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Television Data Sheets

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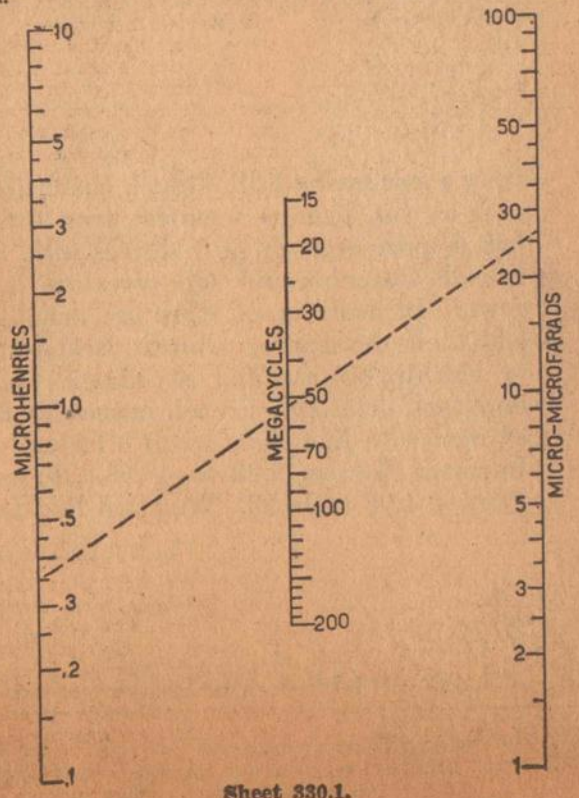
TUNING CIRCUITS FOR H. F. SIGNALS

The usual LC tables, used to determine the values of inductance and capacitance, corresponding to a given frequency, do not always extend down to the television range. The chart shown below is used as follows: A straight line across the center scale will point to the required tuning values on the microhenries and micro-microfarad scales. One solution is shown by the dotted line which indicates that for a frequency of 53 megacycles an inductance of 0.35 microhenry and a capacitance of 27 micro-microfarads might be used.



Sheet 330.1.

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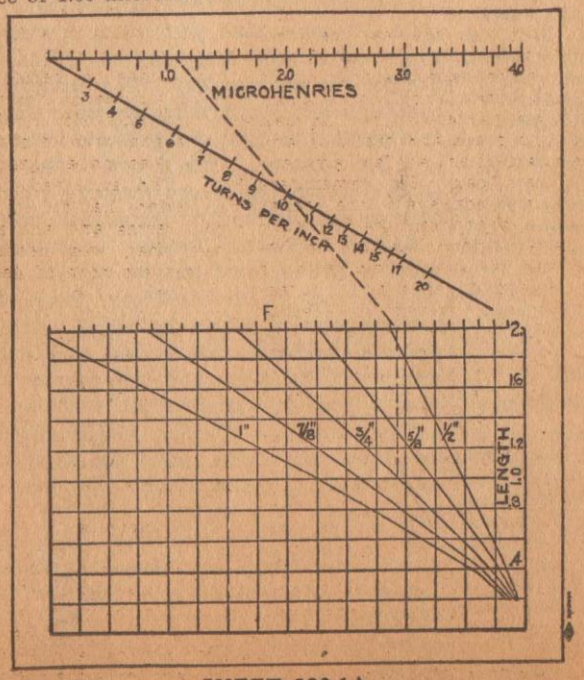
COIL DESIGN

Tuning inductances for the television carrier frequencies do not contain many turns, and are generally wound with heavy wire, with five to ten turns per inch. The chart below will assist in the determination of the correct size for coils having only a few microhenries, as shown on Data Sheet No. 330.1.

Select winding diameter (½ inch to 1.0 inch) and a convenient length on the curves at the bottom section of the chart. Project a line upward from the intersection of the "length" factor and the desired diameter curve, to the F scale at the center. A line from this point on the F scale to the desired point on the top scale, will intersect the turns per inch scale at a point that indicates the required spacing.

The example shown, indicates that a ¾ inch diameter coil, 1 inch long wound with 10 turns (that is 10 turns per inch) will have an inductance of 1.06 microhenries.



SHEET 330.1A.

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R. F. TUNING METHODS

A regular television receiver must be able to tune in any television program. Ultimately it will be necessary to tune in a number of particular frequencies, as for example 47, 53, 69, 81, 87, 99 and 105 megacycles, each of these values being the center of a particular six-megacycle television band. Inasmuch as there are gaps in this range, denoting frequencies assigned to other radio activities, it would seem desirable to use tapped coils in the tuning circuits so that any station could be tuned by a switching operation. Actually by using tapped coils and semi-adjustable condensers it is possible to have a higher L/C ratio in tuning so that greater amplification can be obtained in each radio frequency stage.

This principle has been carried out in an ingenious manner in the RCA television receivers. Here a special three gang switch is fitted with specially shaped metal fins which form small condensers. The inductance of the coils is varied by these switch contacts and at the same time the tuning capacity is altered. This introduces into the circuit predetermined capacitance necessary to tune in a given station.

A vernier control, however, is added to the oscillator tuning circuit in order to permit its frequency to be controlled accurately. The incoming R. F. tuning circuits are broadened to pass the six-megacycle band, by the use of large intercoil coupling factors. To obtain the greatest efficiency in these circuits it is necessary to take all types of coupling between the R. F. circuits into consideration.

At these frequencies, of 50 to 100 megacycles, a short lead common to both circuits may introduce a substantial conductive coupling, which may alter the effectiveness of regular coupling factors, since both inductive and capacitive coupling is present.

The oscillator circuit must be arranged so that frequency drift is not large, or else wide shifts in the receiver sensitivity would occur. A tuned plate oscillator circuit is generally used for this reason.

The number of radio frequency stages which can be incorporated in a given receiver depends upon the efficiency of the tubes used. The R. F. amplification per stage is not large with ordinary types of receiving tubes, so that the R. F. section of the receiver is usually limited to one or two stages. This policy may change, however, with the introduction of new types of receiving tubes.

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RECEIVER DESIGN PROBLEMS.

In an ordinary broadcast receiver the main function of the apparatus is to select a particular signal from among the many in the ether, and to amplify that signal sufficiently to operate a speaker. Basically the television receiver must do the same job, except that the output voltage is applied to a cathode ray tube instead of a speaker. If the modulation characteristic of such a tube could be made many times as sensitive (which is not an unlikely goal), the problem of amplifying a video signal would not be so difficult, and much simpler television receivers would be possible.

As it is, a voltage of the order of twenty to seventy volts will modulate (that is, alter the spot brilliancy over the required range) a present-day tube. This factor varies somewhat with the type and size of tube, but remains fairly constant with anode voltage. However, the latter statement will need some qualification, viz., a certain modulation voltage will ordinarily produce a variation in the spot's illumination from zero up to a certain brilliance, even if the anode voltage were about doubled. Nevertheless, the higher anode voltage would permit a greater maximum intensity of the spot, and hence a greater range of brilliance would result. To get the full benefit of this increased range it would then be necessary to increase the modulation voltage proportionately. To get this voltage swing, of say fifty volts, considerable amplification is necessary.

Assume that a given antenna and receiver location produces a 500 micro-volt signal, which is equivalent to saying that one-two thousandth of a volt is impressed across the input terminals of a receiver. This signal would then have to be amplified 100,000 times in the receiver to be of sufficient intensity to operate the cathode ray tube. assumed to be 50 V.

In the usual broadcast receiver this gain is handled three ways—in the r-f amplifier, which amplifies the received signal directly without any change in its form; in the i-f amplifier, wherein the received signal has been changed to a range that is somewhat more efficiently handled, and in the a-f amplifier wherein the signal has been converted to a form that will operate a loud speaker. In most receivers all three types of amplification are present.

Similarly all three types of amplification will be used in the usual television receiver, although in some cases the type corresponding to a-f (audio frequency) amplification is eliminated. In the succeeding data sheets details of typical amplifier circuits will be discussed, leading into actual receiver layouts.

 of each type

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RECEIVER DESIGN PROBLEMS

Although the problems associated with the design of a radio frequency amplifier suitable for television carrier frequencies (see 330.2) are rather different from other types of receivers, still an actual circuit diagram would not be greatly different from that used in a broadcast receiver. Therefore, the actual circuit does not tell much of the story when laying out a television set, since it gives no details about the important problems of efficiency and the elimination of regeneration (feedback).

It is good practice to include the tuning condenser, the inductance coil and the amplifier tube, all in the same shielded compartment. It is also desirable to mount the coils themselves so that they have minimum mutual coupling effects, so that less reliance need be placed on the shields to keep the feedback down to a low value.

Since it is general practice to use at least one stage of r-f amplification in the superheterodyne type of receiver, and four or five stages in T. R. F. sets, the problem can be analyzed from the individual stage viewpoint, and a unit assembly devised that will permit linking together as many stages as the reception conditions require. It has been customary to use low-capacitance tubes for the ultra-high frequencies of television, such as the "acorn" types, but high transconductance tubes have superseded those types in most designs. These latter tubes are of the metal shell type, using the regular octal base sockets. Their characteristics will be analyzed in a later data sheet, but for the present it can be assumed that they may be used the same as any pentode, and possess the characteristics necessary for r-f amplification.

In mounting this tube, the outer shell which is connected to a base prong in the usual way is grounded, but it may be found that the internal wire, leading from this shell to the base, may have so much resistance to high frequency currents, that it is necessary to add a supplementary ground clamped around the shell at a point about half way up and connected directly to the chassis. Two physical styles are available: the 1851, which has the control grid wire coming out of the top, and the 1852, which has this connection made to a prong in the base. In the latter design the connection to the control grid is adequately shielded from the plate lead so that no more feedback is encountered than with the type 1851, if proper placement of the external wiring is made. The choice between these two types lies mainly in the circuit layout, since in the type 1852 the grid and cathode leads are quite close together and the inductance coil and tuning condenser can be wired to the input circuit without lengthy leads.

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RECEIVER DESIGN PROBLEMS

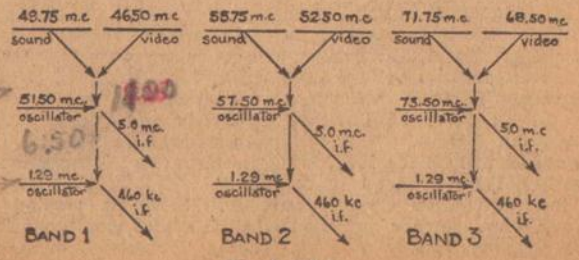
Most of the theoretical considerations concerning the design of a video receiver have been given in previous sheets. It now remains to take up the details of the physical construction of this receiver. A tuned radio frequency receiver can be used for local distances where the interference level is low, but for more consistent reception over greater distances the superheterodyne receiver is necessary. The latter type will be considered first.

The receiver to be described will be laid out, for greatest ease in construction, and with the object of sidestepping as many of the mounting difficulties as possible. It will consist of one stage of r-f using an 1852 tube, a converter stage with self-contained oscillator (using a 6K8 tube) operating into a three-stage broad band i-f amplifier also using 1852 tubes. Provision for the sound program reception is made using a double heterodyning principle with a separate converter tube and oscillator, a 6K8.

The three sections (r-f, video i-f and sound) will be described separately, and can be constructed separately. In this way many of the wiring and shielding complications can be avoided.

In the video i-f amplifier, interstage coupling will be accomplished by special band pass networks, each of which can be adjusted to pass to a three-megacycle band, and yet permitting a lower i-f carrier frequency to be used than is normally considered with transformer-coupled video i-f stages. The i-f frequency nominally will be five megacycles.

The tuning and frequency setting for the first three television bands (see sheet 200.3) are:



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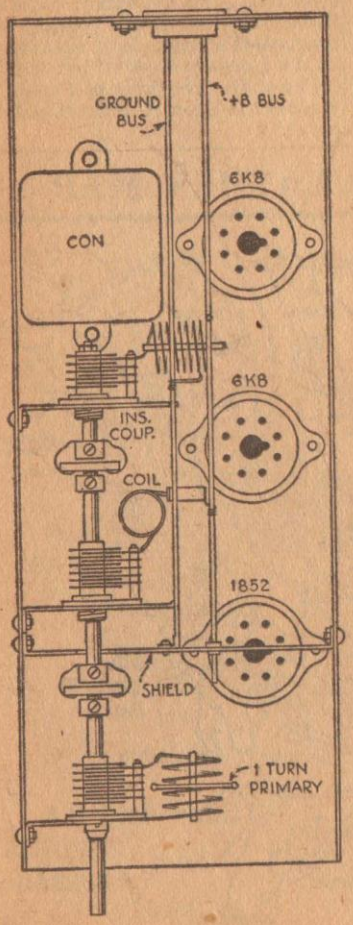
SOUND-VIDEO RECEIVER CHASSIS



The chassis, which is bent up from a single piece of aluminum 9x13", holds the three most important amplifier stages in the whole receiver, since it is these tubes that handle the ultra-high frequency carriers used in television. The preliminary mounting diagram shown on this sheet takes care of the major items in this part of the circuit, the tube sockets (which should be of a good grade of ceramic material and of the octal type), the three gang tuning condenser and the r-f coils. The filament and plate supply is connected by means of a four-prong socket mounted at the rear. Two heavy bus wires, as shown, connect to the plus B terminal and to the ground terminal and run almost the whole length of the chassis. All of the small by-pass condensers and most of the resistors are connected between the appropriate terminals on the octal sockets and these bus wires. This type of wiring keeps all leads at the shortest possible length and carries out the other ideas outlined on sheet 500.2.

The first R-F tuning circuit, shown at the lower end of the diagram, is coupled to the antenna by a single turn of wire connected to the twisted pair cable leading to a dipole antenna. The circuit details and assembly dimensions will follow on succeeding sheets.

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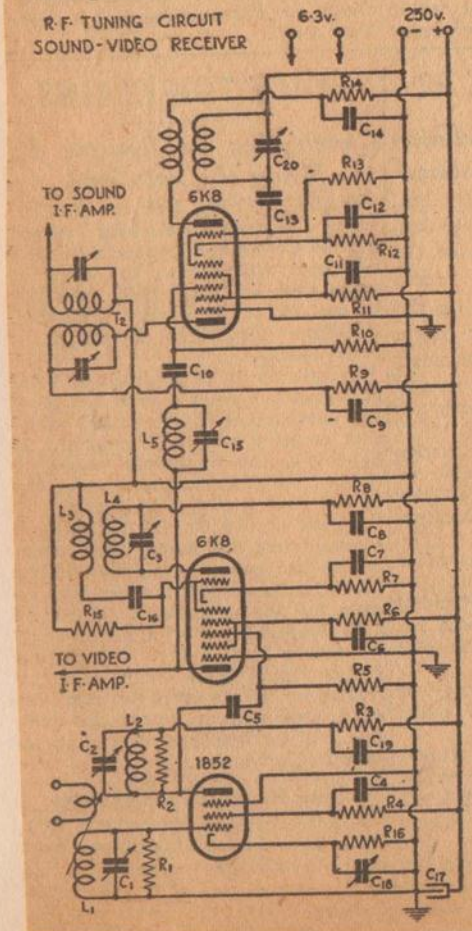
SOUND-VIDEO RECEIVER CHASSIS

The first of the three parts of the sound-video receiver, described on Sheet 330.5, will be assembled on a 4"x10.5" chassis, using the following circuit. The chassis drilling and assembly details will be given on succeeding sheets.



C1 ..35 mmf. Trimair.
C2 ..35 mmf. Trimair.
C3 ..25 mmf. Trimair.
C4 ..250 mmf. (mica).
C5 ..250 mmf. (mica).
C6 ..0.001 mfd. (mica).
C7 ..0.001 mfd. (mica).
C8 ..0.01 mfd.
C9 ..0.01 mfd.
C10..5.0 mmf. (mica).
C11..0.01 mfd.
C12..0.01 mfd.
C13..250 mmf. (mica).
C14..0.10 mfd.
C16..50.0 mmf. (mica).
C17..8.0 mfd.
C18..20-100 mmf. (mica trimmer).
C19..001 mfd. (mica).
C20..10-35 mmf. (mica trimmer).

All fixed mica condensers of small pigtail molded type.
Resistors all ½ watt.
L1, L2, L3, L4, L5 and C15 to be described later.

R1 ..2,000 w.
R2 ..2,000.
R3 ..1,000.
R4 ..60,000.
R5 ..50,000.
R6 ..25,000.
R7 ..350.
R8 ..12,000.
R9 ..12,000.
R10..50,000.
R11..25,000.
R12..350.
R13..50,000.
R14..20,000.
R15..50,000.
R16..160.
T1 ..1,200 kc.
T2 ..456 kc.
Three octal sockets (isolanlite).
Two insulated condenser shaft couplings.

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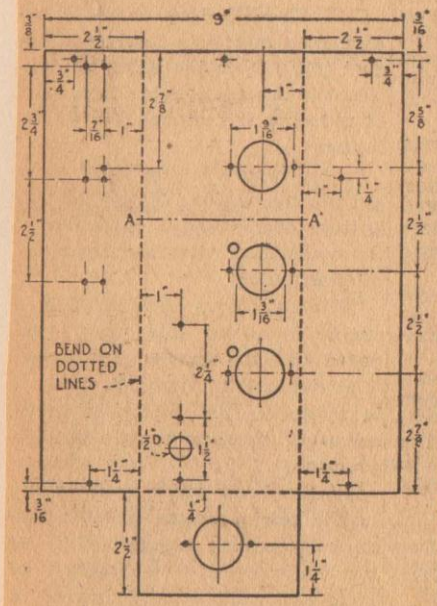
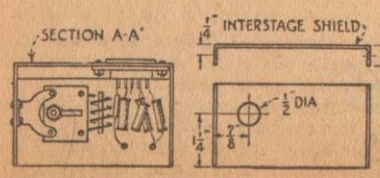
SOUND-VIDEO RECEIVER CHASSIS

The circuit shown on sheet 330.7 will be assembled on a chassis formed from a sheet 9"x13" aluminum, drilled and bent according to the diagram below. In the complete receiver four sheets having these same dimensions will be used, although different drilling plans will be followed on each.





ALL SOCKET HOLES ARE ALIKE
SMALL HOLES - #27 DRILL

The tuning is accomplished by a three-gang variable condenser assembled from individual single units of the Cardwell "Trimair" type, together with standard flexible couplers. Each condenser is mounted by individual horn-shaped brackets supplied with the condensers. This method of assembly accomplishes four things:

(1) The units are spread out so that sufficient space is left between the stages to avoid crowding of the parts; (2) the separate capacities can be individually adjusted for tuning in one or two stations by rotating the shafts of the separate condensers by loosening the set screws in the couplings, so that each condenser can be turned separately; (3) the separate condensers are electrically insulated from each other, so that any of them can be maintained at the high potential level and (4) the oscillator tuning condenser has a lower capacity. It will be necessary to make capacity alignments to insure that correct ganging is obtained when more than one or two stations are to be tuned in, but for initial tests on a single station this can be done by rotating the individual shafts. A shield is mounted so that it divides the prongs on the socket of the first r. f. tube (as shown on sheet 330.6) to prevent intercoupling between the input and output circuits of the 1852 tube.

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SOUND-VIDEO RECEIVER CHASSIS

(Continued)

In the tuning circuits of this chassis (sheet 330.7) the coils L1, L2 and L3 are wound on flat stripes of bakelite ⅝"x2.0"x1-16" with a row of notches 1-6" apart along each edge. The notches on one edge are staggered a little with respect to the other edge and it will be found that a coil of No. 14 bus wire can be wound on a mandrel about 9-16" diameter, slid off and "screwed" onto the notched strip. After a couple of trials with slight changes is the winding diameter it will be found that a simple but substantial coil results. The same construction is used in the other stages except with L4 which is a close wound coil of 5 turns of No. 18 gage insulated wire wound on a mandrel ⅝" diameter, (which is removed) and the coil slipped over L3. The turns are held together by wax or cement to be self-supporting.

The coils L1, L2 and L3 each have 6 turns giving .285 microhenry per coil. The wiring of coil L4 is simplified if it is wound in the reverse direction from L3.

These coils are all mounted by soldering the end turns directly to the tuning condensers with their axes pointing in the directions indicated on sheet 330.6. Wind on a couple of extra turns and straighten out the end turns to provide connection leads.

The choke coil L5 is a wood or fibre tube ⅜" diameter wound with 60 turns of No. 32 silk or cotton covered wire, close wound. It is shunted by a 15. m. m. f. (max.) flat plate trimmer condenser C 15 which does not take up much space physically. The latter condenser is hung by its leads directly on the choke coil L5. It must be tunable within the range 7 to 11 megacycles, to keep the video i-f out of the sound channel.

The transformer T2 connected to the triode section of the second 6K8 is similar to the r-f coupling coil in a T. R. F. broadcast receiver, and forms an oscillator with a 1200 KC frequency. The grid coil may be around 1 millihenry and the plate coil 0.30 microhenry.

This section of the video receiver can be checked only after the video or the sound i. f. section is completed. The sound section is simple to construct and will be covered next week. It is mounted on a chassis similar in size to that shown on sheet 300.8.

This chassis will be bolted alongside the central (r-f) section and the video i-f amplifier chassis on the opposite side.

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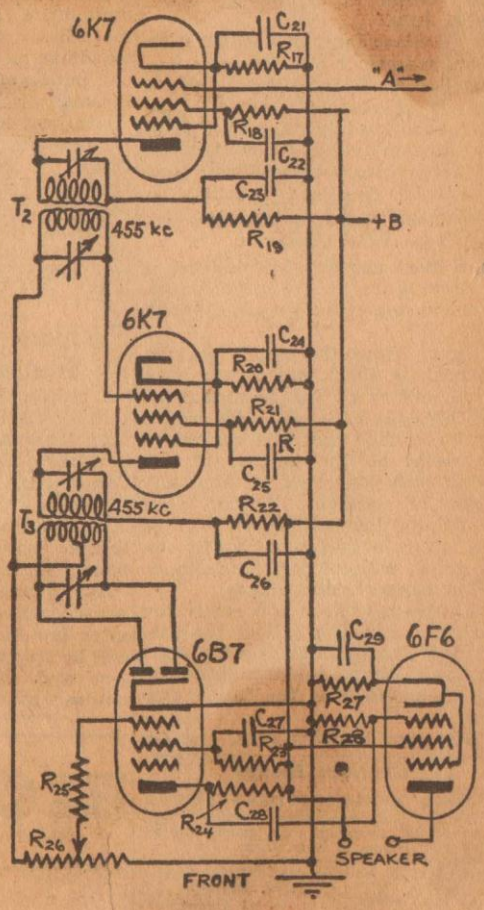
SOUND-VIDEO RECEIVER CHASSIS

Since the double heterodyne principle of reception is to be used for the sound channel in this receiver, almost any convenient intermediate frequency may be used, also any a. v. c. circuit and audio amplifier. Therefore the circuit shown here uses standard 456 kc. intermediates. The lead marked A is a lead that projects from the first i. f. transformer mounted on the other chassis (from transformer T2). The sound i. f. chassis is bolted to the left hand side of the previously assembled chassis, so that the filament and plate supply leads can be connected to the latter. The video i. f. chassis will be mounted on the right side, the three combining to make a complete receiver.

C21 0.1 mfd., R17 500
C22 0.1 mfd., R18 60,000
C23 0.1 mfd., R19 2,000
C24 0.1 mfd., R20 500
C25 0.1 mfd., R21 60,000
C26 0.1 mfd., R22 2,000
C27 0.1 mfd., R23 500,000
C28 0.05 mfd., R24 100,000
C29 10.0 mfd., R25 50,000
T3 456 kc. trans., R26 250,000 max.
T4 456 kc. trans. (push-pull sec.), R27 400
Permanent magnet-type speaker, R28 250,000
4 octal sockets



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SOUND-VIDEO RECEIVER CHASSIS

(Continued.)

On sheet 330.7 a lead from the plate of the type 6K8 converter tube was indicated as leading to the video i-f amplifier. The latter circuit is one of the most important and difficult circuits to adjust in the whole receiver. The nominal or band center frequency in this amplifier is generally set at from 5 to 15 megacycles, the exact value depending on the type of interstage coupling utilized. It has been customary in many of the receivers used in television service in Great Britain to use simple tuned transformers in this amplifier, set at a rather high i-f, say 12 to 15 megacycles, and to shunt each winding with a rather low resistance to broaden the tuning. The coupling transformer may be any one of the following combinations: (1) a tuned plate coil with an untuned secondary coil, (2) doubly tuned plate and grid circuits, or (3) a triple-tuned circuit where the plate and grid circuits are direct coupled by some type of impedance.

The third type of transformer gives the best operation compared with the other types and the higher gain obtained is well wortn the additional effort in construction. It may be stated that it is practically impossible to "design" an i-f transformer for use at these frequencies on account of the different coupling types present, that is, both electromagnetic and electrostatic.

Unlike the triple tuned transformers used in broadcast i-f work where the intermediate winding is not electrically connected to the others, in order to increase the selectivity. This is opposite to what is needed in television, so that the third tuned circuit is used as series impedance coupling between the plate and grid circuits. This arrangement is not unlike a band-pass filter circuit, the main difference being that the latter has little or no magnetic coupling provided between the various inductances in the circuit. The tuned coupling impedance is normally adjusted to a lower frequency than that to which the plate and grid coils are tuned. If the latter are tuned so as to use an i-f of 12 megacycles, the coupling impedance might be tuned to around 9 megacycles.

At this date it is not possible to buy suitable i-f transformers of any type, across the counter, although doubtless several types will be available before long, so that it will be necessary to assemble each transformer coupling from the component parts, in the video i-f chassis associated with the above receiver.

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VIDEO I. F. FILTERS (Continued)

While there are numerous band pass filter circuits that should prove useful as an interstage coupler in an i-f amplifier, many of them are impractical because they contain elements in their structure that are impossible to prepare. To pass a four megacycle band of frequencies, it is not essential that we hold to any definite limits in the selection of the i-f as long as we are able to pass this band, although it is evident that the i-f must be greater than four megacycles. From circuit layouts we have certain factors which affect the filter design. The most important of these is the capacitances of the input and output circuits, due to wiring and tubes. For any design it is possible to hold these capacitances between rather close limits and so they can be utilized usefully as parts of the filter. For best results the filter should be terminated by actual load impedances—that is, they cannot function well operating into the open circuits of a vacuum tube, as echo effects due to phase distortion will result.

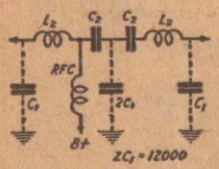

FIG. 1.

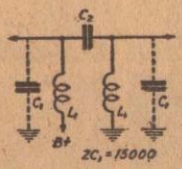

FIG. 2.

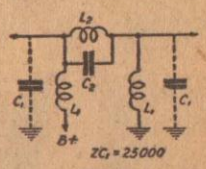

FIG. 3.

Purely as an example—consider Fig. 1 which shows a typical band-pass filter which can be used to pass the frequencies between 7 and 11 megacycles, if the terminal capacitances C1 in m.m.f. at each end are adjusted to equal the constant 12,000 divided by the terminating resistances. Since C1 can never be made less than the tube and wiring capacitances—say about 14 m.m.f.; this would require a terminating impedance of only 900 ohms—too low for consideration if the stage is to amplify efficiently. It is necessary to use great diligence in keeping C1 down to its lowest value.

Other filter circuits, Figs. 2 and 3, should also be examined from this angle. Below each circuit an approximate termination factor is given which permits the arrangement to be analyzed directly as to its utility as a video i-f coupler. This factor is approximately equal to the product of (C × Z) respectively measured in m. m. f. d. and ohms. Assuming that a terminal impedance of at least 4,000 ohms is desired and a circuit capacitance of 12 m. m. f., a termination factor of 50,000 or over is needed.

(To be continued.)

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VIDEO I-F AMPLIFIER

The various problems encountered in the video i-f amplifier construction are being taken up more thoroughly here since it is found that many experimenters desire to make comparisons and tests of the various arrangements possible. The few parts needed in each stage are not expensive and so typical circuits may be readily set up. However, at this time when actual receivable programs are infrequent it is worth while to set up local bench tests to test i-f gain, hence test apparatus and processes will be outlined in later sheets.

The video i-f chassis, of similar shape and size to that shown on sheet 330.8 is provided with four octal sockets. Drilling instructions will follow covering the mounting of the various parts. This chassis is mounted on the right side of the previously described r-f chassis.

On this r-f chassis the plate connection from the converter tube leads to a rejector circuit which is tuned to pass the sound i-f only, a frequency that will be of the order of 6.5 megacycles. The acceptance circuit for the video i-f is also connected to the same point. It must be arranged to pass the frequencies of 7.5 to 11 megacycles, and at the same time it must supply the d-c potential to the converter tube. It is found by test that it is difficult to find any circuit that will accomplish everything desired in the way of filtering and still have a good impedance match for the input and output tube circuits, unless the circuit constants have values that are impractical to construct—that is, condensers having values less than 1 mf., or coils with large inductances and little or no distributed capacitance. In most coupling circuits, therefore, it is necessary to compromise by introducing changes in the impedance matching ratios.

If the first stage has characteristics that satisfactorily cut out most of the sound i-f channel, the subsequent stages can have a different circuit where this rejection is not considered.

It is convenient to couple the converter tube to an 1851 tube which has its control grid on top, so that the first coupler is also mounted on top of the chassis. The other three coupling circuits are mounted beneath the chassis and two type 1852 tubes are used, followed by the video detector, which can be a 6H6. Following this detector, but on the same chassis that holds the cathode ray tube mounting socket, the synchronizing signal and modulation control circuits are found. The video i-f chassis will contain the four filter coupling stages and the four tubes only.

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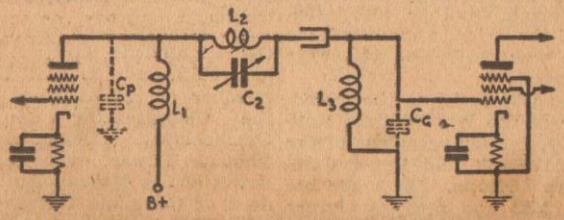
VIDEO I-F CHASSIS

The circuit below shows a filter coupler that may be used between the converter tube and the first i-f amplifier tube, or in fact between any two tubes in this amplifier. In this circuit, as in most of those to be described later, all inductances are single layer in type since a low distributed is necessary. It will be seen that an additional series capacity is inserted to prevent a short circuit to ground. This can be a small molded condenser of about 250 mmf. of the pig-tail type. Its capacitance with respect to ground should be kept low, as well as that of the coil L2 and the trimmer C2. These items must be kept away from the chassis.

All designs will be based on passing from 7.5 to 11 megacycles, with a high attenuation for 6.5 megacycles, which is the sound i-f.

The coils L1 and L3 with the inherent circuit and tube capacities must each tune to about 9.25 megacycles. Several methods are possible for adjusting these circuits: a small trimmer condenser shunted around each coil, or by permeability tuning by pushing a small iron-dust core in or out until resonance is established (and then cementing it in place), or by inserting a brass plunger in it until the inductance is reduced to the correct value. The value of L1 and L3 must be made larger initially than that suggested below in the last arrangement. If iron-dust cores can be obtained, about three-eighths inch diameter and one-half inch long, they are to be recommended.



The coil L2 is tuned by a small trimmer condenser (air or mica) designated C2. It is adjusted to a lower frequency, say from 5.5 to 6.5 megacycles. The exact procedure on making these adjustments will be described later. The condenser C2 should have a capacitance of 10 to 35 mmf., as it will have a circuit setting of around 28 mmf. The coils L1 and L2 have forty-five turns of No. 30 enamel wire, close wound on a tube one-half inch in diameter, and L2 has fifty-two turns similarly wound.

NOTE—The Data Sheet published last week should have been numbered 330.13

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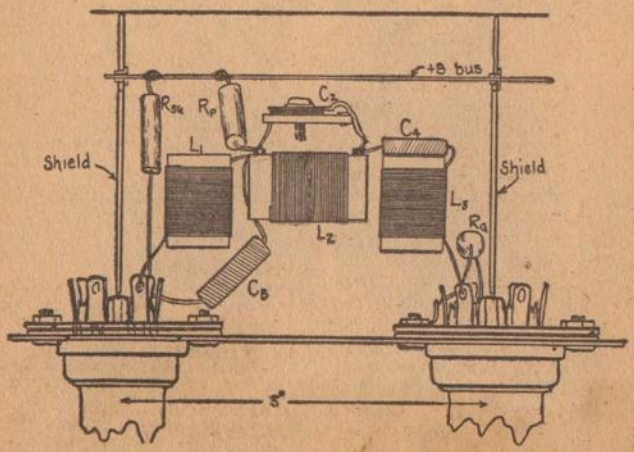
VIDEO I.F. AMPLIFIERS

The use of single-ended amplifier tubes, such as the 1852, with the input and output terminals fairly close together requires extra care to keep the feedback low, since any regeneration will narrow the frequency band passed, and will introduce phase distortion. Interstage shields can be mounted so as to "split" the octal socket, passing near or between terminals 1 and 8 and 4 and 5 on the socket, dividing the input and the output terminals into the separate compartments that hold the I. F. coupling stages. The three coils, wound as shown on the preceding Data Sheet, can be suspended from heavy No. 14 wire leads, as indicated in Fig. 1 below.



As in other sections of this receiver, two No. 14 bus wires extend the length of the chassis, supplying all stages with B and ground bus connections. The resistors and condensers are supended between these bus wires and the appropriate terminals on the socket. A few of these are shown in this figure. Drilling plans for the video I. F. chassis will follow on the next sheet. It is not necessary that the same method of interstage coupling be used in each stage so that the layout will permit future experimentation.

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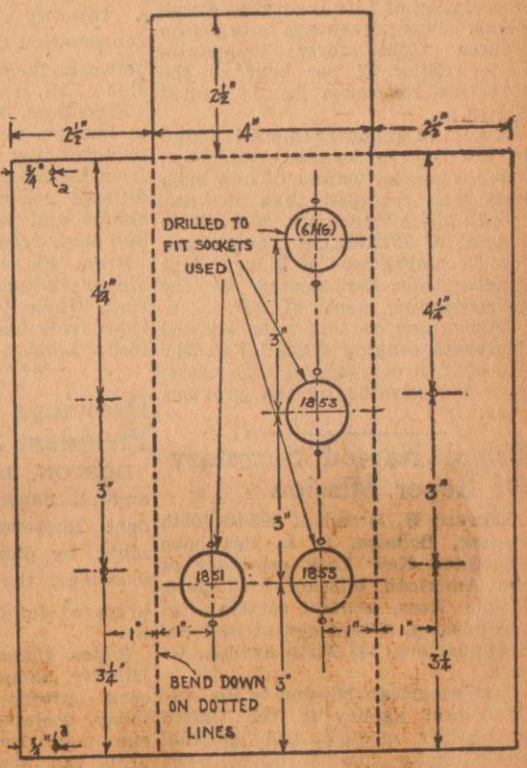
SOUND-VIDEO RECEIVER CHASSIS

The aluminum chassis shown below is the third and final of a set which, clamped together, form the video-sound receiver. The size and shape of each is the same, the only difference being the socket drilling holes. The three pieces are screwed together through holes (marked "a" on diagram below) near the front and rear edges of one side. It is convenient to allow a small space between them, separated by a washer when assembling, to allow for the screwheads which appear on the side walls.

On this chassis the first I. F. coupling filter is mounted on top of the chassis, connecting the plate circuit of the converter tube (on the center chassis) with the input grid of the 1851 tube below. There are three compartments in the space beneath the chassis below, as mentioned in the last sheet, using two aluminum shields, similar to the one shown on sheet 330.8, and bent to fit the inside dimensions of the chassis.

The output of the first I. F. stage (the 1851) connects through a coupling circuit in the front compartment to the input grid of the second tube, and 1853. The circuit connecting the second tube to the third (also an 1853) was described in the last sheet. The final tube connects to a diode rectifier stage, which can be of the type described on sheets 200.13 and 200.14. Since the video amplifier and its associated filter circuits are mounted near the cathode ray tube, socket, the details of the wiring in this section will be given then.



Sheet 330.16.

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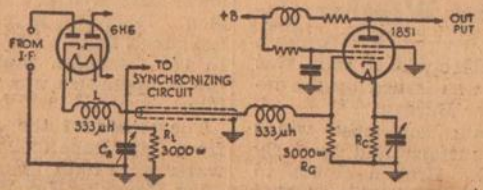
SOUND-VIDEO RECEIVER CHASSIS

The intermediate frequency carrier having passed through several stages of amplification, is now ready for rectification. This carrier has retained the same proportions of amplitude modulation that are in the original transmitted signal and upon rectification will be converted into a video signal, similar to the variable component of the signal output of the Iconoscope in the studio. In some transmission systems the direct current component of this signal may have been cut out, in which case it must be restored by special means in the receiver circuit. In other systems the d-c component is retained in the transmitted signal and shows up as a change in the average carrier level in each scanning line.

It is apparently not essential that d-c restoration in the video stages be made, as good results are possible without considering slow changes in the picture background; but in this case the video amplifier should be capable of amplifying video frequencies as low as 60 cycles. Improvements in the background control can therefore be left until preliminary tests are made on other characteristics in the receiver.



The second detector (a 6H6 diode) can be fed from the same style of i. f. transformer used in the other stages. In this tube, however, the cathode is not at ground potential so that capacitance to ground of both the plate and the cathode elements must be kept low. In Fig. 1 a circuit is shown which (with different values) would be useful in any broadcast receiver. The peculiar frequency requirements in a television receiver require that a low-load resistance be used, viz.: A few thousand ohms at the most. In the usual circuit one section of this diode only will suffice and it is not necessary to multiple both halves.

The output filter must be carefully designed. The ordinary brute-force low-pass filter would prove inadequate with a loss of fidelity. The filter must pass all frequencies up to three megacycles or more, and at the same time must cut out all the i-f carrier frequency range which starts at about 7.5 megacycles.

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SIMPLE RECEIVER FOR TELEVISION SOUND

The chassis shown on the sheet 330.16 provides socket space for the second detector, a 6H6 double diode rectifier. It can be mounted above the chassis on half inch spacers, if convenient, to reduce the capacitance to ground. The tube shield should not be grounded for the same reason. The loading resistance RL has a resistance of about 3,000 ohms, although it is effectively shunted by the resistance RG. The latter also is set at 3,000 ohms for preliminary experiments. Later tests can be made, when the other circuit adjustments have been completed, to determine if this value is best.

The coils that are used in the filter are close wound with No. 36 enamel wire, 183 turns on a cardboard (waxed) or a bakelite tube ¾-inch in diameter. The condenser Ca is a tuning condenser used to set the band range of this filter. It has a capacity of around 25 mmf. maximum and can be a small-sized trimmer. In general the setting of this condenser will be less than 15 mmf. The two inductances in the filter are alike, but one is mounted on the i. f. chassis near the second detector tube (6H6), and the other near the input grid of the video amplifier tube, an 1851 pentode, which is mounted near the socket of the cathode ray tube. This requires the filter to be split with one section at each end of a shielded connection lead. The latter lead should be as short as possible, and should be of the coaxial line type, a short length of copper or brass pipe, three-eighths-inch in diameter inside, with a few coaxial line "beads" keeping the center wire away from the outer shield. In the circuit on sheet 330.17, the video amplifier tube is shown with certain of its constants, although its plate circuit is incomplete, since the actual circuit will depend upon whether a magnetically deflected cathode ray tube is used, or one that has deflection plates. The former tube is operated with its cathode at ground potential, (or approximately so) while the latter operates with the anode at ground potential, so that considerable differences must be noted in the associated circuits, which will be covered on another sheet.

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MODULATION CONTROL OF CATHODE RAY

In the following analysis the easiest system will be assumed, viz., modulating a magnetically deflected cathode ray tube such as the type 1800, for in this tube the cathode is operated at ground potential or at a potential very nearly so.

In order to take care of a wide intensity range, even when the tube is operated at anode potentials of over 5,000 volts, it will be well to consider that a grid voltage swing of at least 30 volts will be necessary. In the circuit—sheet 330.17—a video amplifier stage using an 1851 tube is shown. The term video amplifier is used to designate an amplifier that will handle the video frequency range (of zero to three megacycles) efficiently. The function of this amplifier (as outlined on sheet 200.12) is to alter the bias to a more negative value whenever the carrier level or its rectified envelope increases.

It is desirable that the amplifier tube and the modulation grid be conductively coupled, so that the low frequency components of the carrier are not lost.

In the circuit—sheet 330.17—as the carrier level increases the drop across RL increases, which amounts to saying that the control grid of the 1851 tube goes more positive. Thereupon its plate impedance decreases and the potential appearing between the output terminal (connected to the anode) and ground is reduced. A simple arrangement would be to connect this output lead directly to the modulation grid of the cathode ray tube and the cathode of the latter tube to the arm of a potentiometer connected across the "B" potential terminals of the power unit supplying the 1851 tube. This circuit was already described on sheet 200.14, so will not be repeated again.

The cathode ray tube is operated from its own power unit in so far as its anode and focusing potentials are concerned. The grid bias, however, is obtained from the power unit that supplies the video amplifier tube. This arrangement, however, requires that the latter potential be applied ahead of the high voltages. It is usually convenient if the heater of the cathode ray tube be operated from a winding on the transformer in the amplifier power unit.

Probably the ideal system would have the high voltage applied by a relay-operated device or timer that would function only after the low-voltage units have started to work. This would prevent the fluorescent screen from becoming damaged by a heavy stream of electrons due to insufficient biasing voltage before the low-voltage power units start functioning.

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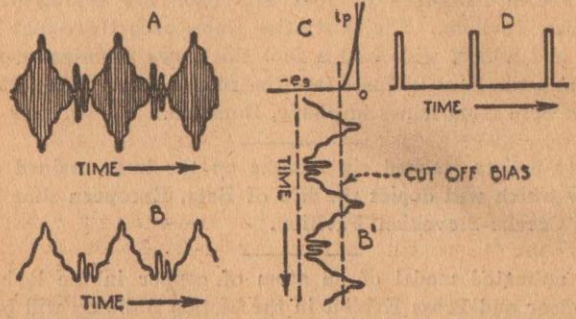
SYNCHRONIZING PULSE SEPARATION

When the direct or conductively coupled video amplifier stage is used, as outlined on sheet 330.19, the need of d-c restoration circuits (of the type described on sheet 200.14) is not important and may be omitted for preliminary tests. Instead of using the pulse filter circuit shown, an alternate method can be applied to the circuit on sheet 330.17 which shows a lead designated "To synchronizing circuit." This connection represents a method whereby the synchronizing pulses can be separated out of the video signal, without applying unusual capacitive loading to the filter circuit. The input circuit of a synchronizing pulse amplifier tube can be directly connected to this lead, with certain precautions. The d-c voltage across the resistance RL follows the envelope of the carrier so that both the video signals and the synchronizing pulses to this tube are present.



The video signal should be eliminated as quickly as possible from the pulse amplifier circuit at least before any amplification takes place. It is also desirable that the input circuit of the pulse amplifier tube present a high impedance at least during the video pulse interval. During the blanking signal periods it makes little difference whether the pulse amplifier affects the video amplifier stage or not.

In figure 1, curve A represents an oscillogram of the incoming i-f carrier, and curve B the rectified envelope of this wave. If the potential curve B were to be applied to a tube, whose plate current characteristics are represented by the curve C, the output circuit of this tube would have a sharp pulse given out each time the blanking signal occurs. If the bias on the tube is carefully adjusted the video signal is entirely eliminated from the synchronizing pulse channel since it does not have enough amplitude to counteract the cut-off bias of the grid.

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THE PROBLEM OF VIDEO AMPLIFIER DESIGN

The whole matter of television equipment design would be much simpler if it were not for the problems associated with broad band amplification. The need for an equalized gain at all frequencies up to some 3 megacycles is common knowledge, but the requirement of equal phase displacements over this range of frequencies is less understood.

In laying out either an i. f. amplifier system or a broad-band video amplifier for television use, both effects must be considered.

In this problem a great many factors must be considered by the designing engineer, but the experimenter will probably be satisfied by knowing first what tubes to select and then what circuit constants to use with those tubes. In this application it can be stated that tubes with the highest amplification factors are usually less suitable than tubes with other characteristics, such as: (1) the mutual conductance (gm) should be as high as possible, (2) the interelement capacity should be low. The term mutual conductance is not as commonly understood as the amplification factor. However the difference can be readily estimated from the following relation: Mutual conductance is equal to the amplification factor divided by the internal plate impedance of the tube. The mutual conductance of a type 6J7 tube is 1100 micromhos, while that of the new 1851 tube is 9000 micromhos. The gain that can be obtained from a given amplifier stage is proportional to the product of the applied load impedance and the mutual conductance of the particular tube used.

All tubes have more or less capacitance between any one element and the other elements and ground. The leakage across this capacity at the higher frequencies is sufficient to cut the amplification down to a low value unless precautions are taken to compensate for this effect. In order to equalize the amplification at high and low frequencies the usual plan is to sacrifice some of the gain possible in the latter range. This can be done by reducing the value of the plate load resistance until it is much lower than the impedance of the capacity shunt values at the highest frequency it is desired to pass.

The i. f. transformers therefore are shunted, in some designs, by a resistance of, say, 5000 ohms. The voltage change produced by the tube across this load is equal to

$$\frac{5{,}000 \times 9{,}000}{1{,}000{,}000} F E_g$$

where F is a loss factor that depends upon the values of numerous shunting impedances &c., that tend to lower the gain. If we assume that F equals 0.6 and the type 1851 tube is used the gain per stage is 45x.6 or 27.0.

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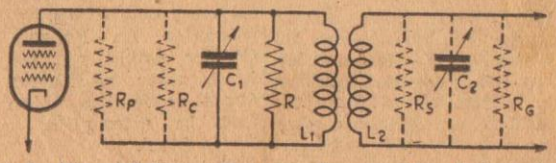
VIDEO I. F. CHANNEL TUNING.

In the superheterodyne type of television receiver the separation of the video signals from its adjacent sound program and from other signals is accomplished by the tuning of the Video I. F. circuits. Possible methods are:

1. Tuned interstage transformers.
2. Impedance coupled circuits.
3. Filter coupling networks.

These methods will be considered separately. In the transformer method, some of the problems encountered have been outlined on sheet 200.6. In analyzing the problem, consider Fig. 1, where the essential circuit factors are enumerated.

Whereas, in the design of I. F. transformers for sound reception, sufficient band width can be obtained by close coupling, the same method cannot be extended so as to include the video band as the double hump characteristics of closely coupled circuits comes into play and prevents any constancy in gain over the desired band.



In Fig. 1, the resistance Rg, can be considered infinite except for the final stage, where the load is usually a diode rectifier. In the transformer itself the important factors which affect the selectivity and gain, are the primary and secondary power factors.

This term takes into consideration the combination of a number of loss factors, that is, the primary power factor is equal to the reactance of the primary winding at the nominal intermediate frequency divided by the effective resistance in the circuit. As shown in Fig. 1, this resistance is equal to the parallel combination of Rp, Rc and R. Here Rp is the plate impedance of the tube, Rc the effective resistance due to losses in the coil, and R an external shunt resistance added to obtain the required band pass.

(To be continued.)

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VIDEO I. F. CHANNEL TUNING

(Continued.)

It can be shown that

In the video frequency I. F. amplifier circuit shown on Sheet 340.2 the pass band width is proportional to the sum of the primary and secondary power factors, so that either or both can be made high. However, the gain per stage can be increased if the primary power factor is made larger than the secondary power factor, which is the equivalent of saying that all resistance loading should be done in the primary circuit. At the same time the secondary circuit should have as high an inductance as possible, giving a step-up transformation ratio. The rules therefore for a successful I. F. transformer are:

1. A large step-up ratio, preferably where the secondary inductance is tuned to the desired frequency by the stray circuit capacitance only.

2. A low value of shunting resistance across the primary.

3. A minimum load across the secondary. When operating into a diode rectifier the load resistance is approximately equivalent to one-half the d. c. resistance of the resistor connected in series with the diode. This resistance therefore should be quite large.

4. The coupling should be rather tight. However, the output will be affected by the capacitive coupling between windings. The relative polarity of the windings therefore has an appreciable effect so that this factor must be studied by experiment.

In using the new high conductance tubes, such as the 1851, 1852 or 1853, it is found that both the input capacitance and input conductance are not constant, but vary considerably as the plate current changes. Actually the plate resistance and plate circuit capacitance are transferred back into the input circuit, producing degenerative effects, unless the plate load happens to be inductive at all values of frequency encountered in the I. F. system. As a result the tuning of the grid circuit shifts somewhat, producing effects which are difficult to compensate. In the Operating Notes of the Raytheon R K 1851 it is stated that this effect can be reduced if a part of the cathode resistor is left un-bypassed, but at some loss of effective transconductance and some increase in effective grid to plate capacitance. To prevent excessive grid-to-plate capacitance the external capacitances between plate and cathode leads should be kept at a minimum.

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For several reasons the design of coupling units for wide-band i. f. amplifiers is quite intricate if all factors are considered. One difficulty is that of securing correct impedance matching. A transformer with a particular turn-ratio may be used to couple circuits having different impedances, but in the case of the television i. f. range, a transformer is not a very efficient transfer device. For true transformer action, magnetic coupling only should be present between windings, but it is difficult to eliminate all of the electrostatic coupling in practical designs. It is also possible to couple the circuits by electrostatic means, (such as band-pass filters) by condensers or by combinations of condensers and coils, but in this case the design is complicated by having any magnetic coupling present.

The gain of an amplifier stage using such a coupling unit is generally found to be proportional to the transconductance (which is abbreviated as Gm) of the amplifier tube, and inversely proportional to both the effective capacitance to ground of the circuits elements, and the band width required.

The first item depends entirely upon the characteristics of the amplifier tube selected, but it is also necessary to operate this tube with the correct voltages or much of its Gm is lost. Recent television amplifier tubes have a value of 8,000 or 9,000 for this factor. However such tubes have a larger input capacitance as well, so that this theoretical gain is lowered. The importance of maintaining a low capacitance to ground in all parts of the circuit is frequently lost sight of in some television assemblies. For example the 6K7 is a well known i. f. amplifier tube, and corresponds almost identically with the glass tube 6D6, but the latter has a lower capacitance in both its grid and plate circuits and therefore has a higher amplification factor on a wide-band amplifier. The band-width requirement sets serious limitations on the average amplification over the selected band, and in fact a four-megacycle pass band gives only half the gain of a two megacycle band.

An analysis of the results can be predicted by a study of the above-mentioned factors, for several representative tubes:

Tube	Cg mmf.	Cp mmf.	Gm	Rel. Gain.	Tube	Cg mmf.	Cp mmf.	Gm	Rel. Gain.
6K7	7	12	1650	1.8	1851	11.5	5.2	9000	11.7
78	4.5	11	1650	2.35	1852	11	5	9000	12.2
6D6	4.7	6.5	1600	2.9	1853	8	5	5000	7.9