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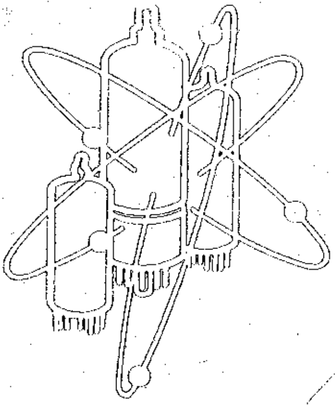

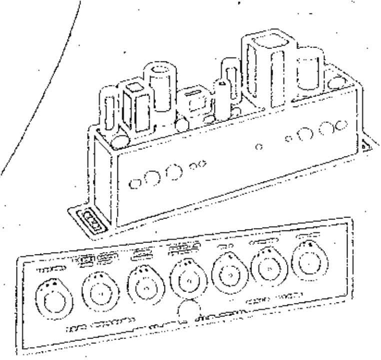

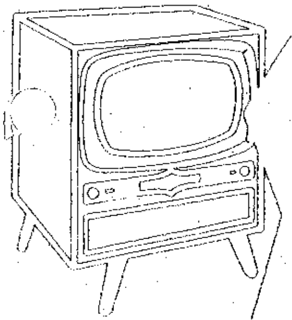

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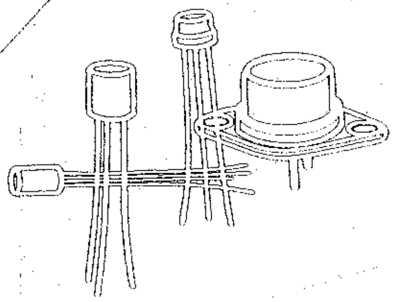

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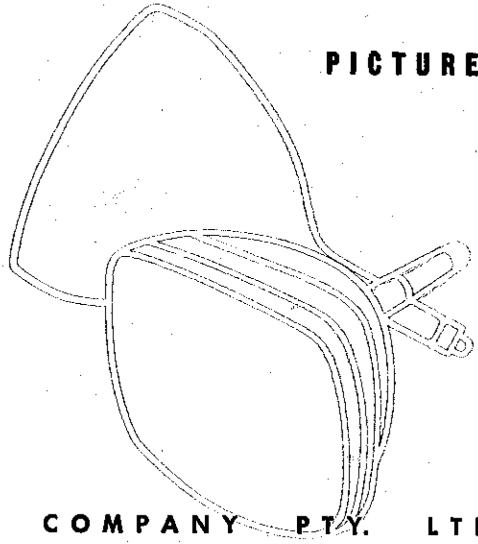

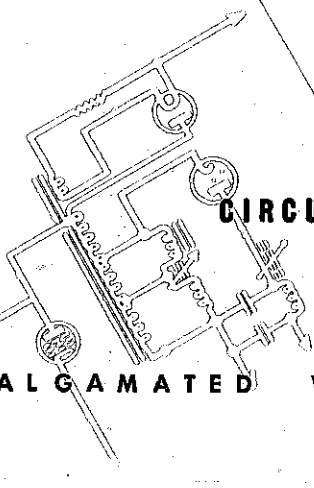

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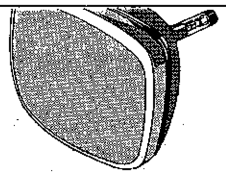

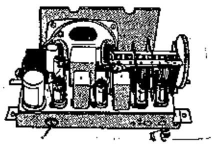

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LINEAR R-F POWER AMPLIFIERS ...... Reprinted from July '56, P.80 107

The increase in the use of single-sideband, suppressed-carrier transmission in amateur radiotelephony has revived interest in linear r-f power amplifiers. This article deals with the determination of typical operating conditions for this type of circuit.

VISUALISING SWR 112

The use of the "SWR Circle" clarifies theories on standing wave ratio, and assists amateurs in minimising SWR on aerial feeders and the like.

NEW RCA RELEASES 114

Brief data is given on the new types listed below.
Further information is available on request.
6814 Subminiature medium-mu triode.
7027 High perveance beam power valve.
7200 Multiplier phototube, 9-stage.
2CY5 Sharp cut-off tetrode for v-h-f TV tuners.
6CY5 Sharp cut-off tetrode for v-h-f TV tuners.
Deflection Systems and Components.

HIGH FIDELITY — PART 3 — HIGH FIDELITY CIRCUITS 115

The first two parts of this article discussed general considerations of high fidelity and acoustics. The discussion now turns to the elements of high fidelity circuits.

RADIOTRON 6146 120

Notes on how to get more hours from this popular valve.

EDITOR ...... **BERNARD J. SIMPSON**

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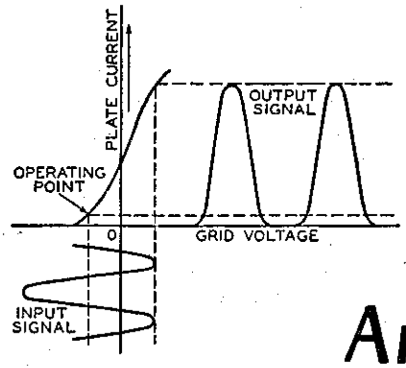
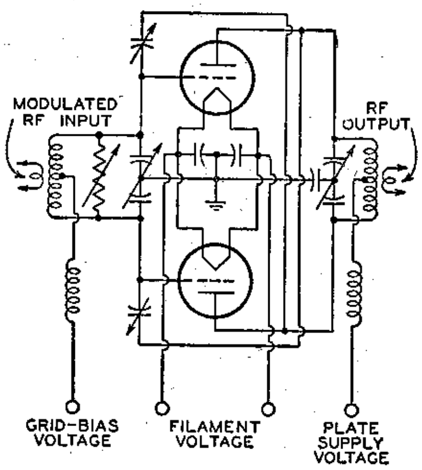
Each side band has power of [illegible]
Carrier power = 2/3 [illegible]

[illegible] = Total of 100%



Linear r-f Power Amplifiers



By A. P. Sweet

During the past several years, there has been a tremendous increase in the use of single-sideband, supressed-carrier transmission in amateur-radio radio-telephony. This type of transmission offers several advantages over the widely-used amplitude modulation methods. These advantages include reduced band-width and the elimination of heterodyne-interference problems. More useful power can be obtained with the same valves and power supplies or, conversely, smaller valves and power supplies can be used to deliver the same useful power.

With high-level amplitude modulation, a carrier and two groups of sideband frequencies are generated. The total power in the two sidebands at 100 per cent. modulation is equal to one half of the carrier power. Thus, for every 100 watts of total transmitted power, 67 watts is in the carrier and 16.5 watts is in each sideband. Yet, one sideband contains all of the necessary intelligence for communication, provided certain receiver requirements are met.

HALF THE BANDWIDTH

Single-sideband, suppressed-carrier transmission utilises only one sideband. By the elimination of the other sideband, the bandwidth is cut in half. By suppression of the carrier, heterodyne interference is eliminated. Only 16.5 watts of power is required to convey the same intelligence. Conversely, if the original 100 watts of power is transmitted in a single sideband, six times the former useful power will be obtained.

The literature contains considerable information on various methods of generating single-sideband, suppressed-carrier signals. However, little information is available on the choice of valves for amplifying these signals and the methods of calculating typical operating conditions for these valves.

LINEAR R-F AMPLIFIERS

Single-sideband signals must be amplified by linear r-f amplifiers. These amplifiers are identical to a-f power amplifiers except that resonant tank circuits are used in the grid and plate circuits instead of audio-frequency transformers. Consequently, the valve manufacturer's ratings for a-f power amplifier and modulator service for class A, AB_1, AB_2, and class B and typical operating conditions will apply, provided the valve is also capable of operating at the higher frequencies involved. The same derating factors for plate voltage and input versus frequency shown by the manufacturer for class-C telegraphy ratings should be applied to single-sideband operation at the frequencies where they become applicable.

Because the tank circuits act as energy-storage systems, it is not necessary (as in the case of audio work) to use two valves in push-pull in class-AB or class-B, linear r-f amplifiers. However, if only one valve is used, the r-f harmonics will be higher, thereby making the TVI problems more severe.

Although the manufacturer's ratings are based on 100 per cent. modulation with sine-wave signals, normal voice modulation reaches this condition only on the peaks of modulation. The ICAS ratings have taken this factor into account. Consequently, no attempt should be made to operate above these maximum ratings. Such operation will result in shorter valve life and the possibility of early valve damage during transmitter adjustment or unexpected overloads such as microphone "howl."

Since only r-f power amplifiers are being considered, Class A operation will not be discussed further. Of the remaining classes, AB_1 operation with tetrodes or pentodes is the simplest since only the plate and screen-voltage supplies require good regulation.

Table 1 includes the maximum ratings and typical operating conditions for several valves used as linear r-f power amplifiers. If it is desired to operate at conditions other than those given, typical conditions can be calculated by means of the following procedure:

1. Make sure E_b is within valve ratings.
2. Refer to the published curves. On the average plate characteristics curves, select a point

on the zero grid-voltage curve near the "knee", and record i'_b, and e_{bmin}; from the average screen-grid characteristics curves, determine i'_{c2} for this point.
(E_{c2} equals the value shown for the curves used.)

3. Calculate I_{bms}: $I_{bms} = i'_b/3$.
4. Calculate PD:
$$PD = \frac{I_{bms}}{4} (E_b + 3e_{bmin}).$$
5. Calculate SI: $SI = E_{c2}i'_{c2}/4$
6. Calculate PI: $PI = E_b I_{bms}$
7. Check the values found in steps 4, 5, and 6 to determine whether they are within valve ratings. Normally, they will be within ratings for AB_1 operation. If they are not, a lower value of i'_b (either in the negative-grid region or at a lower screen voltage) must be selected and steps 2 to 7 inclusive repeated.
8. Calculate PO: PO = PI—PD
9. Calculate I_{bo}: $I_{bo} = I_{bms}/5$.
10. E_{c1} can now be found on the plate characteristics curves as the grid voltage where the plate voltage is E_b and the plate current is I_{bo}.
11. $E'_g = (E_{c1}) + e_{cm}$.
This value of E_g is the absolute value of E_{c1} (the brackets mean ignore the sign) plus the algebraic value of e_{cm} (include the sign). If the original point in step 2 was selected on the zero grid-voltage curve, then e_{cm} is equal to zero and
$$E'_g = (E_{c1}).$$
12. Calculate I_{c2}: $I_{c2} = i'_{c2}/4$
13. Calculate DP: $DP = \frac{E'_g i'_{c2}}{2}$ (for AB_1 operation, $i'_{c1} = 0$ so DP is zero.)

E_b	D.C. plate voltage.
e_{bmin}	Minimum plate voltage for the required peak current (from the characteristics curves).
E_{c2}	D.C. screen voltage.
E_{c1}	D.C. control grid voltage.
e_{cm}	Maximum grid-voltage drive to obtain the required peak plate current at a given minimum plate voltage.
E'_g	Peak value of grid-voltage swing.
I_{bms}	Maximum-signal, d.c. plate current.
I_{bo}	Zero-signal, d.c. plate current.
i'_b	Instantaneous peak plate current.
I_{c2}	Maximum-signal, d.c. screen current.
i'_{c2}	Instantaneous peak screen current.
i'_{c1}	Instantaneous peak grid current.
PD	Plate dissipation at maximum signal.
PI	Plate power input at maximum signal.
PO	Power output at maximum signal.
DP	Driving power at maximum signal.
SI	Screen input at maximum signal.

CLASS-AB_2 TETRODE OR CLASS-B TRIODE OPERATION

Class-AB_2 tetrode and class-B triode operation provide more power than class-AB_1 operation, but have the disadvantage of placing stiffer requirements on the driver and grid-bias supply regulation.

Calculation of typical operating conditions other than those given in the valve data sheets is slightly more complicated for class-AB_2 and class-B operation than for class AB_1, but is still relatively simple with the procedure outlined below: *

1. Make sure E_b is within valve ratings.
2. Assume a value of I_{bms}. A good starting point is at
$$I_{bms} = \frac{3 \text{ (rated PD)}}{E_b}$$
Check this value to see whether it is within ratings. If it is not, use the maximum rated value of I_{bms}.
3. Calculate i'_b: $i'_b = 3I_{bms}$
4. From the plate characteristics curves, select a value of e_{bmin} near the "knee" of the curves at which i'_b can be obtained. Also record E_{c2}, e_{cm}, i'_{c1} and i'_{c2} for this point.
5. Calculate PD:
$$PD = \frac{I_{bms}}{4} (E_b + 3e_{bmin}).$$
6. Calculate SI: $SI = \frac{E_{c2}i_{c2}}{4}$
7. Calculate PI: $PI = E_b I_{bms}$

Check the values found in steps 5, 6, and 7 to determine whether they are within the maximum ratings for the valve type. If the calculated values exceed the maximum ratings, choose a lower value of I_{bms} and repeat steps 3 through 7.

If the plate dissipation and input are below the maximum ratings but the screen input is high, it may be possible to choose a higher value of e_{bmin} in step 4 (and repeat steps 5, 6, and 7) to get all values within ratings. The reverse case can also be applied.

If all the values are well below maximum ratings, a higher value of I_{bms} can be chosen in step 2, and steps 3 to 7 inclusive, repeated to see whether the operation is still within ratings. If so, this latter set of operating conditions will provide slightly more power output.

When values that are slightly below the maximum ratings are obtained for plate dissipation, screen input, and plate input, the corresponding value of I_{bms} represents the maximum value which can be used at the original plate voltage selected. Lower values of I_{bms} which give more conservative

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* Calculation for tetrodes is discussed: the triode case is the same except for the omission of the calculation of screen-input power.

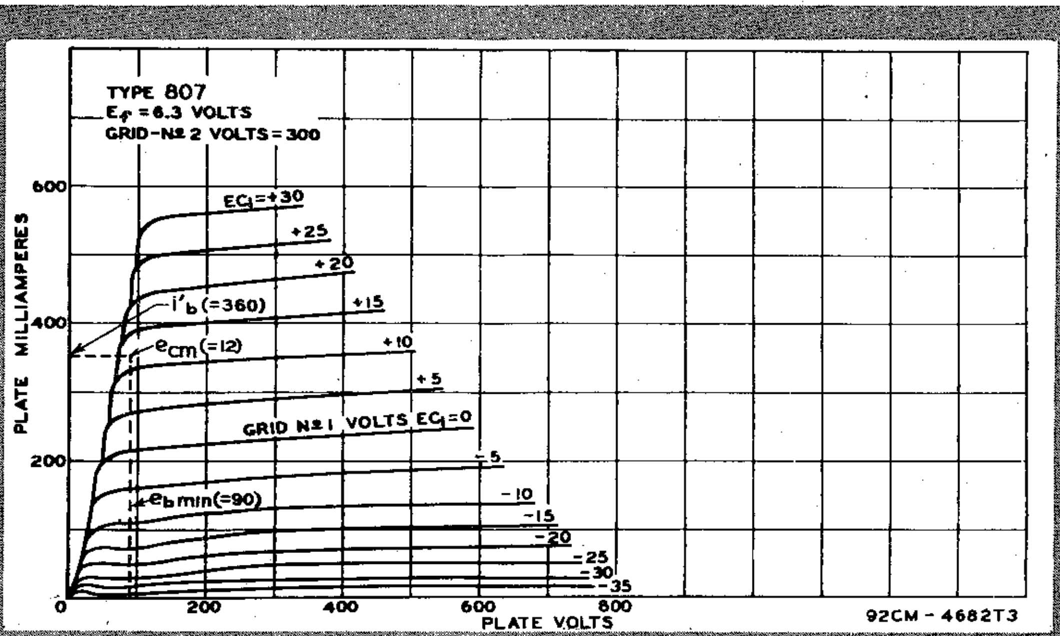


Fig. 1. Average plate characteristics for the type 807 (grid-No. 2 voltage = 300).

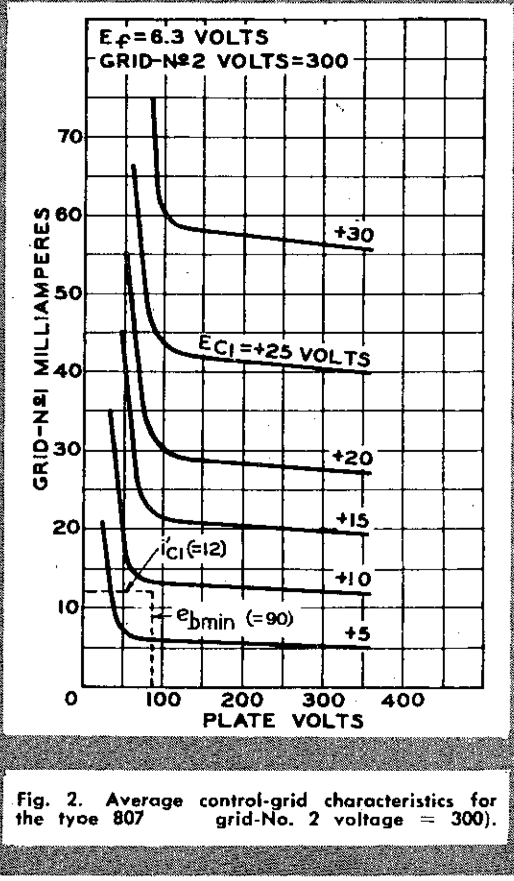


Fig. 2. Average control-grid characteristics for the tyoe 807 grid-No. 2 voltage = 300).

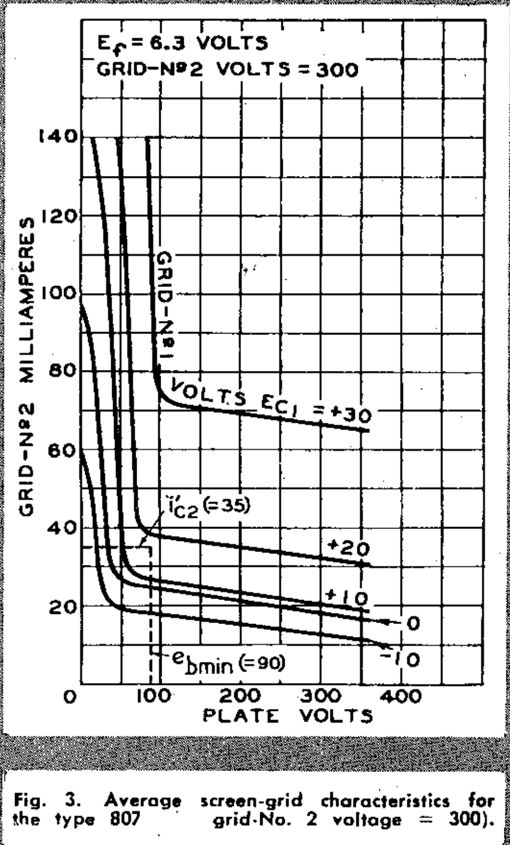


Fig. 3. Average screen-grid characteristics for the type 807 grid-No. 2 voltage = 300).

These curves are drawn to more open scales in July '56 issue, P82.

			Maximum Ratings - Absolute Values							Typical Operation								
Tube Type	Class of Operation	Service	Plate Voltage (E_b)	Screen Voltage (E_{c2})	Max-Signal Plate Current (I_{bms})-ma	Max-Signal Plate Input (PI)-watts	Max-Signal Screen Input (SI)-watts	Plate Dissipation (PD)-watts	Grid Resistance -ohms	Plate Voltage (E_b)	Screen Voltage (E_{c2})	Grid Voltage (E_{c1})	Peak Grid Voltage (E'_g)	Zero-Signal Plate Current (I_{bo})-ma	Max-Signal Plate Current (I_{bms})-ma	Max-Signal Screen Current (I_{c2})-ma	Drive Power (DP) -watts	Max-Signal Power Output (PO)-watts
2E26	AB$_1$	CCS	400	200	75	30	2.5	10	30 K	400	200	-25	25	9	45	10		12
		ICAS	500	200	75	37.5	2.5	12.5	30 K	500	200	-25	25	9	45	10		15
	AB$_2$	CCS	400	200	75	30	2.5	10		400	125	-15	30	10	75	16	0.2	20
		ICAS	500	200	75	37.5	2.5	12.5		500	125	-15	30	11	75	16	0.2	25
4-65A	AB$_1$	CCS	3000	600	150		10	65	250 K	1000	500	-85	85	15	85	12		40
										1500	500	-85	85	15	90	7		70
										1750	500	-90	90	10	85	9		85
	AB$_2$	CCS	3000	600	150		10	65		1000	250	-30	105	30	150	22	2.5	85
										1500	250	-35	100	30	125	15	1.5	125
										1800	250	-35	90	25	110	13	1.0	135
4-125A	AB$_1$	CCS	3000	600	225		20	125	250 K	1500	600	-90	90	30	110	9		80
										2000	600	-94	94	25	120	3		115
										2500	600	-96	96	25	115	4		165
	AB$_2$	CCS	3000	400	225		20	125		1500	350	-41	141	44	200	17	5.0	175
										2000	350	-45	105	36	150	3	3.0	175
										2500	350	-43	139	47	130	3	2.5	200
4-250A	AB$_1$	CCS	4000	600	350		35	250		2000	500	-88	88	55	200	11		230
										2500	500	-90	90	60	215	7		310
										3000	500	-93	93	60	205	5		370
	AB$_2$	CCS	4000	600	350		35	250		2000	300	-48	100	60	255	13	5.5	325
										2500	300	-51	100	60	250	12	5.0	420
										3000	300	-53	100	62	236	16	4.5	520
807 1625	AB$_1$	CCS	600	300	120	60	3.5	25	100 K	500	300	-32	32	22	70	8		23
										600	300	-34	34	18	70	8		28
		ICAS	750	300	120	90	3.5	30	100 K	750	300	-35	35	15	70	8		35
	AB$_2$	CCS	600	300	120	60	3.5	25		500	300	-30	43	30	120	10	0.2	38
										600	300	-32	40	24	100	9	0.1	40
		ICAS	750	300	120	90	3.5	30		750	300	-35	48	15	120	10	0.2	60
811A	B	CCS	1250		175	165		45		750		0	100	16	175		10	90
										1250		0	78	25	130		4	120
		ICAS	1500		175	235		65		1000		0	93	22	175		7.5	125
										1250		0	88	27	175		6	155
813	AB$_1$	CCS	2250	1100	180	360	22	100		2000	750	-90	80	25	130	20		165
										2250	750	-95	85	25	125	26		190
		ICAS	2500	1100	225	450	22	125		2500	750	-95	90	25	145	27		245
829B Natural Cooling	AB$_1$	CCS	750	225	250	100	7	30	100 K	500	200	-20	40	20	100	20		35
										600	200	-18	36	40	100	18		44
		ICAS	750	225	250	120	7	40	100 K	750	200	-21	42	20	100	20		55
	AB$_2$	CCS	750	225	250	100	7	30		500	200	-18	50	30	180	26	0.6	60
										600	200	-20	50	26	155	22	0.4	65
		ICAS	750	225	250	120	7	40		750	200	-19	50	32	160	25	0.5	65
832A	AB$_1$	CCS	750	250	90	36	5	15	100 K	500	180	-30	60	14	70	7		22
										600	150	-30	60	12	60	7		23
		ICAS	750	250	115	50	5	20	100 K	750	150	-32	64	12	60	7		30
833A	B	ICAS	3300		500	1300		350		3300		-80	190	60	300		20	710
6146 6159	AB$_1$	CCS	600	250	125	60	3	20	100 K	400	190	-40	40	32	114	13		27
										500	185	-40	40	29	108	13		35
										600	180	-45	45	13	100	12		40
		ICAS	750	250	135	85	3	25	100 K	600	200	-50	50	14	115	14		47
										750	195	-50	50	12	110	13		60
	AB$_2$	CCS	600	250	125	60	3	20		400	175	-41	48	17	116	9	0.2	31
										500	175	-44	51	14	121	9	0.3	41
										600	165	-44	49	11	104	9	0.2	45
		ICAS	750	250	135	85	3	25		600	190	-48	55	14	135	10	0.3	55
										750	165	-46	54	11	120	10	0.4	65
6524	AB$_2$	CCS	500	300	150	70	3	20	30 K	400	200	-23	72	25	145	10	0.1	39
										500	200	-26	70	20	116	10	0.1	40
		ICAS	600	300	150	85	3	20	30 K	500	200	-25	76	25	145	10	0.1	50
										600	200	-26	76	21	135	13	0.1	57

TABLE 1

Ratings and Operating Conditions for Radiotron Valves used as Linear R-F Power Amplifiers operation but less power output, can also be used.

Once the value of I_{bms} is selected, the remainder of the calculation follows steps 8 to 13 shown for class AB_1 operation. The driving power (DP) calculated does not include the r-f valve and circuit losses. Consequently, for adequate performance, at least ten times this value of power should be available from the driver.

The following example illustrates the calculation of "typical operation" conditions for the class-AB_2, CCS operation of the type 807 with an E_b of 600 volts:

1. The maximum plate voltage rating is 600V.

2. Determine I_{bms}:

$$I_{bms} = \frac{3\ (\text{rated PD})}{E_b} = \frac{3(25)}{600} = .125\text{A}.$$

This value is above the maximum-signal, dc plate-current rating (from valve handbook or valve bulletin): therefore, the maximum rated value of 120mA will be used as a first approximation.

3. $i'_b = 3I_{bms} = 3(120) = 360\text{mA}.$

4. From the 300V E_{c2} curves, Fig. 1, select $e_{bmin} = 90\text{V}$. and read e_{cm} $(= +12\text{V})$. From Figures 2 and 3, read $i'_{c1} = 12\text{mA}$, and $i'_{c2} = 35\text{mA}$ respectively.

5. $$\text{PD} = \frac{I_{bms}}{4}\left[E_b + 3\ (e_{bmin})\right]$$

$$= \frac{120}{4}\left[600 + 3(90)\right] = 26\text{W}$$

6. $$\text{SI} = \frac{E_{c2}i_{c2}}{4} = \frac{300(.035)}{4} = 2.6\text{W}.$$

7. $\text{PI} = E_bI_{bms} = 600(.120) = 72\text{W}.$

PD and PI are both above ratings, and a lower value of e_{bmin} at the required current cannot be found on the curves. Therefore, a lower value of I_{bms} must be chosen; try a value of 100mA, and repeat steps 3 to 7:

3. $i'_b = 3(100) = 300\text{mA}.$

4. From the 300V E_{c2} curves: $e_{bmin} = 70\text{V}$.
$e_{cm} = +7\text{V}$, $i'_{c1} = 8\text{mA}$, $i'_{c2} = 35\text{mA}$.

5. $$\text{PD} = \frac{.100}{4}\left[600 + 3(70)\right] = 20.3\text{W}.$$

6. $$\text{SI} = \frac{300(.035)}{4} = 2.6\text{W}.$$

7. $\text{PI} = 600(.100) = 60\text{W}.$

These values are within ratings; therefore, the remainder of the calculations can be completed:

8. $\text{PO} = \text{PI} - \text{PD} = 60 - 20.3 = 39.7\text{W}.$

9. $$I_{bo} = \frac{I_{bms}}{5} = \frac{100}{5} = 20\text{mA}.$$

10. E_{c1} (from Fig. 1) $= -35\text{V}.$

11. $E'_g = (E_{c1}) + e_{cm} = 35 + (+7) = 42\text{V}$

12. $$I_{c2} = \frac{i'_{c2}}{4} = \frac{35}{4} = 8.7\text{mA}.$$

13. $$\text{DP} = \frac{E'_gi'_{c2}}{2} = \frac{42(.008)}{2} = .17\text{W}.$$

These values compare reasonably well with the published values.

Table 1 shows the maximum ratings and typical operating conditions for several popular valves in linear r-f amplifier service for single-sideband, suppressed-carrier transmission.

It should be remembered that the typical operating conditions shown by the manufacturer (or calculated by the preceding methods) are approximate only. Minor adjustments are usually made in actual operation by varying the grid bias or screen voltage slightly. In linear r-f amplifier circuits for single-sideband, suppressed-carrier transmission, it is particularly important to check the actual operating conditions when the transmitter is first set up to assure that linear operation within the maximum valve ratings is being obtained.

* * *

VISUALIZING SWR

'SWR Circle' Clarifies Theories

By Morton Eisenberg, W3DYL
Defence Electronic Products Division, RCA

Most amateurs have a working knowledge of Standing Wave Ratio (SWR) and are aware that it is preferable to have minimum SWR on feeders so that power lost in the antenna feeder is kept to a minimum. However, this writer has heard numerous remarks on the air which indicate that many theories exist on the subject of how the SWR can be varied, including the erroneous idea that SWR can be varied by changing the length of the feeder.

To help clear the air of such misinformation, this article contains a graphical presentation of the relationship between the SWR on a transmission line and the length of the line. The presentation, usually referred to as the "SWR Circle", shows how the feed-point impedance can be found when the SWR and electrical length of the transmission line are known.

The SWR on the transmission line between the transmitter and the antenna coupler, "A" in Figure 1, can be varied by tuning and adjusting the coupler by inserting a device such as an impedance bridge in the "A" line. In this manner, a "flat" or nonresonant line (SWR = 1.0) can easily be realised.

The SWR circle applies to the "B"-line coupler to antenna or, if no coupler is used, transmitter to antenna. Although optimum tuning of the transmitter and coupler assures that the maximum r-f power is being transferred to the feeder terminals, it has no effect on the SWR.

In Figure 2, the SWR circle is plotted for a 52-ohm cable. Similar SWR circles can be drawn for any other cable characteristic impedance and the procedure will be described later in this article.

Referring to Figure 2, suppose an SWR of 2:1 is measured on the "B"-line because a 52-ohm coaxial feeder is terminated by a 26-ohm resistive antenna impedance. Depending on the feeder length, the feed-point impedance could be 26 ohms resistive at Point X, 104 ohms resistive at Point Y, or any one of the infinite number of complex impedances, such as Point Z. Point Z represents a feed-point impedance of 65 ohms resistive in series with a 39-ohm inductive reactance. The convenient way to write this mathematically is: $65 + J39$.

Point X is the feed-point impedance which is found when there is no feeder, or when the feeder length is equal to a half-wavelength or any multiple of a half-wavelength. Point Y is the feed-point impedance when the feeder is equal to a quarter-wavelength or odd multiples of a quarter-wavelength. The feed-point impedance at Point Z is due to the feeder length being equal to one-eight-wavelength.

It should now be clear that varying the length of the feeder cannot vary the SWR on the "B" line, nor can it vary the feeder losses per foot. When the feeder length is increased, simply "go around the SWR circle" in a clock-wise direction. Remember that one full trip around the SWR Circle is equal to a half-wavelength of feeder.

The use of different feeder lengths to obtain variation in feed-point impedance is known to hams as "pruning the feeder to get the antenna to load." "Pruning the feeder" is sometimes necessary because of the limited impedance-matching capabilities of the coupling circuits. In this manner, a feed-point impedance which will more easily match the feeder to the transmitter (or coupler) can be obtained. It is important to note that although the feeder length has been changed, the SWR remains constant. You are simply going to another point on the SWR circle.

The SWR on transmission line "B" can be adjusted for minimum only by doing one of the following: (1) changing the transmitter frequency, (2) adjusting the length of the antenna element or elements, or (3) adding or adjusting a matching device at the junction of the antenna and the feeder.

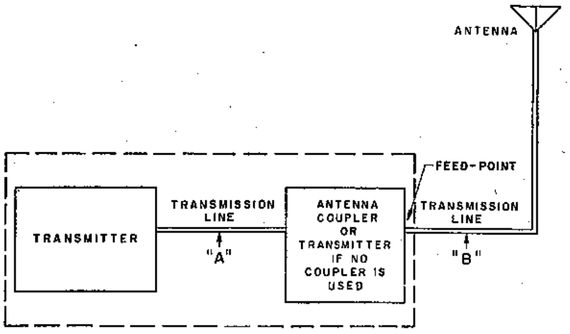


Fig. 1.

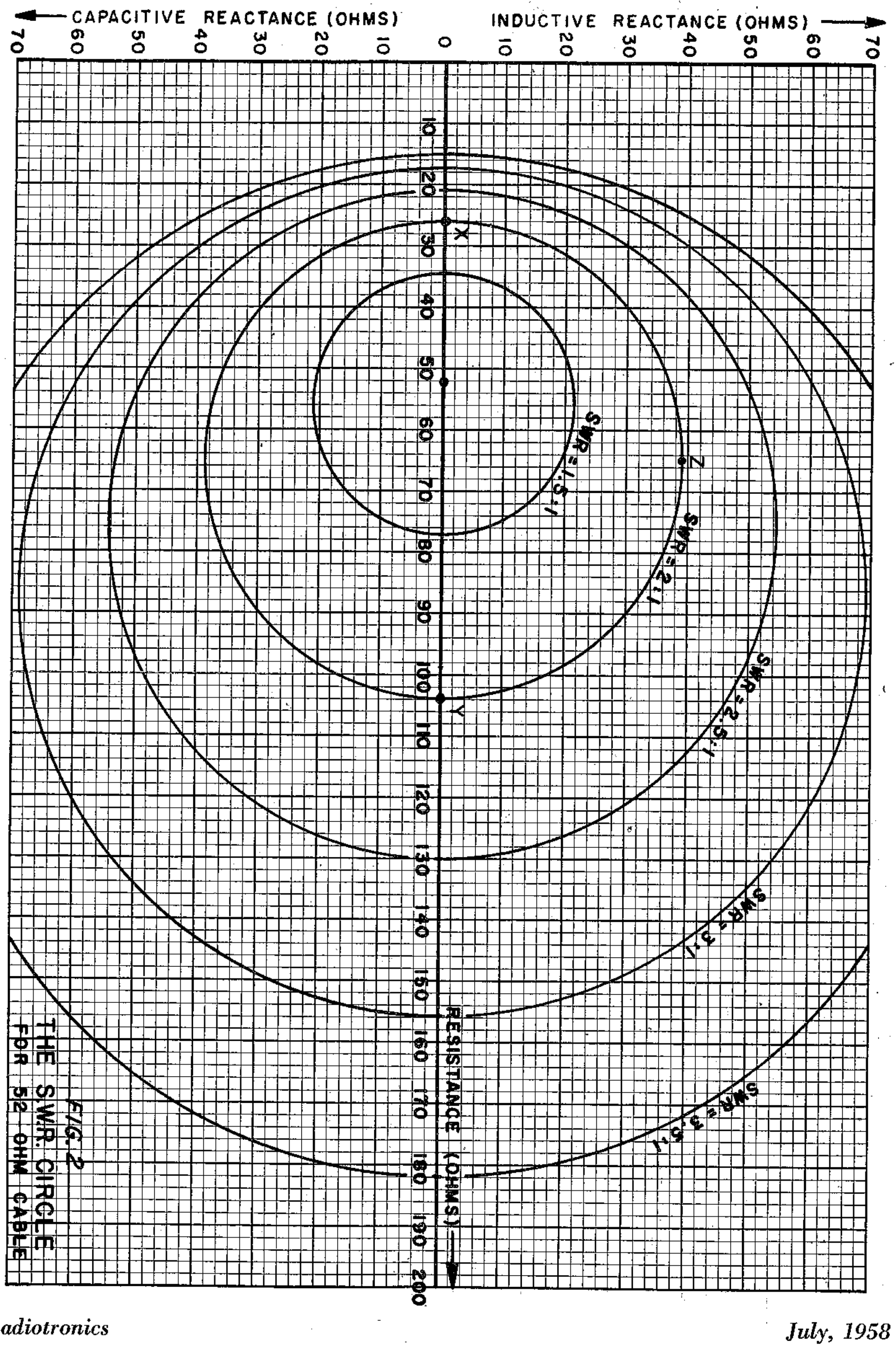


FIG. 2

THE S.W.R. CIRCLE FOR 52 OHM CABLE

ADJUSTING SWR FOR RECEIVER FEEDERS

The SWR situation on the receiver feeder is slightly different from the problems arising in transmitter feeders. In this case, the SWR is a result of a mismatch of the input impedance of the receiver and the characteristic impedance of the feeder.

Consequently, the SWR can be adjusted to 1.0 by the use of a coupler at the input terminals of the receiver. This coupler is only necessary, of course, if the input impedance of the receiver is not equal to the characteristic impedance of the feeder.

OTHER SWR CIRCLES

For various cable characteristic impedances, SWR circles can be drawn by the procedure in the following example:

To draw a circle where the SWR = 3:1, with a 300-ohm line, the circle would cut the 100-ohm point ($\frac{300}{3} = 100$) and the 900-ohm point ($300 \times 3 = 900$) on the horizontal axis.

The centre to be used for the compasses would be $\frac{900 + 100}{2} = 500$. Setting the compasses to a distance equivalent to $\frac{900 - 100}{2} = 400$ units, with 500 as the centre, will complete the job.

The SWR circle is an extremely simple method of visualising the effect of an antenna-to-line mismatch on the feed-point impedance. It is also an easy, more understandable way of showing that varying the feeder length is a futile way to minimise losses. The SWR (or the loss) remains unchanged. To accomplish a change in SWR (or to eliminate a line loss) for any specific frequency would require a climb up to your "sky-piece."

NEW RCA RELEASES

RADIOTRON 6814

The Radiotron 6814 is a subminiature medium — mu triode with a pure tungsten low-wattage heater requiring less than 1W of heating power. This valve has a number of applications in compact electronic computers and other "on-off" equipment, and is particularly suited for use in pulse amplifier, inverter and cathode follower circuits of high-speed digital-type electronic computers. The 6814 is suitable for use in mobile and airborne equipment, and may be operated at full ratings at altitudes up to 80,000ft. without pressurisation.

RADIOTRON 7027

The Radiotron 7027 has been specially developed to meet the demands of critical AF amplifier designs, and features exceptionally high plate dissipation, high power sensitivity and high efficiency. The 7027 is a high-perveance beam power valve especially designed for use in push-pull amplifier stages of high fidelity equipment. Two 7027's in class AB1 with 450V plate voltage can handle up to 50W of AF power with only 1.5% distortion.

RADIOTRON 7200

The Radiotron 7200 is a 9-stage multiplier phototube intended primarily for the detection and measurement of ultraviolet radiation, but is also useful in applications involving low-level light sources. The envelope has a fused-silica section which transmits radiant energy in the ultraviolet region down to and below 2000 angstroms, at which figure the spectral sensitivity is nearly 80% of maximum. The spectral response of the 7200 covers the range of approximately 1800 to 6000 angstroms.

RADIOTRON 2CY5 AND 6CY5

These types are sharp cut off tetrodes designed for use as RF amplifiers in VHF TV tuners. They feature high transconductance (8000 micromhos) to provide high stage gain with corresponding reduction in equivalent noise resistance. A high ratio of plate to screen currents of 7:1 provides good signal/noise ratio. The two valves are identical except for heater voltage and current.

DEFLECTION SYSTEMS & COMPONENTS

A complete line of deflection systems and components has just been released by RCA, including ruggedised units for military applications. Included are components for use with image orthicons 5820, 6474, 6974 and 7037, one-inch vidicons 6198, 6198A, 6326, 6326A, TV monitor tube 17BP4A, TV projection tube 5AZP4, and flying spot scanner tubes 5ZP16 and 5WP11.

HIGH FIDELITY

PART 3

HIGH FIDELITY CIRCUITS

Introduction

When referring to a high fidelity system, every unit which goes into the operation of the equipment or instrument must be considered. This, of course, includes players, both disc and tape, FM and AM radio, amplifiers, and speaker systems.

Frequency Response

Figure 15 shows what is normally called a flat response curve. It doesn't look flat, but look at the db scale. The greatest deviation is approximately 3 db, which is just discernible to the average person. Therefore, the response is relatively flat. In order to be called really "high fidelity", the frequency response of the equipment must be wide enough to give excellent bass response, and at the same time give response to all of the overtones that go into the creation of sounds which determine the quality of an instrument, voice, or combination of the two. An acceptable high fidelity equipment therefore, should have reasonably flat response from at least 40 c/s through at least 10,000 c/s. When the frequency range is given in these terms, the terms refer to the sound pressure curve. The sound pressure curve is obtained from a calibrated microphone and amplifier system which is extremely flat in characteristics, so that the actual output of the speaker (of the equipment being measured) is plotted, and not just the input to the speaker system.

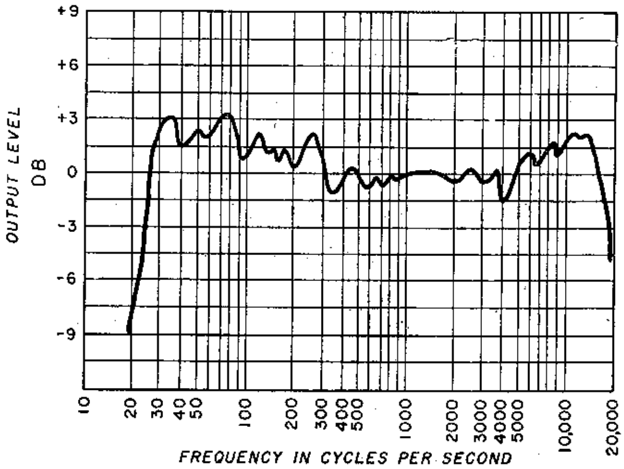


Fig. 15. Satisfactory High Fidelity Characteristics.

This curve must be taken in a "dead" room. Most service technicians do not have a "dead" room so it is usually not possible to do more than listen to the sound output from the loudspeaker. To give satisfactory reproduction to the average person, the equipment should have a response range flat from approximately 20 or 30 c/s to 15,000 c/s.

It is not intended to go into great detail here on the power output of the equipment in order to give satisfactory coverage. However, power output should always be considered from the viewpoint of undistorted power output, since, when distortion is introduced into a reproducing system, the system ceases to be high fidelity.

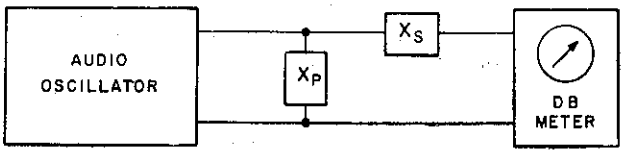


Fig. 16. Measurement of Component Effects.

Effect of Circuit Components

In order to investigate the effect of circuit components, a circuit similar to the one shown in figure 16 is required. The audio oscillator can be just the plain old hand adjusted variety or one with a sweep. The measuring device may be either a meter as shown, or in the case where a sweep is used, an oscilloscope. The two blocks marked Xs and Xp are the points at which will be connected certain circuit components to be investigated.

In figure 17 are shown the types of curves that would be seen on the scope, or plotted from the meter readings, for each component or combination illustrated, when connected in each position for X of figure 16.

(a) shows a capacitor connected across the line. Of course, this assumes a poor voltage regulation of the sweep oscillator so that the voltage drops off rapidly with load. The capacitor across the circuit, as would be the case here, would offer very little load at low frequency. As the frequency is increased, the load will increase and consequently the voltage will decrease, giving the decreasing voltage pattern shown for this connection.

(b) shows the effect of an inductor placed in the same position. The inductor offers practically no load at high frequencies, but does offer a considerable load at low frequencies. Therefore, a high voltage will be shown at the high-frequency end of the curve, with low voltage at the low-frequency end.

(c) shows a series-resonant circuit connected across the line. If this series-resonant circuit is composed of constants which tune it to the centre of the range of frequencies being plotted, it will offer practically no loading at the low end of the band, due to the capacity. It will also offer practically no loading at the high end of the band, due to the inductance. However, somewhere between these two points, the combination will become resonant and cause considerable loading of the oscillator, reducing the voltage at that point.

(d) shows the effect of a parallel resonant circuit across the line. Here the circuit loads the oscillator at all frequencies except the one to which it is tuned. At low frequencies the inductor loads the circuit, and at high frequencies the capacitor loads the circuit. However, at the resonant frequency of the inductor and capacitor, there is no loading, and consequently at this frequency a high voltage is applied to our scope or meter.

(e) shows the effect of a condenser connected in the series position for the block Xs in figure 16. A capacitor in series with the circuit offers a high impedance to the low-frequency end of the band, and a much lesser impedance at the high-frequency end of the band. Consequently, the voltage applied to the measuring instrument will be low at low frequencies and high at the high frequencies, just opposite to the parallel arrangement shown in (a).

(f) shows the inductor connected in series. The inductor will pass the low frequencies much more readily than it will the high frequencies. Consequently, a high voltage will be obtained at the low-frequency end of the band, and low voltage at the high-frequency end of the band.

(g) shows that the series-parallel circuit also does the opposite when connected in series as it did in parallel. This series-resonant circuit offers a high impedance to all frequencies except the one to which it is tuned.

(h) also shows, for a parallel-resonant circuit when connected in series, opposite results to those when connected in parallel..

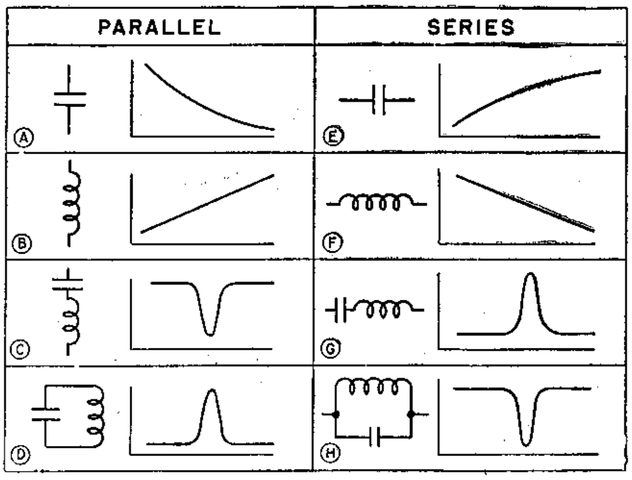


Fig. 17. Circuit Components in Parallel and in Series.

There are several interesting facts to point out in connection with figure 17. It is noted that a parallel-resonant circuit in series with the signal gives practically the same effect as a series-resonant circuit in parallel with the signal. Also a parallel-resonant circuit in parallel with the circuit gives the same effect as a series-resonant circuit in series with the circuit. An inductor in parallel with the circuit has practically the same effect as a capacitor in series with the circuit, and an inductor in series with the circuit has practically the same effect as a capacitor in parallel with the circuit. From this it can be seen that loss of high frequencies or loss of low frequencies can be brought about by a change in component values, and can be restored by restoring the values of the circuit components to those used originally.

It will also be interesting to investigate some simple circuits in which the capacitor and induc-

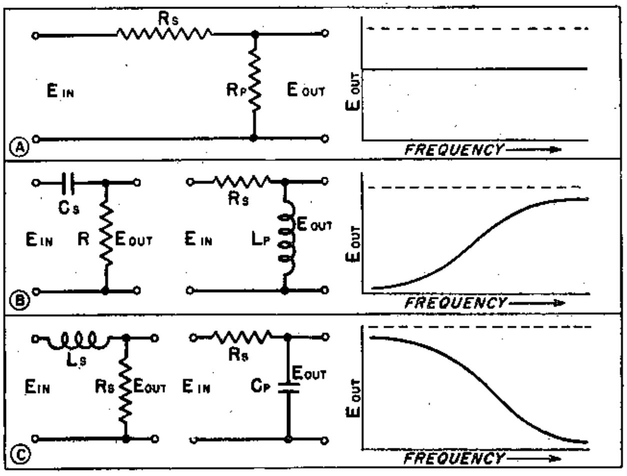


Fig. 18. The Effect of Circuit Components.

tance are connected into series-parallel circuits with a resistor. These are actually tone control circuits. These are simple circuits but they will cover the fundamentals of operation. These circuits are also applicable to amplifier compensation networks and volume and loudness control circuits.

Figure 18 (a) shows what happens when two resistors are inserted in an audio line. Resistors are not frequency discriminating, so if a voltage is inserted at the input to the network (Ein) represented by the dotted line at the top of the curve, the network output voltage will also be represented by a straight line (solid) measured across the resistor Rp. This line, of course, will be lower on the curve by an amount equal to the loss of the circuit. This is a volume control circuit.

In figure 18 (b) are two simple circuits. Remember, in figure 17 we found that a capacitor in series had the same effect as an inductor in parallel. Here again the voltage inserted into the network is represented by the dotted line, but this time the network is a frequency-discriminating network, and at the low-frequency end of the spectrum, considerable attenuation, or loss occurs.

The impedance of the capacitor is extremely high at the low-frequency end of the spectrum. Also, the inductance offers practically no impedance, and shorts the low frequencies to ground. As the frequency increases, the impedance, in the case of the capacitor, becomes less, and in the case of the inductor, greater. When the high-frequency end of the spectrum is reached it is found that the circuit loss is at a minimum, and that the high frequencies are readily passed by both circuits.

In figure 18(c) two other circuits are shown. One, with a series inductance, and the other with a parallel capacitor. Again it is found, in the discussion of figure 17, that the effect of these two components in these ways will be the same. Here again, the inductor will have very low impedance to the low frequencies, and the capacitor will have very high impedance. So the low frequencies will have only a minimum of loss, and the line on the curve will almost equal the voltage represented for the input by the dotted line. Again, as the frequency is increased, the impedance of the inductor becomes higher, and the impedance of the capacitor lower. Therefore, by the time the high-frequency end of the spectrum is reached, a maximum loss or attenuation occurs and the voltage across the output of the network at the high frequencies is very low.

The circuit shown in each section of figure 18 is found to be a voltage-dividing circuit, with a resistor supplying either a loss or a load to other components, thus controlling the effectiveness of the network.

In no case is there a bass boost, or a high-frequency boost. In all cases there is a loss. More voltage must be supplied than is needed and then a loss must be inserted to attenuate the frequencies that are to be controlled. It is possible to design a circuit that will actually "boost", by the use of resonant circuits, but these are generally not smooth, and cover only narrow frequency ranges.

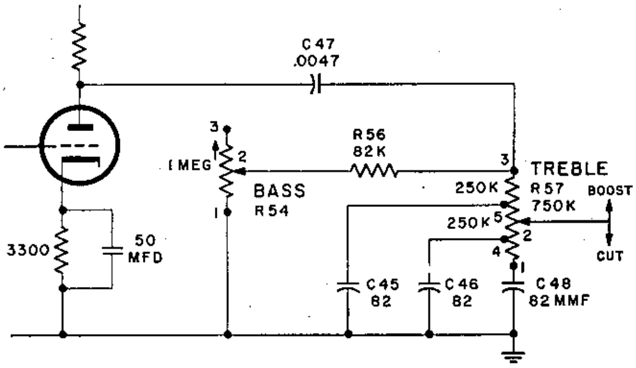


Fig. 19. A typical Tone Control Circuit.

Tone Control Circuit

The low-frequency and high-frequency tone control circuits used in the better type high fidelity instruments are shown here in figure 19. In figure 18 the fundamental circuits used in tone controls were discussed. Here is a much more refined circuit which gives very smooth control of both highs and lows with a minimum of interaction. The high-frequency control is composed of resistor, R-57 and three capacitors, C-45, C-46, and C-48, with the capacitive section of the circuit serving as the load portion of the voltage divider. As the control is turned towards the minimum high position, the resistance of the series portion becomes higher and the impedance of the capacitive portion becomes lower, and the high-frequency voltage to the following valve grid becomes lower. The series portion of the low frequency control is capacitor C-47, and the load section is composed of two resistors, R-54, and R-56.

At minimum low-frequency position the impedance of the capacitive section of the divider is high as compared to the resistive load section, and the low-frequency voltage to the following valve grid will be minimum.

Loudness Sensation of the Human Ear.

Compensated volume controls have been mentioned several times. Since tone control circuits have now been discussed, compensated volume control can be investigated. This is also a modified tone control, and that is why it's discussion was put off until now.

The proper design of a radio receiver should take into account the characteristics of the human ear. If one were to feed into a loudspeaker, a signal which varied in frequency from an extremely low value to an extremely high value, and maintain the amount of energy fed into the speaker constant as the frequency was varied (assuming the speaker to be perfect and therefore to reproduce an equivalent constant amount of energy output) all of these sounds would not seem equally loud under all conditions.

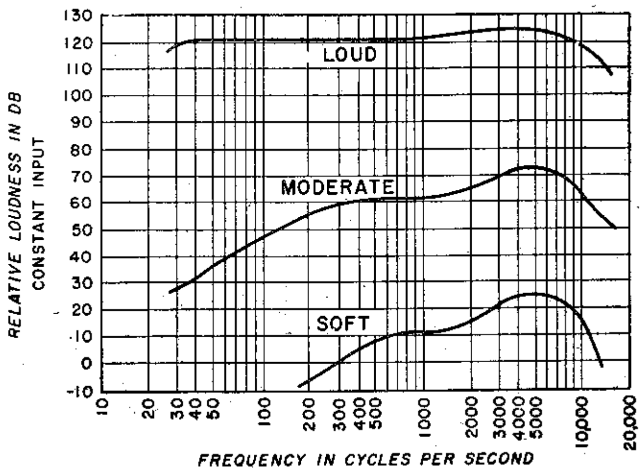


Fig. 20. Sound Levels in Terms of Loudness.

If the energy level was high, all frequencies would seem to be of the same loudness, up to about 1,000 c/s, when there would be a slight rise, reaching a maximum at about 4,000 cycles, and from then on the higher frequencies would appear to be less loud. Now if the amount of input energy were to be reduced to a more moderate level, the low-frequency notes would be less loud, and as the frequency was increased the loudness would appear to increase to a maximum at 4,000 cycles and then gradually fall off. If the amount of energy fed into the loudspeaker was reduced to a very low value, practically none of the low-frequency sounds would be heard. The fact that the ear is constructed to respond in this fashion is a very decided asset from the hearing standpoint, because at extremely low sound levels the ear covers just that frequency range required for maximum intelligibility, so that we can understand what is said in a low tone of voice. However, this is not good from a musical standpoint, for most of us find the low-frequency notes of an orchestra definitely pleasing, and these are not heard at extremely low energy levels. Figure 20 shows sound levels in terms of relative loudness rather than intensity, as were the earlier curves showing the ear characteristics, so it is the reciprocal of those earlier curves, but shows better what is being discussed here.

Volume Control Characteristics.

In modern instruments the audio system is compensated at various loudness levels to take into account the characteristics of the ear in such a way as to reproduce music which sounds pleasing to the ear, regardless of the volume level at which the instrument is adjusted.

In order to do this, several loudness levels are chosen where the change in quality of the music becomes noticeable (usually two points are sufficient) and the volume control is tapped at these points. Tone control circuits are then installed to compensate for the characteristics of the human ear. Figure 21 shows what must be done to the audio frequency response of the instrument in order to accomplish this.

A volume control is considered a control which is not frequency-discriminating. A loudness control is a control (compensated) which is frequency-discriminating. From here on, this nomenclature will be used.

Loudness Control.

Figure 22 shows the loudness control circuit of a modern high fidelity instrument. This control is compensated at two points. At (or near) full volume, the response of the ear is approximately flat, so all frequencies when played through a reasonably flat equipment, will be heard in true proportion to all other frequencies.

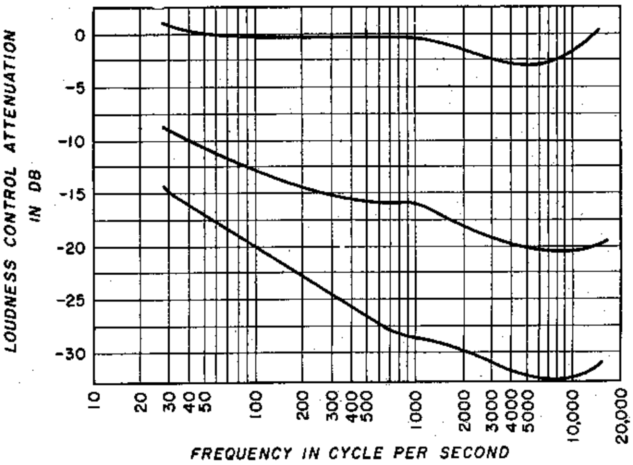


Fig. 21. Loudness Control Characteristics.

As the loudness is lowered, however, the ear sensitivity drops off at the low-frequency end of the spectrum, so the bass is no longer heard as loudly as actually played by the orchestra. Therefore, it is necessary to make some compensation when the control position reaches the point of the top tap. A capacitor of such a size as to be effective at the very highest frequencies covered by the instrument is used. A series resistance is also connected into the circuit in order to control the effectiveness of this capacitor through that range. The effect of this circuit is felt over a reasonably large area of the volume control.

As the loudness control is reduced to a very low volume, it again becomes necessary to compensate the circuit in order to hear the music in a way that sounds normal over the entire frequency range. Exactly the same thing is done from a tap placed at this lower point. This then, gives a satisfactory loudness control circuit.

Types of Distortion

At one time, not too many years back, the criterion of good sound was the width of the frequency range. Many people judged the quality of a system by the amount of record scratch heard during the playing of a record.

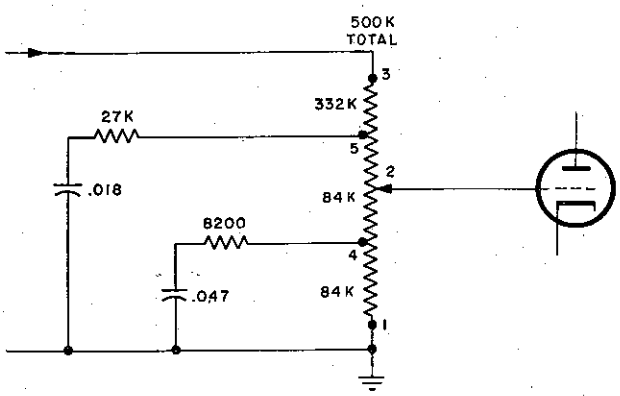


Fig. 22. Typical Loudness Control.

This type of thinking is now becoming obsolete. Of course, frequency response is important, but both the highs and the lows as well as the middle range must be heard, and the overall response of the system must be reasonably flat. Sufficient power handling capacity to fill the listening room at maximum desired average volume plus the peaks must also be available. The response of the system must be linear, or many types of distortion will result.

Figure 23 lists the types of distortion that are most important and shows the amount that can be tolerated for each, where a limit has been set.

TYPE OF DISTORTION	SATISFACTORY LIMIT	ACCEPTABLE LIMIT
HARMONIC DISTORTION	*2 % TOTAL HARMONICS*	*3–5 % TOTAL HARMONICS*
INTERMODULATION DISTORTION	*4 %*	*10 %*
PHASE DISTORTION	*NO SET STANDARDS*	
FREQUENCY RESPONSE	*20–15,000 CPS*	*40–10,000 CPS*
TRANSIENT DISTORTION	*NO SET STANDARDS*	
NOISE	*–60 DB BELOW FULL OUTPUT*	*–50 DB BELOW FULL OUTPUT*
FREQUENCY MODULATION DISTORTION (WOW)	*0.1 %*	*1 %*
POWER OUTPUT DEPENDS UPON SIZE AND TREATMENT OF LISTENING ROOM		

Fig. 23. Types of Distortion.

HARMONIC DISTORTION is the type of distortion created by a non-linear system where harmonics are amplified in different proportions than the fundamental frequencies. This type of distortion will very seriously affect the quality of tone. For instance, should a particular instrument that was very rich in a certain harmonic be listened to, and should that harmonic be amplified at an entirely different ratio to the fundamental in the reproducing equipment, the quality of the instrument could be changed so much that it would not be possible to recognise it for the same instrument.

INTERMODULATION DISTORTION. When considering a signal in which more than one frequency is represented, the modulation of one or more of these frequencies by either of those frequencies may occur. This type of distortion causes most of the disagreeable quality in a system.

PHASE DISTORTION is the type of distortion that occurs when the phase of some of the frequencies are different at the output of a component, than at the input.

FREQUENCY DISTORTION is when a system has a different amplification at different frequencies. In other words, the system is not flat.

TRANSIENT DISTORTION is where distortion occurs as a result of short bursts of signal more than for steady signals.

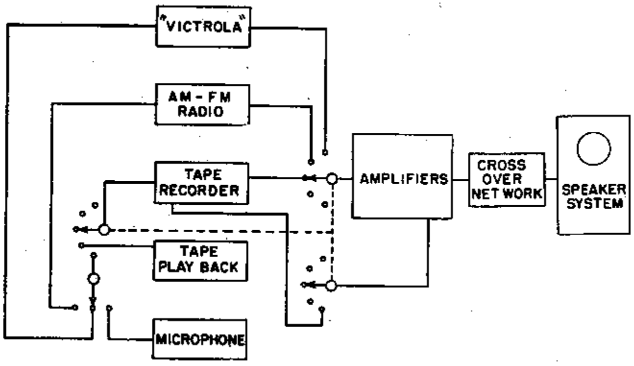


Fig. 24. Hi-Fi Block Diagram.

NOISE. There are three major types of noise which must be considered. Atmospherics, or static, is important when radio reception is being used. Valve noise is important when amplifiers of any type are in use. Record surface noise, of course, is important only when disc records are being used. There is also noise in the playback of tape. But this is so much less than the disc noise that it was not felt necessary to list it as a major problem.

FREQUENCY MODULATION DISTORTION. Wow and flutter resulting from mechanical and motor speed variation.

High Fidelity System Block Diagram

Most of the general circuitry that applies to systems of all types has now been covered. Figure 24 shows a block diagram of a high fidelity system. Of course, there should be a radio (both AM and FM) in the system. Likewise, it would be unthinkable to have a pick up excluded as record-playing is an important feature in any home these days. A complete high fidelity system, usually includes a good tape recorder. This recorder, must be capable of playing tapes through the system, as well as making recordings.

In order to operate all of these individual items, a switching system should be included. There must also be an amplifier system. The amplifiers will consist of pre-amplifiers, voltage amplifiers, and power amplifiers. They can be built separately or all together in one unit, depending on the size and completeness of the system.

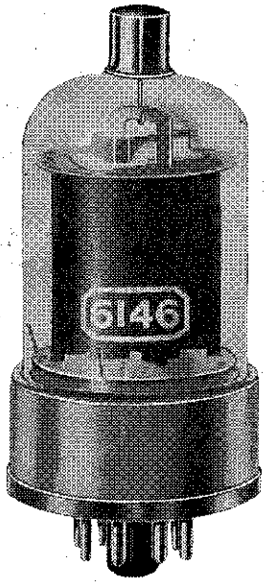
In order to obtain the fidelity required from a high fidelity system more than one speaker should be used if a very wide range speaker is not available. For efficient design, when average units are used, at least one speaker should be used for the low frequencies, and one for the highs. In order to filter the high frequencies from the low-frequency speaker, and the low frequencies from the high-frequency speaker, a cross-over network must be used. An important part of any speaker system is the baffle, or enclosure. These units complete the high fidelity system, and this block diagram shows how the individual units can be used to obtain good quality reproduction.

See June issue, P.90, for Novice Tx using 6146 Final.

RADIOTRON

6146

Notes on Increasing the Life-expectancy of this Popular Valve.



The life of a 6146 beam power valve can be increased if these 12 simple procedures are followed:

1. Hold the heater voltage at 6.3 volts — at valve terminals.
2. Provide for adequate ventilation around the valve to prevent valve and circuit damage caused by overheating.
3. Keep shiny shielding surfaces away from the valve to prevent heat reflection back into the valve.
4. Design circuits around the valve to use the lowest possible value of resistance in grid circuit and screen circuit.
5. In high-frequency service, operate the valve under load conditions such that the maximum rated plate current flows at the plate voltage which will give maximum rated input.
6. Have overload protection in plate and screen circuits to protect the valve in the event of driver failure.
7. See that the plate shows no colour when operated at full ratings (CCS or ICAS conditions).
8. Reduce B+ or insert additional screen resistance when tuning under no-load conditions to prevent exceeding grid No. 2 input rating.
9. Maintain tuning and loading adjustment precisely so that the valve will not be subjected to excessive overload. The 6146 is a high-gain, high-perveance valve and can be more easily overloaded through circuit misadjustments than older types not having such features.
10. Use adequate grid drive, keeping within maximum grid-current and screen-dissipation ratings of the valve. Too little grid drive can cause high plate dissipation.
11. Make connections to the plate with flexible leads to prevent strain on the cap seal.
12. Operate 6146 within the published ratings.