XVIII. SENSORY REPLACEMENT

Dr. C. M. Witcher
L. Washington, Jr.

RESEARCH OBJECTIVES

As its title implies, this program has as its ultimate objective the development of means for replacement of the visual and auditory senses in the performance of certain specific tasks. The areas in which possibilities for visual prosthesis have thus far been conceived are: (a) development of means to enable the blind to walk about safely and independently and at normal speed (4-5 ft/sec) when not passing through vehicular traffic; (b) development of apparatus to enable the blind to read printed or written material; and (c) invention of devices to permit the blind to recognize familiar objects at a distance, probably through the conversion of visual patterns into auditory patterns. Thus far, the major effort has been concentrated in the first of these areas, but considerable thought has been given to the second.

Up to the present time, one auditory prosthesis project has been initiated. This is the development of the Vocatac – a device intended to transform voice sounds into tactually perceptible patterns. If this device proves successful, it should be of considerable help to the totally deaf who are not familiar with lip reading and to those who are both blind and totally deaf. A description of this apparatus appears in Section XVIII-B.

A. TRAVEL AID

As mentioned in the Quarterly Progress Report of July 15, 1955, the optical system now in use in the travel aid was shown to be quite inadequate. In the receivers, systems are needed whose circles of confusion do not exceed 0.001 inch in diameter. The image quality is not important; only the condition that the dimensions of the area imaged by the receivers should not significantly exceed those of the simple geometric image presents difficulties. For some weeks the problem of designing such systems, subject to specified conditions regarding weight, physical dimensions, and so forth, has been under consideration by the optics design group at Boston University. Quantitative examinations have been made of the possibilities of utilizing either an unmodified Maksutov system or a Schmidt system. The computations are based on a specified "F" number of 0.7 or less, an aperture diameter of 2-2.5 inches, and a maximum field of 9.0°. Actually, in the receiving systems, the field would not need to exceed 3.6°, but it may prove advisable to use a similar system for the transmitter, which requires a 9.0° field (1).

The Maksutov system would be more economical to produce, especially in relatively small quantities, since the correcting meniscus has only spherical surfaces. However, in this kind of system the focal plane is very nearly tangent to the corrector meniscus. This is not a serious disadvantage in systems that are to be used as receivers because the corrector plate could have at its center a hole that is large enough to admit the photocell without degrading the performance significantly. However, the disadvantage in the case of the light source projector (1) would be serious. At this time, calculations for both systems are nearing completion. It should be mentioned that the Schmidt system which has been in use as the projector is of very poor quality, having been designed for use in a piece of military infrared equipment in which image quality was not important.

Calculations recently made by Witcher (2) have indicated that, with acceptable optics, the present travel aid should be able to provide reliable step-down detection except when signal attenuation caused by a puddle or a wet surface amounts to 33-34 db. This figure is based on the fact that the signal-to-noise ratio reaches a value of unity when attenuation from these causes amounts to 37 db. Hence, false alarms may be expected under the worst possible reflection conditions, since values of attenuation as great as 40 db have been observed under such conditions (3).

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2. C. M. Witcher, Analysis and design of a travel aid for the blind. Paper presented at the meeting of the A.A.A.S., Dec. 1955.
3. Quarterly Progress Report, Research Laboratory of Electronics, M.I.T., Jan. 15, 1954.

B. THE VOCATAC

Some years ago J. B. Wiesner, N. Wiener, and others in this Laboratory (1) carried out theoretical and experimental studies of the possibility of converting speech into a sequence of tactually perceptible patterns that a totally deaf person might learn to interpret. Unfortunately, the project had to be dropped because of the press of other work, and hence the matter remains open. We have often considered the problem of designing a relatively simple apparatus with which a new attack on this problem could be initiated. The apparatus has now been constructed as a bachelor's thesis project by L. Washington, Jr.

In the original device (Felix), a number of bandpass filters were used to subdivide the voice range. The condition employed to fix the successive band limits was that each band should represent approximately an equal amount of energy when averaged over speech. At first, five channels were used, the outputs being arranged to control the amplitudes of five small vibrators on which the fingers of one hand rested. The vibrators all operated at the same frequency, supplied by an auxiliary oscillator. Later, a seven-channel system was used in which the outputs controlled a set of electrical stimulators in contact with the forearm.

In the present version, use is made of tactile stimuli of the presence-or-absence type with no amplitude variations. In fact, the outputs of the six channels in the present apparatus actuate six small round-head pins that are thus brought in contact with the tip of the index finger. The arrangement and spacing of pin positions is the same as that of dot positions in a standard Braille cell. This scheme has been adopted because of the remarkably high rate of speed with which the blind can receive information in reading Braille (2, 3). In addition to the six tactile stimulator channels, a seventh channel is provided to energize a fairly rugged vibrator that permits perception of the syllabic rhythm of speech and furnishes an indication of the occurrence of voiced consonants.

Instead of bandpass filters, tuned circuits are used in the present apparatus. As this is written, single-tuned circuits with 10 per cent bandwidths are being employed, but provisions have been made to use double-tuned circuits if it is found advisable. The resonant frequencies of the tuned circuits have been selected on the basis of the so-called importance function given by Fletcher and Galt (4). This function measures the relative importance of each frequency in the voice range to reduce errors in the identification of isolated syllables. By using this function, the part of the voice range from 200 cps to 4500 cps was first divided into six frequency bands, each of which contributed equally to the reduction of errors in syllable identification. The resonant frequency corresponding to each of these bands was chosen at the point where the "importance function" attained its maximum value within that band. The frequencies thus obtained are: 382, 548, 715, 990, 1529, and 3000 cps. The gain characteristic at the outputs of the tuned filters rises at the rate of 6 db per octave, in accordance with the procedure of Potter and Steinberg (5), so that approximately the same

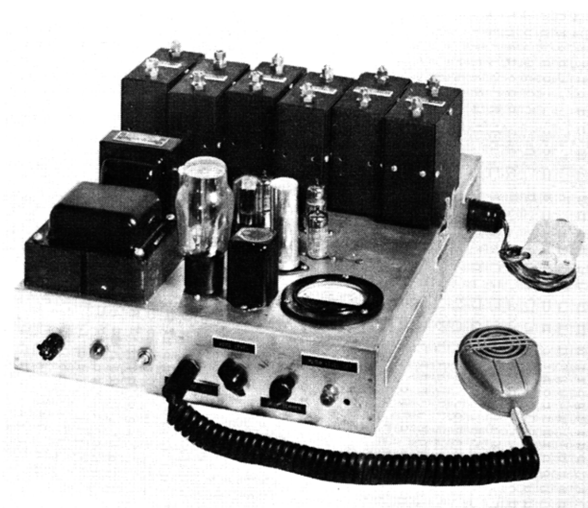


Fig. XVIII-1. Six-channel Vocatac.

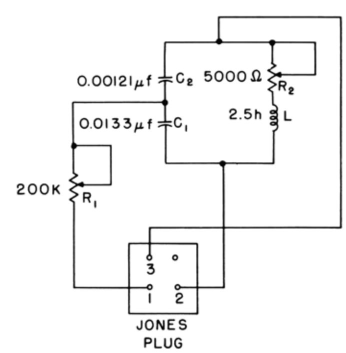
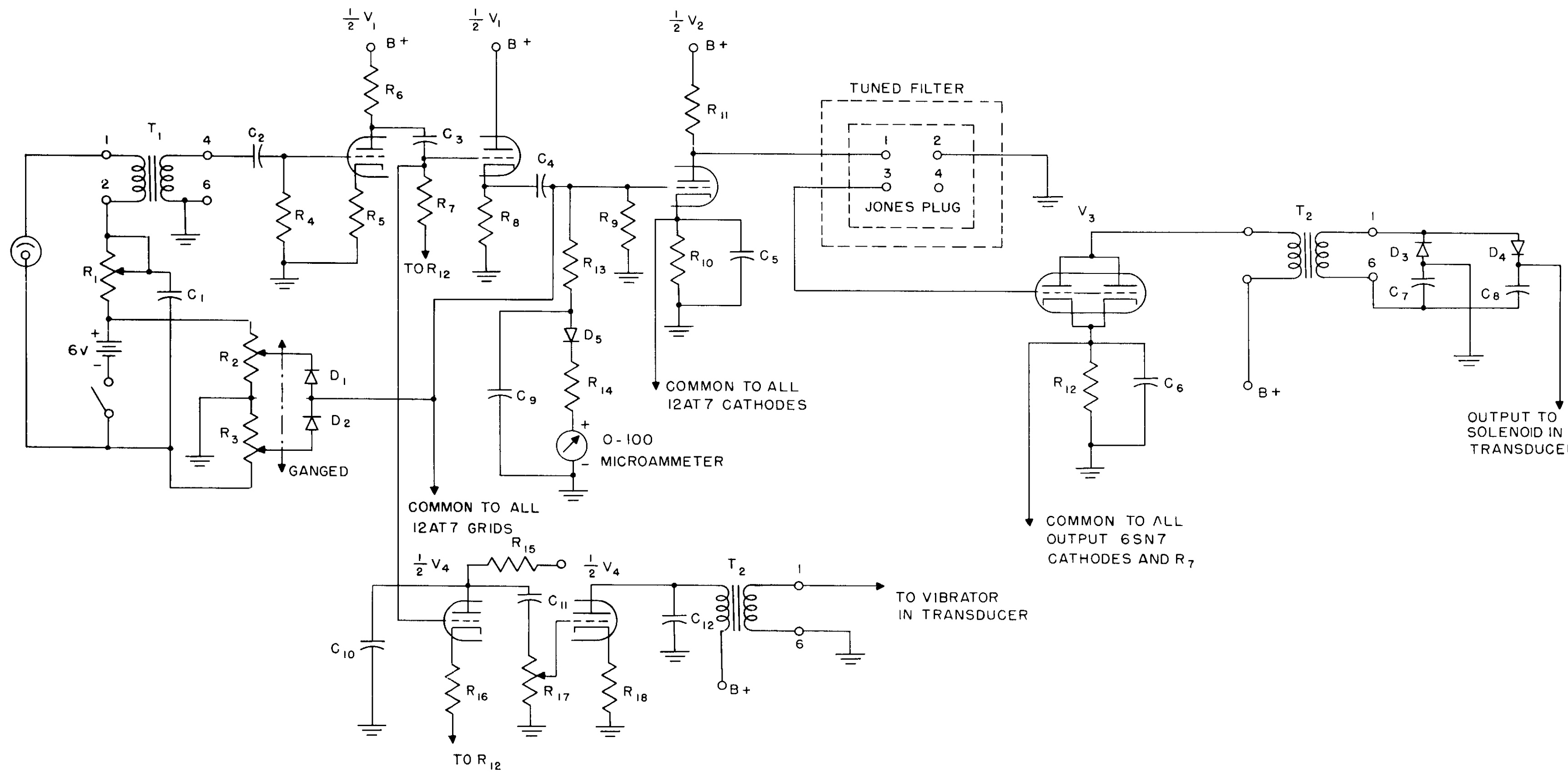


Fig. XVIII-2. Schematic of typical tuned filter of Vocatac.



R_1	1000Ω POT	R_{10}	33Ω	C_1	100μf	V_1	12AX7
R_2	100Ω POT	R_{11}	18K	C_2	0.005μf	V_2	12AT7
R_3	100Ω POT	R_{12}	75Ω	C_3	0.002μf	V_3	6SN7
R_4	100K	R_{13}	10K	C_4	1.0μf	V_4	6SN7
R_5	1200Ω	R_{14}	18K	C_5	200μf	D_1	IN93
R_6	120K	R_{15}	22K	C_6	200μf	D_2	IN93
R_7	500K	R_{16}	500Ω	C_7	50μf	D_3	IN91
R_8	10K	R_{17}	IMEG POT	C_8	50μf	D_4	IN91
R_9	470Ω	R_{18}	1000Ω	C_9	10μf	D_5	IN34
				C_{10}	0.1μf	T_1	CHICAGO TRANSFORMER CIS - 2
				C_{11}	0.001μf		
				C_{12}	0.1μf	T_2	STANCOR TRANFORMER A3849

Fig. XVIII-3. Input and typical channel of Vocatac.

amplitude for all frequencies present in each vowel sound is obtained.

Figure XVIII-1 is a photograph of the Vocatac, as the apparatus has been called. A carbon microphone of good quality is used. The frequency range of carbon microphones is adequate for this application, and the amplification needed for them is much less than that required for others. However, measurements of second-harmonic distortion should, and will, be made. The small device at the upper right of the chassis is the electrotactile transducer which converts the electrical outputs of the six channels into Braille-like tactile patterns. It consists of a set of six small solenoids with plungers connected to the round-head pins and with provisions for necessary adjustments. The six boxes that contain the tuned filters are designed to plug into the chassis interchangeably, so that any sampling frequency may be assigned to a given position in the tactile pattern.

Figure XVIII-2 is a schematic of a typical tuned filter. The input is applied between pins 1 and 2 of the Jones plug and the output is taken between pins 2 and 3. The resistor R_1 is used to adjust the gain of the channel, and R_2 is used to adjust the circuit Q to a value of 20. The coils used are type HQA torroids manufactured by United Transformer Corporation. The input impedance at resonance with $R_1 = 0$ is approximately 6500 ohms, which is the value of the combined plate and load resistance of the 12AT7 to which it is connected. This condition maximizes the gain of the tuned stage for a given circuit Q, but it also effectively doubles the bandwidth. Hence the need for a Q of 20 to obtain 10 per cent bandwidth.

A schematic of the input circuits and one typical channel is given in Fig. XVIII-3. Three type 12AT7 tubes are used, each section of each tube serving for one channel. All six control grids of these tubes are connected to R_9. The cathode-follower section of the 12AX7 makes it possible to use a low value (500 ohms) for this resistor, so that the signal at this point will not be affected materially by grid current drawn by the 12AT7 tubes. In the lowest-frequency channel, the gain is such that a signal voltage of 0.18 volt rms at the grid of the 12AT7 will operate the solenoid in the output unit. However, the level is set so that speech frequencies in the neighborhood of 382 cps will apply a signal voltage of 0.4 volt rms. This is done in order to speed up the operation of the solenoid. Under this condition, the effective bandwidth for sustained speech sounds is increased to approximately 20 per cent. This would appear to be unavoidable with the present scheme for producing the tactile patterns. The performance of a 12AT7 is linear for rms grid voltages less than about 2.0 volts. Calculations indicate that the average rms voltage of speech should be somewhat less than 1.54 volts when the speech level gives 0.4 volt rms within the 10 per cent bandwidth of the 382 cps channel. The figure 1.54 is the rms voltage obtained from a noise spectrum that (a) is flat from 200 cps to 400 cps, (b) decreases at a rate of 6 db per octave above 400 cps, and (c) produces 0.4 volt rms in a band 40 cycles wide centered at 400 cps.

Note the control R_1 used to set the signal level, and the diodes D_1 and D_2 and the gang potentiometer R_2 and R_3 which are used to clip the speech if the voice level exceeds that for which R_1 was originally set.

At present, no tests of the Vocatac have been made, but we plan to start testing in the next few days.

C. M. Witcher, L. Washington, Jr.

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