housing, the various parts of which were screwed together, for effective screening in that case would call for the use of numerous screws to ensure good electrical contact at many points over the parts of the housing. This, of course, would make it impossible to open and close the set quickly. A satisfactory solution was found in a housing consisting of two parts each fitted with lugs in which two pins of stainless steel can be inserted (see fig. 13). The lugs act as contact springs, thus ensuring effective electrical screening.

The cooling block \( B \) (see fig. 4) is slid on to the bottom part of the housing at the rear, and is clamped between the two parts when the housing is closed. It is connected to the bottom part of the housing by only one screw, which in most cases is the same screw used for securing the set in the car. In such cases, the receiver housing is in fact “screwless” after removal from the dashboard.

The receiver is mounted in the dashboard by means of two heavy threaded bushings, fitted concentrically with the operating shafts. If the opening in the dashboard does not correspond to the dimensions of the set, a special ornamental plate can be used. If necessary the set can be additionally supported at the rear.

Fig. 14 shows a photograph of the complete receiver, and in the title photograph it can be seen mounted in the dashboard of a car. The set can also be mounted in the car in other ways; for example it can be mounted in a cover suspended under the dashboard.

As the loudspeaker is not incorporated in the set, it can be set up in any appropriate part of the car. If required, two loudspeakers can be used, connected in parallel to the tapping available for that purpose on the output transformer.

Summary. After briefly considering the requirements to be met by a car radio, the authors review the development of these sets in the last twenty years. A description follows of one of the latest car radio receivers, type N5X04T, which is entirely equipped with semiconductor devices, viz. ten transistors and three germanium diodes. The circuitry and construction are discussed, with special emphasis on the tuning mechanism using push-buttons, which calls for very high precision to ensure reproducible tuning.
ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS BY THE STAFF OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN

Reprints of those papers not marked with an asterisk * can be obtained free of charge upon application to the Philips Research Laboratories, Eindhoven, Netherlands, where a limited number of reprints are available for distribution.

2954: B. Jansen: A rapid and accurate method for measuring the thickness of diffused layers in silicon and germanium (Solid-state electronics 2, 14-17, 1961, No. 1).

Surface-layer thicknesses can be measured very practically by making use of the brittleness of silicon and germanium, thus eliminating cumbersome, precise grinding and polishing procedures. The germanium or silicon slice is broken in a special manner producing a rather flat cleavage surface, in which any disturbing fracture line is more or less perpendicular to the very sharp, long edges. In this surface the exposed P-N junctions are marked as very thin lines by one of the well-known methods (electrolytical, chemical). The distances between these lines or to the edge of the cleavage surface are measured under a high-power metallographic microscope with an eyepiece micrometer. Magnification factors mostly used are 400 or 600 times. Very thin layers of about 1 μm are still measurable. The method is used for diffused layers as well as for alloyed contacts or combinations as in the case of alloy diffusion.

2955: J. Ubbink: Moderne ruisarme versterkers, I. Masers (Ingenieur 73, 01-06, 1961, No. 3).

An introduction to the maser (which gives Microwave Amplification by Stimulated Emission of Radiation), a new sort of low-noise amplifier. Three types of masers are discussed. The ammonia maser is not suitable for use as an amplifier, but it is an excellent frequency standard. Solid-state masers, which make use of the magnetic properties of e.g. ruby (Al₂O₃ containing a small percentage of Cr³⁺ ions), are better amplifiers. The ruby can be used in two ways: in a cavity resonator or in a waveguide. The first method has several disadvantages; the second is much better, if a system is used in which the group velocity of the microwaves is much smaller than in free space (a "slow-wave" structure). A practical execution of such a maser is described.

2956: H. Mooijweer: Moderne ruisarme versterkers, II. Parametrische versterkers (Ingenieur 73, O23-O32, 1961, No. 7). (Modern low-noise amplifiers, II. Parametric amplifiers; in Dutch.)

Discussion of the principle of operation of parametric amplifiers. The effective input noise temperature is higher than that of a maser (see 2955), but a parametric amplifier is simpler to make. Some actual amplifiers and some possible designs are described. The article contains extensive references to the literature.


A new method is described for studying electrical surface properties of semiconductors. The (very simple) method consists of resistivity measurements, at oxygen pressures ranging from 10⁻⁶ to 10⁻² mm Hg, of thin germanium single crystals, the diameter of one sample varying from 1 mm to 10⁻² mm. The crystals can be given the desired shape by "burning off" the germanium at 700 °C in an oxygen gas pressure of 10⁻² mm Hg. By this method the roles played by surface conductivity and bulk conductivity can easily be separated. Results are given for intrinsic germanium and are in qualitative agreement with results obtained by Handler et al.


Comment on a publication by Weiss and Tauer, who claimed to be able to explain the asymmetry of the phase diagram of the system Au-Pt from measurements of the specific heat only. It is shown that the phase diagram calculated by the method of Weiss and Tauer in fact differs in two essential points from that found experimentally.

2959: C. Haas: Vibratiespectra van kristallen (Ned. T. Natuurk. 27, 105-118, 1961, No. 4). (Vibration spectra of crystals; in Dutch.)

Data about vibrations in crystals obtained by measurement of specific heat and thermal conductivity are difficult to interpret. This is because all the
vibrations in the crystal contribute to these quantities. This article discusses two methods whereby more selective information about the lattice vibration can be obtained: infrared spectroscopy and Raman-spectroscopy.

2960: A. Schmitz: De tunneldiode (Ned. T. Natuurk. 27, 133-142, 1961, No. 4). (The tunnel diode; in Dutch.)

Esaki published his article on the tunnel diode in Jan. 1958. The most important property of this diode is a part of the \( I-V \) characteristic with a negative slope. Various workers have studied the properties and applications of this diode. This article gives a survey of the present state of knowledge in this field.


An electrical double layer is often formed at the boundary between two phases which contain a sufficient number of free charge carriers. This phenomenon is very important in colloidal systems, but also in semiconductors, as regards both surface effects and \( P-N \) junctions. In this article a survey is given of the theory of these double layers for various cases; the points of similarity and dissimilarity between the different cases are pointed out.


\( \text{AlTh}_2 \) absorbs hydrogen readily. This article describes an investigation, carried out with the aid of neutron diffraction, of the manner of incorporation of the hydrogen in the \( \text{AlTh}_2 \) lattice. In fact, deuterium was used instead of hydrogen, in connection with the demands made by neutron-diffraction techniques. The investigation was restricted to solid solutions of composition \( \text{AlTh}_n \text{D}_{n} \), with \( n = 0, 2, 3 \) and 4. It was found that the hydrogen is taken up in tetrahedral interstices between thorium atoms, just as in thorium which contains no aluminium. If \( n = 4 \), all the available tetrahedral interstices are filled. At lower values of \( n \), i.e. when the filling is incomplete, no order could be found in the distribution of the deuterium atoms over the available sites, even at a temperature of 82°K. See also Philips tech. Rev. 23, 69, 1961/62 (No. 3).


If it is desired to determine the radiation intensity per mg of a radioactive sample from measurements of the radiation actually emitted, a correction must be applied for the absorption by the sample itself. The correction factor is often given as a function of the mass of the sample. There is disagreement in the literature as to the form of this correction curve for \( \beta \)-emitters. The author shows that this disagreement may be due to differences in the geometry of the sample and the measuring set-up.


Textbooks on the application of statistics to experimental investigations usually give examples where the design of the experiment is taken as given, and the experimental results are successfully processed with the aid of standard statistical methods such as variance analysis. In practice, the situation is often different. This publication describes two cases from industrial practice where the help rendered by the statistician consisted in analysing the problem and designing a suitable experiment or series of experiments on the basis of this analysis. The results of these experiments spoke for themselves: there was no need to subject them to any form of statistical analysis.

This aspect of the task of a statistician is often neglected in textbooks of statistics. See also Philips tech. Rev. 22, 105, 1960/61.

2965: P. C. van der Willigen: Booglasmethodes voor staal en de rol die de waterstof daarbij speelt (Chem. Weekbl. 57, 170-176, 1961, No. 14). (Methods of arc welding of steel, and the role of hydrogen in such methods; in Dutch.)

A short survey of the historical development of arc-welding methods for steel. Welding electrodes with an "acid" coating are still used on an immense scale. A characteristic of the acid coating is that it produces much hydrogen during welding. Hydrogen has come to be regarded as an enemy of good welding, for reasons which are stated in this article. Hydrogen-free welding methods (submerged-arc welding, use of electrodes with basic coatings, welding with a bare wire in a protective atmosphere of argon or \( \text{CO}_2 \)) are therefore gaining more and more ground. Hydrogen in steel is also one of the causes of the cracking of enamel.