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Department of Physiology

12 November 1968

NASA CONTRACT NO. NSR 05-018-087

QUARTERLY PROGRESS REPORT:

Period covered: July 10, 1968 through October 9, 1968

1. SUMMARY

During this reporting period major effort was concentrated in circuit development, acquisition of components, experimental evaluation of implant sites and tentative scheduling. Three of the major circuits are either in the prototype packaging or in the final breadboard stage. The basic planning has been established based on a one year contract, however, the change from one year to 18 months is being considered, as shown in Table 1.

2. PLANNING

Table 1 illustrates the major flow pattern of the contract. The essentials comprise the development of the following: Blood pressure signal conditioning systems, blood flow signal conditioning systems, implant cases, auxiliary circuits (such as biopotential signal condition switches) and an integrated design and specification.

As indicated by the flow chart, the approach is to develop equipment for each parameter, then test its operation, independent from other channels. When satisfactory results are obtained with each parameter, an integrated system will be fabricated and tested.

Upon obtaining satisfactory operation of a two-channel implant (approximately late December, 1968) several two-channel implants will be fabricated and tested in February, 1969. In March, April and May, 1969, a three-channel implant (blood flow, blood pressure and biopotential) will be fabricated and tested.

Paralleling the hardware development, a system design review will be conducted in early 1969 and circuits specifications written for sub-contracting. It is anticipated that a proposal will be disseminated to obtain a three-channel implant of a flight nature. These systems would be used for further evaluation during June, 1969.

TABLE 1

TIME INTERVAL	TENTATIVE ACTIVITY	APPROXIMATE STAFF	
		*E	*M
July - Sept. 1968	Contract Organization Circuit Development Implant Site Investigation	3	2
Oct. - Dec. 1968	Circuit Development Preliminary Individual Circuit Testing Development of Cases for Implanting Preliminary Implant Tests	3	2
Jan. - March 1969	Circuit Changes, Etc. Specification Generation for Circuits Integrated System Development Major Implants (Single Channel)	3	2
April - June 1969	Circuit Modifications Single Channel Implants Generation of System Specifications Integrated System Implants Generation of Request for Proposal	3	2
	Issue Subcontract (Tentative)	3	2
July - Sept. 1969	Modification of System Integrated System Implants System Design Evaluation Generation of Flight Experiment Plan	3	2
Oct. - Jan. 1970	Testing of Final Three-Channel Implant System Circuit Specifications	3	2

* E = Engineering

* M = Medical

3. BLOOD PRESSURE CIRCUIT DEVELOPMENT

The primary design goals considered in the development of a blood pressure detecting system were low power operation, small size and reliability. The low power requirement necessitated the use of a low bridge drive current, thus making it necessary to use a high-gain D.C. amplifying system.

The high-gain D.C. amplifier is not commensurate with stability. Therefore, in order to maintain stability, yet obtain low power operation, a chopper type amplifier is required.

Figure 1 illustrates the prototype of the resulting circuit. It consists of the basic parallel-T oscillator, a switching transistor and an A.C. amplifier. The oscillator output drives the chopper transistor Q_1 to produce a chopped current to the resistive pressure sensor.

The differential amplifier integrates and amplifies the square wave output from the bridge. The output of this amplifier is then subtracted from the primary feedback through the parallel-T network by the action of the differential operational amplifier. The result of this subtraction is a violation of a condition for oscillation; to re-establish this condition, the frequency of the oscillator changes. The end result is direct frequency modulation proportional to the pressure input.

Total power requirement is low, on the order of 300 μa at 6 volts. Packaging can be extremely small due to the small number of components and the use of flat pack operational amplifiers.

4. BLOOD FLOW SUMMARY

Blood flow measurement typically requires the use of rather large power-consuming devices, thus limiting its applicability to continuous use. Therefore any system intended for continuous use must be designed to eliminate the large power consumption.

The typical systems currently used are the electromagnetic and the ultrasonic. The electromagnetic provides more accuracy at the expense of large power consumption, while the ultrasonic is adaptable to low power design but does not measure as accurately.

For our initial effort we have used the ultrasonic technique. This system is now in the prototype breadboard stage undergoing bench testing. The essentials of operation are as follows: An oscillator is triggered on for approximately 1 microsecond with a free-running switch, exciting both crystals simultaneously at the same level. After cessation of the excitation, each crystal is affected by the energy conducted from one crystal to the other. If there is no blood flow, each crystal has the same voltage level and the sum is zero. However, if there is a flow, the addition of the cross-coupled energy is enhanced in one crystal and decreased in the other and the sum is not zero.

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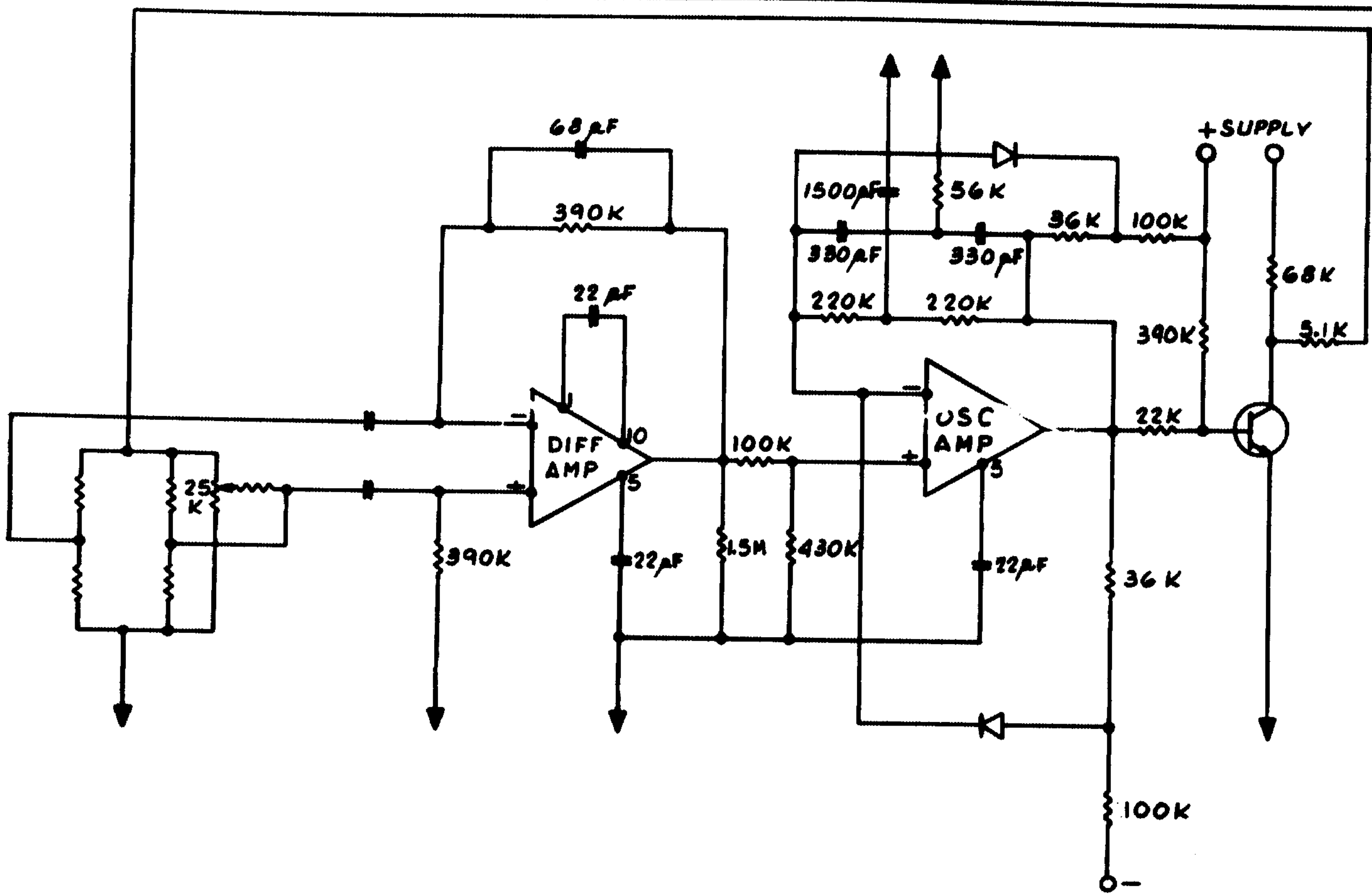

Figure 1

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CIRCUIT BLOOD PRESSURE

It is necessary, however, to control the timing of the events since it takes several microseconds to transmit the energy from one crystal to the other. The reflected signal requires approximately 6 to 8 microseconds to appear on the cross crystal, therefore, the amplifier is gated approximately 6 microseconds after the crystal is excited and remains on for approximately 1 microsecond. The effect of the blood flow, then, is to amplitude modulate the input to an amplifiér. After suitable amplification, the amplitude modulation is peak detected to recover an analog signal of blood flow.

4.1 BLOOD FLOW BLOCK DIAGRAM

Figure 2 illustrates the block diagram of the blood flow signal conditioner.

Switch S_1 activates the 5 megahertz oscillator for 1 microsecond each 200 microseconds. The activation of the 5 megahertz oscillator excites both crystals with a 12-volt peak-to-peak sine wave signal for a period of 1 microsecond. The excitation sends a burst of energy from one crystal to the other within approximately 6 microseconds. The relative phase of this energy is modified by the blood flow during transit and, therefore, the voltage measured from point A to B varies in amplitude proportional to the phase difference.

Assuming there is no blood flow, the energy reflected from crystal A requires 6 microseconds to reach crystal B, and that from crystal B requires 6 microseconds to reach crystal A. Therefore the amplifiers K_1 and K_2 are gated at 6 microseconds after the oscillator is gated.

The amplifiers are gated off after 7 microseconds to avoid detecting and amplifying the second reflected signals from the crystals. Amplifier K_3 peak detects the amplitude modulation signal and produces an analog signal of the blood flow.

5. IMPLANTED TRANSMITTER POWER CONTROLLER

Since it is unwise to design low-current circuits when stability is of major importance, an alternate method must be found to conserve power.

Controlling the transmission time to approximately 5 % is one technique to alleviate the problem. Continuous transmission is not generally beneficial in a space application since the ability to recover data continuously is absent. Analyzing this much data is also a rather formidable task.

A 5% duty cycle will allow data capture of 4½ minutes for each orbit, which is the typical available data capture time. Thus an efficient operation would be to activate the implanted transmitter by command upon the spacecraft's entry into the data capture zone, and to design the switch to automatically deactivate at the end of 5 minutes. Transmission could be activated upon the craft's entry into any data capture zone; thus spot checking the animals would be possible if necessary.

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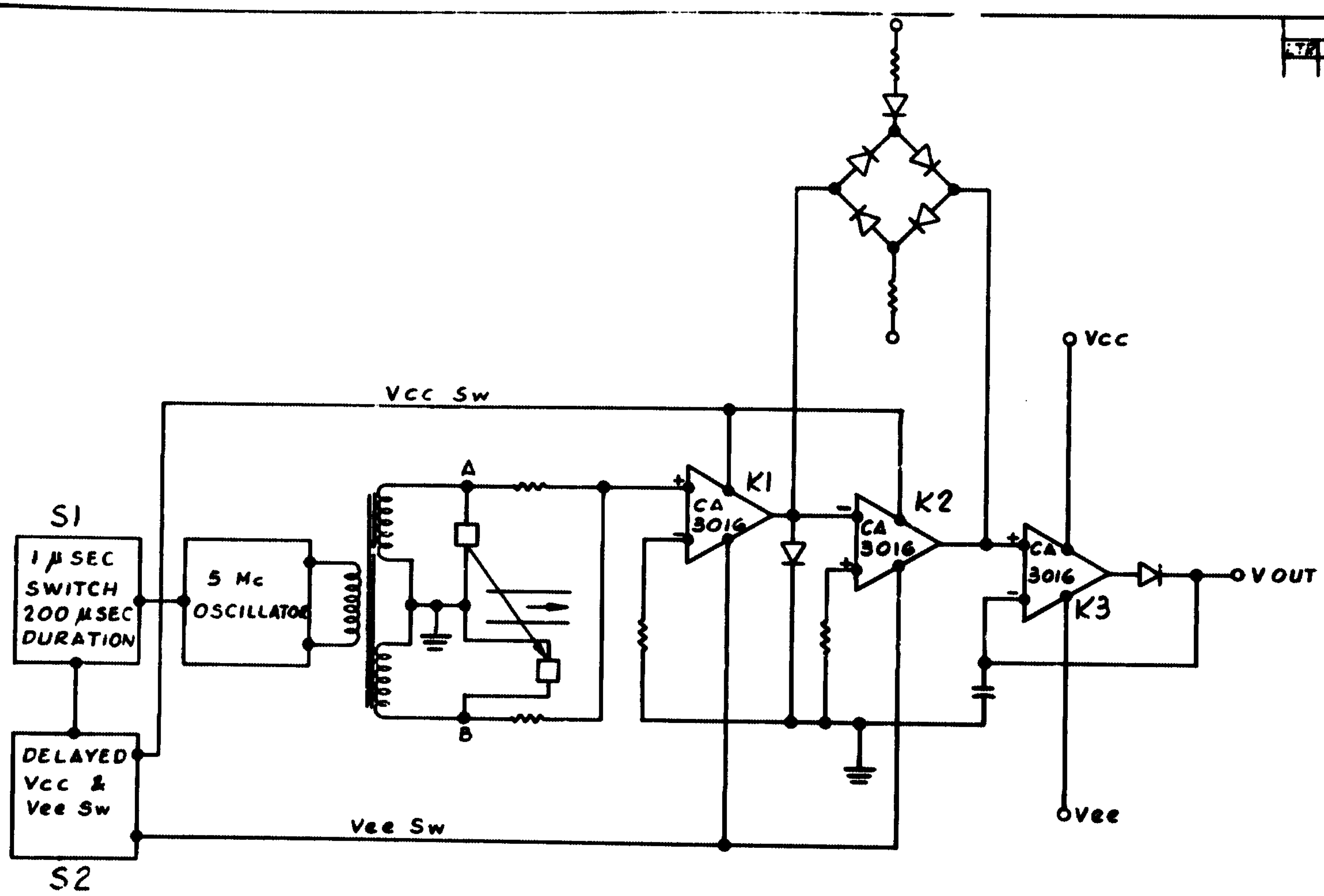

Figure 2

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It might be of further benefit to design the control device with two modes of operation, i.e., (1) command activation with automatic deactivation (2) command activation with command deactivation. The two-mode operation would be beneficial in ground testing where a 4½ minute interval is inadequate to complete the experiment and, on occasion, it might be required for obtaining more than a 5 minute continuity of data during flight. Such a possibility might occur if there was an on-board recorder and it was desired to obtain data on the recorder during certain tests. Such a switch would require three commands:

(1) Command ON -- automatic OFF
(2) Command ON -- continuously
(3) Command OFF

Currently the control being designed and used is of the two-command variety, i.e., command ON continuously and command OFF. The ON command is initiated by a 250 KC-conducted signal and the command OFF by a 500 KC-conducted signal. Investigation of a three-command control will also be considered.

5.1 SWITCHING TECHNIQUE

Since it is difficult to radiate energy to a subject at any distance from the command source, it is suggested that under certain circumstances the command frequencies actually be applied directly to the animal.

A possible technique would be to condition the unrestrained animal to grasp the electrodes which would inject the command signal directly into the subject. The command signal's presence on the electrode would be established by ground command and the animal could be cued by an audio or visual signal slaved to the ground command.

This method has the disadvantage of disturbing the animal before each recording session during an unrestrained type of experiment. Consequently, a technique for transmitting high energy signals to the animal must be established when it is necessary not to disturb the animal. For a restrained experiment a permanent electrode could be positioned to be in contact with the animal at all times.

5.2 SWITCH OPERATION

The circuit is centered around a device (3N84) which is basically a four layer semiconductor that operates on an avalanche principle (Figure 3). This type of device is highly desirable for power switching due to its low output impedance and very fast rise and fall times. The only problems encountered in the configuration of a power switch is that of gating the device off. When the device is on, the impedance looking into the gate is approximately 100 Ω using about a 1 K Ω load at 6 V DC. This necessitates the use of a high gain amplifier in the off gate situation. In the on gate situation the gate input impedance is very high and only requires about 10 μa for gating.

Once the gating requirements have been met DC wise, then the timed circuits for the ON gate and OFF gate were easy to design. The timed circuits in either case are merely a LC tank circuit tuned to two separate frequencies far enough apart to avoid accidental gating.

Coupling to the ON and OFF gate amplifiers was accomplished with AC coupling and clamping.

6. RESULTS

The results of the first three month's effort has been mainly the design and development of the blood pressure and blood flow signal conditioning systems. This work is of paramount importance since simultaneous application of these two measurements permits determination of the peripheral resistance component of the cardiovascular system. The ability to obtain these two parameters continuously by using implanted equipment is nearing realization. Instantaneous low power operation linked with a 5% duty cycle of transmission theoretically will allow several months of data acquisition.

7. FUTURE EFFORTS

During the next three months work will continue on the development of blood pressure and blood flow signal conditioning systems.

Original Copy Signed
By John P. Meehan, M.D.

John P. Meehan, M.D.
Principal Investigator

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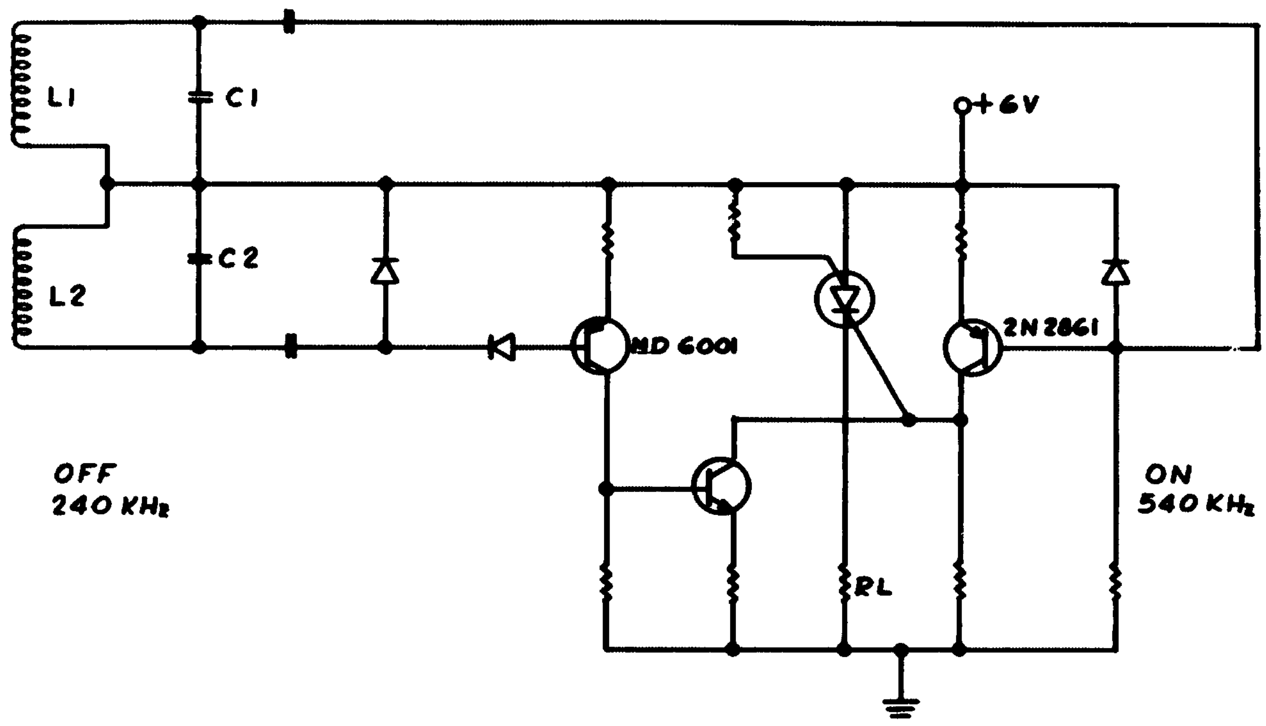

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CIRCUIT POWER CONTROLLER

Figure 3