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FINAL TECHNICAL REPORT ON MICROPHONE MINIATURIZATION AND IMPROVEMENT

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FINAL TECHNICAL REPORT
ON
MICROPHONE MINIATURIZATION AND IMPROVEMENT

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June 22 - August 28, 1970

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PREFACE

The technical results presented here represent a ten week effort by its authors during the Summer Institute for Biomedical Research sponsored by the Technology Utilization Office at the Goddard Space Flight Center. Their challenge was to apply NASA developed technology toward the solution of this particular problem and to demonstrate its usefulness to other problems in medical diagnostic monitoring instrumentation.

This report has been published and made available for general use so that others in both the technical and medical communities might benefit from the work of these individuals.

Wayne T. Chen, Coordinator
Summer Institute for Biomedical Research
Technology Utilization Office

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MICROPHONE MINIATURIZATION AND IMPROVEMENT

We have decided that the purpose of this project is to take an existing microphone and reduce it in mechanical size and to work on a method of measuring the response of the microphone. This was done after reviewing the different types of microphones available.

July 9, 1970

An ideal heart sound microphone should encompass some of the following characteristics:

1. Flat frequency response from 20-2000 Hz

2. Sensitivity must be sufficient to pick up heart sounds while at the same time be insensitive to environmental noise

3. In light of #2, a contact-type microphone is recommended

4. The response of the device should be linear

5. A constant probe pressure must be maintained which is independent of the applicator pressure of the device against the chest wall

6. Light weight and small size required for easy application to chest wall

7. Durable for day to day clinical use

Keeping the above criteria in mind the following types of microphones were considered:

1. Carbon microphone - high inherent noise

2. Condenser 11 - requires large D. C. voltage which may be dangerous to patient

3. Foil-Electret Condenser Mic. - direct pressure application not possible

4. Moving Coil -

5. Ribbon Microphone - not good for direct pressure applications

6. Crystal (piezoelectric)

7. Piezoelectric transistor (Pitran) - too delicate for clinical use at present stage of development.

Piezoelectric or moving coil-type microphones appear to be best suited for heart sound pickup.

Some of the characteristics of an existing heart sound microphone, as described in the article, "Heart-Sound Transducer" by Coleman are:

A. Polyurethane foam spring holds transducer against chest — minimizing pressure variation between microphone and chest wall which might alter the microphone's response.

   Pressure does not vary by more than 50 gm. over the functional range of movement.

B. Heart-Sound Transducer

   Ceramic crystal acts as the sensing element.
   Disc probe used to transmit chest wall vibrations.

C. Microphone Specifications

   Maico contact heartbeat pickup with disc probe
   Contact microphones are needed to avoid room noise
   Transducer had a high impedance of 270 K

   - Any direct cable from transducer would tend to pick up noise.
   - Preamplifier is incorporated into microphone housing to reduce noise problem.

   Polyurethane foam spring is used as a switch to turn off the amplifier when probe is not in contact with chest wall. This eliminates the monitoring of extraneous noises and reduces battery drain.

A check of the frequency response of the existing preamplifier was made and found to be linear, approximately between 30 Hz and 1000 Hz. Nevertheless, we plan on eliminating this amplifier and replacing it with a smaller-integrated circuit.

The results of this check can be seen on pages and .

July 15, 1970

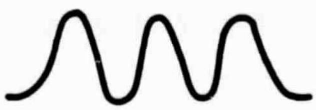
Unholtz-Dickie Calibration Shaker Table #106

Double-backed tape was applied between disc probe and shaker head.

at 700 Hz, lg 40 u inches

20 Hz, lg 0.5000 u inches

OUTPUT



-700 Hz,

Check shows support bracket was vibrating with shaker head.

microphone output 200 Hz

f = 100

8 isms = T

Very little coupling between support and shaker at 2000 Hz

Connecting 500 r load across output - because output was not referenced to ground and load must be added for this reason.

Experiment was declared a failure, probably because of the inability of this machine to produce a small enough signal.

July 22, 1970

<u>Calibration</u>

Since the Unholtz-Dickie machine was not sensitive for our measurements, we decided to look elsewhere. To try something to make sure the microphone worked properly, we hooked a signal generator to a 7 1/2" Jenson loudspeaker. A crude setup was used, just holding the microphone to the anchored speaker. A very good sinusoidal output was obtained down to 15 cycles per second.

We were satisfied the microphone worked and so borrowed a MB electronics Model FA 1250 shaker from GWU. Upon experimentation, however, we found that below approximately 80 Hertz we could not obtain a sinusoidal output. Either the signal was a clipped sine wave or just noise. We concluded that this shaker was also too large and not sensitive enough.

Then we borrowed from the Goddard Space Flight Center a one pound shaker, Model LT-100, made by Gutton Industries, Metuchen, New Jersey. After initial failure in obtaining a sine wave output, success was obtained by feeding in a signal directly from a Hewlett-Packard test oscillator on the order of 0.1 volt rms at low frequencies down to 18 Hz. The signal output was very unstable and appeared to turn into noise without warning.

We decided to both search for a flesh-like material to act as a buffer between the shaker head and the microphone tip to simulate more closely the microphone in contact with the chest wall.

July 27, 1970

<u>Design of Microphone Housing</u>

We decided that the main objective of this project would be the reduction in size of the microphone housing to the smallest dimensions possible without replacing the existing microphone element. The complete microphone will be small enough to be strapped to the chest. We would have preferred to work on the utilization of a new transducer element, but felt, since we only have 10 weeks to work, that if nothing else, we should reduce the complete microphone to manageable proportions. The overall response of the streamlined microphone will be compared with that of the original microphone. Although the microphone element will be the same in both cases, the size reduction in the new design will result in new mechanical resonance frequencies, so this must be investigated. While work on the microphone housing is proceeding we made contact with: Shegoto Industries, Ltd., Empire State Building, 350 Fifth Avenue, New York, New York (Telephone 212-695-0200), a manufacturer of contact-type microphones. We spoke to their sales manager, Irwin Weinstein, and he agreed to submit a proposal covering a microphone with a flat response from 20 to 2 KH_2 which will be small enough to be strapped to the chest. Mr. Weinstein's letter was dated July 15, 1970 and he said we would hear from him in seven to ten days. So far we have not heard from him and plan to call tomorrow if nothing arrives today.

New technology will be utilized in replacing the existing transistor amplifier with a Motorola MC1303 L 11 Dual Stereo Preamplifier Integrated Circuit. A printed circuit board will also be used to simplify wiring.

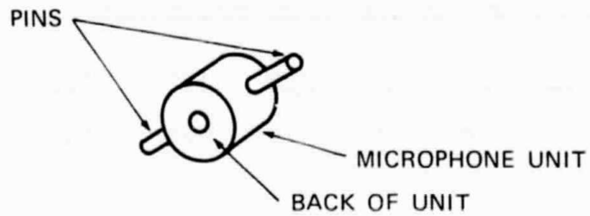
In our new design we decided to eliminate the bearing rod which was present in the original design. We viewed this rod as unnecessary and space consuming. The elimination of this rod presented us with two new problems:

1. How to keep the microphone unit from falling out when the microphone was held in a vertical position and

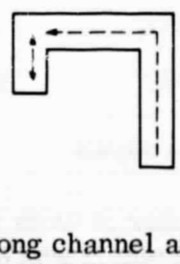
2. How to limit the distance that the microphone unit would be allowed to slide back into the teflon sleeve.

We first thought of placing an "0" ring near the outer edge of the teflon sleeve. However, this would not permit the contact disk to extend out (beyond the white rubber cover ring) for enough, so this idea was deemed unfeasible.

We then came upon the idea of using a bayonet-type groove mechanism as a solution to our problem. Two pins would be placed on opposite sides of the microphone unit. This is indicated below.



A side view of the channel to be cut into the teflon sleeve is indicated on the next page.



The pin would be guided by the long channel and then the microphone unit would be twisted around so it would slide to and fro in the smaller channel (marked by double-headed arrow). This type of arrangement would prevent the microphone unit from falling out by accident and would also act as a stop mechanism to prevent the microphone unit from being pushed back too far into the housing. Several possibilities came to mind after it was decided to use the bayonet groove:

1. Using the channel-pin setup as a means of activating and turning off the microphone. This would be done by lining part of the smaller groove with a thin metal strip, so that when the pin slides across the strip, electrical contact is made. We decided against this method because we questioned the reliability of the method. Dust and age may affect the electrical contact.

2. A small spring may be placed inside the groove to maintain the constant pressure feature of the microphone. If time permits, this method will be tried if we can't find a suitable substitute.

Since we are having most difficulty in calibrating the microphone, we decided to at least put down some of our efforts. This first one is using a Jensen loudspeaker with the microphone attached to a metal table, but mechanically insulated from the table by foam rubber. A constant input of 0.33 volts RMS was fed into the speaker. The output was taken from the integrated circuit preamp and monitored for uniform output on a scope and simultaneously measured on a VTVM with a decibal scale. Following are some of the output values.

FREQ	20	30	40	50	80	100	110	117	125	140
DB	-17	-14	-7	-6	+1	+75	+13	+14.4	+13	+8

FREQ	160	180	200	250	325	350	435	470	625	800
DB	+4	+1	-0.5	-3	-1.2	-10.8	-2.7	-15.6	-9	-13

FREQ	940	1040	1.25K	1.5K	1.8K	2.0K
DB	-20	-14	-16	-8	-6	-8

0 db = 1 VRMS

This measurement was taken using a buffer of foam rubber between the microphone tip and the speaker. A sinusoidal output was only obtained down to 35 cycles. Below that the signal was distorted.

Next I tied the microphone directly coupled to the Gulton one-pound shaker. Again 0 db = 1 VRMS. The input was 0.13 volts RMS.

FREQ	20	35	39	50	100	150	250	400	500	600	750
DB	-24	-26	-3 db	-6 db	-5 db	-2 db	+2.4	+8	+13.6	+12.4	+10.3

FREQ	900	1000	1.1 K	1.2 K	1.33 K	2 K	1.6 K
DB	+4	-2	+7	+11.6	+5	-5.3	0

As a check I measured the response of the integrated circuit amplifier alone and found it to have a perfectly flat response from 40 to 200 Hertz and dropped of 0.4 db between 20 and 40 db, quite adequate for our purposes.

With the shaker we still would not get good sinusoidal output below 35 Hz.

July 28, 1970

Next I tied the shaker table with a piece of silicone rubber as a buffer. Input = 0.3 V RMS.

FREQ	20	30	35	40	50	75	100	125	150	175	200	250	350
DB	-21	-20	-15	-7	-7	-4	0	4.6	+11	+15	+10	+4	-0.5

FREQ	400	500	750	1000	1250	1500	1750	2000
DB	-1.5	-12.6	-18	-20	-20	-25	-23	-21

Again, I could not obtain a sinusoidal output below 35 Hz.

Because I was getting an irregular response, I obtained a calibrated accelerometer, an ENDEVCO Model 2221D and an ENDEVCO Charge Amplifier Model 2620 associated with the accelerometer.

The accelerometer is very small and light. I placed it between the shaker head and the silicone rubber of the previous test with the microphone loading the rubber. I was trying to duplicate the above test only looking at the output from the shaker.

I could not get even a near sinusoid below 50 cycles, so I'm going to go on the assumption that it is not the microphone's fault, rather the shaker's. The results follow.

Input is 2.6 volts RMS

FREQ	50	60	70	80	90	100	110	130	150	200	300	400
DB	-14	-10	-4.5	+1	+7.5	+10	+8	+4	+1.5	-1	-2.5	-3.2

0 db = 1 volt RMS

FREQ	500	750	1000	1250	1500	2000
DB	-3.5	-4	-3.4	-3.5	-3	-4

The accelerometer was calibrated so that 0 db = 2 g and -10 db = 1 g. It appears as though the loaded shaker is putting out a fairly consistent and uniform output above about 300 ips.

July 30, 1970

The following is the work done on the first prototype of the new design microphone. We have decided to use the setup of the Gulton vibrator, the ENDEVCO accelerometer attached to the shaker head, a piece of silicone rubber on top of the accelerometer and the microphone tip depressed on top of the silicone rubber. The microphone is held in place by a table overhanging the whole setup with a hole in the center. The microphone is in the center of the hole, mechanically isolated by a piece of foam rubber.

First I took measurements on the microphone output. The constant input is 0.4 volts RMS. Below 25 cycles the output was not a perfect sine wave, but is a close approximation.

August 13, 1970

Using the described integrated circuit we fabricated a printed circuit. We brought the cable into the microphone using several layers of shrinkable tubing. This was done because space was very limited and we wanted to have some sort of strain relief.

Once that was completed I went back to calibration. This time we ran into many problems from 60 cycle hum. After much experimentation we found that grounding the table, even though it was electrically isolated from the circuit, considerably reduced the hum.

We used the same setup as previously described with the accelerometer sandwiched between the accelerometer and microphone.

A set of points was obtained for the output of the microphone and another set from the accelerometer. I subtracted the two to eliminate any variations caused by the shaker. The composite curve follows.

August 14, 1970

Since our microphone is a displacement device, an ideal curve for it would have a slope of -2, as indicated by the dotted line or since we have a db scale a slope of -20 db per decade.

The graphs from the above tests are in the lab book on pages 32 and 33. Both graphs are from the same microphone and yet widely vary in the low frequency region.

I am concluding that the obtained data in the graphs is essentially meaningless, for some of the following reasons. When in use the microphone outer rubber ring is in contact with the medium, the chest, something we did not have here. The mechanical impedance of the chest and coupling of the microphone to the skin was not even closely approximated here by the simple piece of rubber. The rubber itself has a resonance frequency that would not be picked up and subtracted by the accelerometer. If the microphone was not perfectly vertical our curves would be different. The accelerometer noise level was so high below 50 Hz so as to render virtually meaningless the obtained results.

August 24, 1970

Fabrication Problems

On the preceding pages are the mechanical drawings of the microphone unit. On the actual fabrication of the microphone unit, the shop cut four grooves instead of two. The microswitch was not clicking off each time so we elevated the switch with a piece of cardboard, which did the job. The spring wafer should be made to have maybe another 1/8" trovel so that the spring is always in compression.

One problem we had not allowed for was the cable between the transducer and the input of the amplifier. We wanted to be able to remove the transducer from the rest of the case for servicing, if necessary. Shielded cable was used to reduce noise pickup. The method used of putting a long wire in is adequate, but not completely satisfactory since in order to reinsert the transducer, the back must be removed also.

One other adequate, but not entirely satisfactory arrangement, is the tip itself. With normal use it will begin to unscrew and become loose. However, it is not worth spending that much time on it. A better method would be to use a different transducer, where the copper plate attached to the crystal can be directly applied to the skin. This has several other advantages. There is not the problem of someone applying pressure to the tip at an improper angle and exerting a torque on the crystal. It also reduces the mass of the sound-receiving area. Since sound is a pressure variation, and $P = \frac{F}{A} = \frac{MA}{A}$, reducing the mass with the same pressure would increase the acceleration and therefore the displacement on the crystal. Eliminating the tip would increase the area receiving the sound, also giving a bigger displacement.

All of the preceding are problems with the existing design; however, if we had more time, we would not use the existing transducer. The next step for someone who has more time is to either design or purchase a better transducer — one in which, as I spoke about before, the whole face of the transducer is available for contact to the chest.

Another possible step is to coat the outer aluminum case with some soft sound-absorbing material. This will reduce contact noise in holding the case.

For calibration, a possibility might be using the forearm to simulate the impedance of the human chest, as described in the article later in this book.

Evaluation of Microphone Samples from Shigoto Industries

Two moving coil-type microphone samples received from Shigoto were connected to a commercial operational amplifier. The diaphragm of the microphone was placed against the chest wall. Despite changing the gain on the amplifier, no heartbeat of any kind was recorded on an oscilloscope. This is probably due to the fact that the diaphragm of the microphone is not sensitive enough to detect the vibrations of the chest wall. A special contact-type probe, similar to the one used on the crystal microphone, may help. This was not tried due to lack of time.

Maico Electronics, Inc.
21 N. Third Street
Minneapolis, Minnesota
612-941-3900

(maker of original crystal microphone)

Task II
MICROPHONE MINIATURIZATION AND IMPROVEMENT

COMMENTS

Methodology

Methodology for this project was good. The documentation consisted of daily entries in the laboratory notebook. A formal report was not generated for this project. The initial entries revealed the effort of the literature search in the area of microphones and previous works. Methodology was quite thorough in that the characteristics of types of microphones were reviewed and a plan was followed, although not written. This team was also very resourceful. Generous use was made of outside resources such as manufacturers, various experts and other NASA installations.

Results

The present existing microphone was then reviewed and a method of miniaturization was developed. Standard electronic testing was done to monitor the work such as data on frequency response. In this manner resonant frequencies could be dealt with. This project required interface with fabrication shops at NASA. They experienced the technique of the fabrication and machining of parts through sketches and not formal drawings. There were problems in fabrication, but they were able to be worked out in conjunction with NASA personnel. The students were made aware of some of the seemingly complicated procedures that can be accomplished in a research (electronic) laboratory such as the ease by which a printed circuit board can be fabricated. A prototype miniature microphone was constructed, tested and demonstrated.

Conclusions

The documentation showed no formal section on conclusions of the work. The student's conclusions were stated as follows. A special contact-type probe similar to the one used in the crystal microphone may help. Thus, this project succeeded in miniaturizing a crystal-type microphone for use with the cardiogram. The miniaturization of this microphone is crucial to the acceptance of patient testing. The microphone is extremely useful in the recording of phonocardiograms when used with envelope detector developed by another task for patient screening.

Future Applications/Expansion

The prototype miniature microphone has been delivered to the Department of Clinical Engineering where a project to evaluate the envelope of the phonocardiogram is being conducted. The work is being conducted by one of the former Summer Institute students on a part-time basis. The microphone is being interfaced to the envelope detector. The plan is to record preliminary data of phonocardiograms and evaluate the merit of the envelope detector in disease detection.