

## XI. SENSORY REPLACEMENT\*

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### A. VOCATAC

The transducer mentioned in the Quarterly Progress Report of July 15, 1956, was completed; its speed of operation is significantly superior to that of the previous output device. As stated before, the tactile stimuli are produced by small ( $3/32$  inch in diameter) steel balls which are pushed upward against the finger tip by motion of the armatures of six small relays. Figure XI-1 is a sketch of the "sandwich" arrangement in which the stimulator balls are suspended. To assemble this arrangement, the relatively thick middle plate was machined with small shoulders that could be spun down around the outer edge of each of the outer plates. Accurate alignment was obtained by pinning the three plates together at one point before carrying out the final spinning operation. The ball support assembly fits into a circular hole in the center of the top cover plate of the transducer and is clamped in place by a ring, after having been rotated to align the balls with the ends of the relay armatures. The relays are Allied Control Company type AS3D, with coil resistances of 8945 ohms. After removing the contacts, small brass extension arms were soldered to the armatures in order to actuate the stimulator balls. When connected to the Schmitt circuit, which will be described below, the elements of this transducer would respond satisfactorily to an impulse of 8-10 msec duration.

In accordance with our plan, a set of Schmitt trigger circuits was developed to replace the former output circuits of the Vocatac. Each of these trigger circuits was coupled through a diode and RC filter directly to the output side of one of the tuned filters (described in the Quarterly Progress Report of Jan. 15, 1956, p. 134). Figure XI-2 is a schematic of the typical Schmitt circuit and coupling network. A very useful property of the Schmitt circuit is the fact that the plate current of  $V_2$  can be switched on or off by varying the dc potential of the grid of  $V_1$ . By proper selection of the value of  $R_5$  and of the positive and negative supply voltages, the potentials on the grid of  $V_1$  that are required for switching the plate current of  $V_2$  on and off can be brought very close to each other. For the circuit constants shown in Fig. XI-2, the plate current in  $V_2$  was turned on when the dc potential of the grid of  $V_1$  reached negative values in the range from -2.3 volts to -2.7 volts.  $V_2$  is switched off for potentials on the grid of  $V_1$  between -1.5 volts and -1.8 volts. A bias battery connected in the common ground lead maintains the  $V_1$  grids of all the trigger circuits at a positive potential when no signals are passing through the Vocatac, as can be seen from Fig. XI-2. When the signal-voltage amplitude in any tuned circuit reaches a sufficiently high value,

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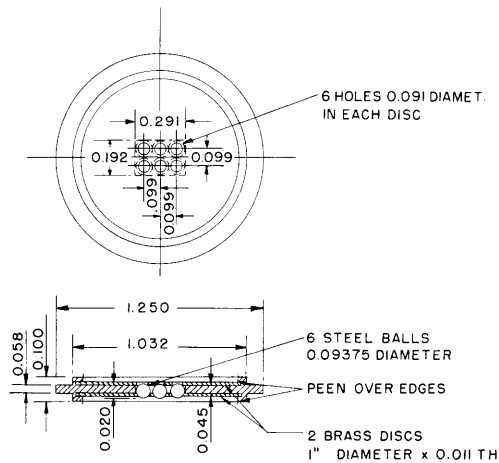


Fig. XI-1. Ball assembly for tactile transducer.

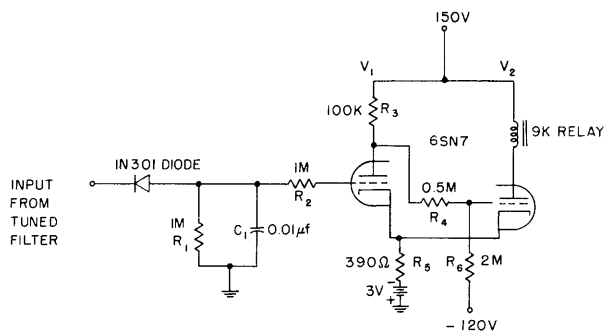


Fig. XI-2. Schematic of typical Schmitt circuit used in the Vocatac.

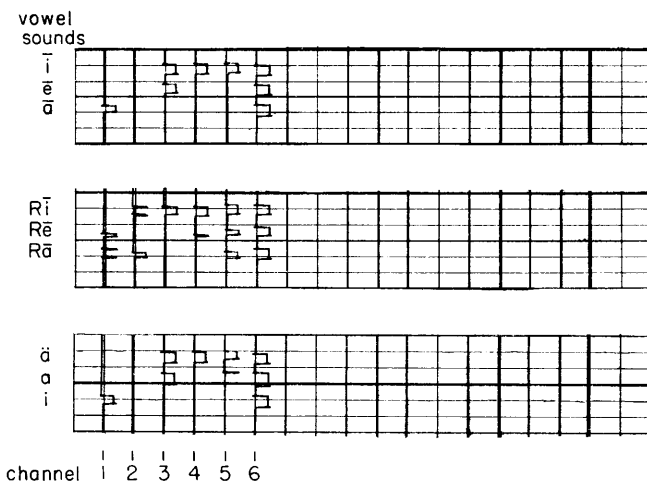


Fig. XI-3. Recorded response patterns of the Vocatac. Center frequencies of channels: (1) 382 cps; (2) 548 cps; (3) 715 cps; (4) 990 cps; (5) 1529 cps; (6) 3000 cps.

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the negative potential applied to the corresponding  $V_1$  grid through the diode and filter will cause the circuit to switch on. When these circuits were completed, the tuned filters were all readjusted to give a loaded  $Q$  of 10, and the system was adjusted to give a gain characteristic that rises 3 db per octave. This slower rate of rise was previously found to be preferable when clipping circuits were introduced into the initial stages of the Vocatac system.

The tactile patterns obtained with the new arrangement exhibited considerably more detail than those previously obtained. They also appeared to be somewhat more consistent for any given talker, but their more detailed space and time variations of structure served to emphasize differences between voices of different individuals. To facilitate accurate observation of the patterns, the transducer was replaced by a similar set of relays which had not had their contacts removed, and these relays were connected to energize six of the pens on an Esterline-Angus recorder. Figure XI-3 is a photograph of three sets of patterns thus obtained. The first set is for the vowel sounds "a", "e", and "i", pronounced as in the syllables "ray", "ree", and "rye". The second group exhibits the syllables just written; and the third is for another set of vowel sounds, "i", "a", and "ä", pronounced as in "it", "at", and "ah". These sounds were actually recorded on an endless loop of tape and then played back repeatedly through the Vocatac system. For any given tape recording, the patterns were invariant under at least a 20-db change in signal level. When successive tape recordings were made by the same talker and then played back to produce printed patterns, the consistency was good, although not absolutely perfect. Note the differences between the patterns for the three initial "r" sounds in the second group of Fig. XI-3. These are apparently caused by the anticipatory effects of the succeeding vowels. A few other combinations of vowels and final consonants ("r" and "d") were studied, with similar observations.

Unfortunately, one discouraging result appeared. When attempts were made to observe the patterns tactually by one of us (Witcher), a reasonably good Braille reader, much of the spatial and temporal detail was imperceptible. This was still true after considerable time spent in attempting to "learn" to perceive this detail. As we now see it, further study may be in order along any or all of the following lines. (a) After recording a variety of patterns such as those of Fig. XI-3, an attempt can be made to extract the details that remain essentially invariant when produced by different talkers of the same sex and same approximate age. The system might then possibly be redesigned to present only these invariant details. (b) Further studies could be conducted to determine the rate at which a subject can comprehend temporal changes, first involving two stimulus points and then progressively passing to the six stimulus points of the transducer. (c) Using the present system, experiment with other test subjects who are reasonably proficient Braille readers to determine whether or not they might be able to manifest more success in pattern learning. (d) Finally, the idea of a Braille-like form

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of output may have to be abandoned in favor of a set of tactile stimulators arranged more like those employed by J. B. Wiesner, N. Wiener, et al. (Quarterly Progress Report, Jan. 15, 1949, et seq.). Perhaps one stimulator might again be assigned to each of the five fingers and one to some area in the palm of the hand. This procedure would be based on the hope that tactile patterns characterized by rapid spatial and temporal variations may be capable of transmitting information to the brain at a higher rate when they have an opportunity to affect a larger number of nerve fibers.

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[Note added in proof. We recently undertook the design and development of a direct-translation reading machine for the blind. The tape output of the machine would display a facsimile of printed material by a dense array of pin holes that could be perceived as a roughness to touch. If this idea were applied to the output of the Vocatac, it would allow a deaf-blind reader to examine, at his own rate of comprehension, the details of patterns such as those shown in Fig. XI-3.]