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DEPARTMENT OF THE NAVY

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THE ACOUSTIC RANGE MEASURING SYSTEM

by

Jay C. Brown and William G. Niner

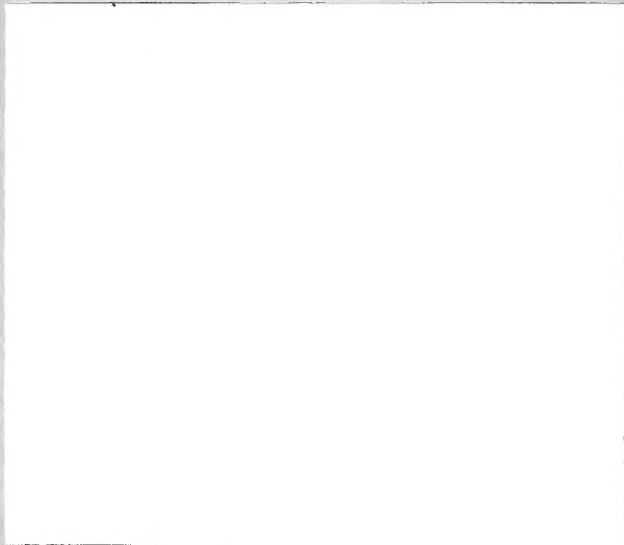


HYDROMECHANICS LABORATORY
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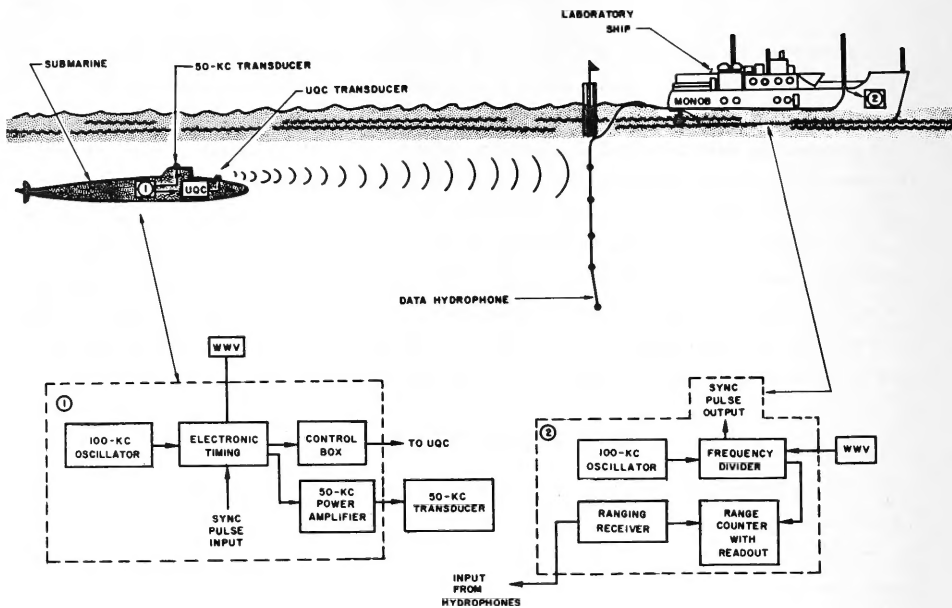


Figure 1 - Operational Diagram

(laboratory ship and submarine) and the sound velocity. Accordingly, one of the major requirements in the system is the precise synchronization of the two clocks. Two methods are now in use. In the first method both clocks are synchronized with National Bureau of Standards Radio Station WWV; in the second a pulse is sent from the laboratory ship over an FM radio circuit and the submarine clock is synchronized with this pulse.

Included as an option in the submarine electronics are a 50-kc power amplifier and a 50-kc transducer. These instruments may be used instead of the AN/UQC-1A to avoid interference with acoustic measurements in the AN/UQC-1A frequency range.

SUBMARINE COMPONENT DESCRIPTION

A detailed description of the ARMS equipment employed by the submarine follows.

TIME STANDARD (Submarine)

The time standard, as shown in Figure 2, is used to provide a precise time base for the operation of ARMS. A drift from synchronization between the two time standards will result in an error in range. So that this error does not exceed 1 yd/day, the drift must not exceed $600 \mu\text{sec}$ in a 24-hr period ($8.64 \times 10^4 \text{ sec}$) or

$$\frac{600 \times 10^{-6} \text{ sec drift}}{8.64 \times 10^4 \text{ sec}} = 7 \times 10^{-9} \text{ sec drift/sec}$$

$$\text{or } 7 \times 10^{-9} \frac{\text{cycle drift}}{\text{cycle operation}}$$

The time standard used is Model FS-1100T, manufactured by Sulzer Laboratories of Rockville, Maryland. It is a 100-kc oscillator with a stability figure of an order of magnitude better than that required.

ELECTRONIC TIMING PACKAGE

The timing package, shown in Figure 3, uses the 100-kc output of the time standard to produce the pulses needed for the operation of the other parts of the submarine system. The 100-kc output is divided by successive decade dividers and then by two flip-flops to yield 10 kc, 100 cps, 1 cps, 1/2 cps, and 1/4 cps. Each decade divider or divide-by-ten circuit consists of four flip-flops and associated gating circuits.

These dividers must be phase synchronized, as has been mentioned. Two methods are used: The first is to trigger an oscilloscope on the positive rise of the 1-cps pulse while viewing the timing pulse from Radio Station WWV. Two switches located on the front panel of the timing package allow the subtraction of a preset number of pulses or the addition of

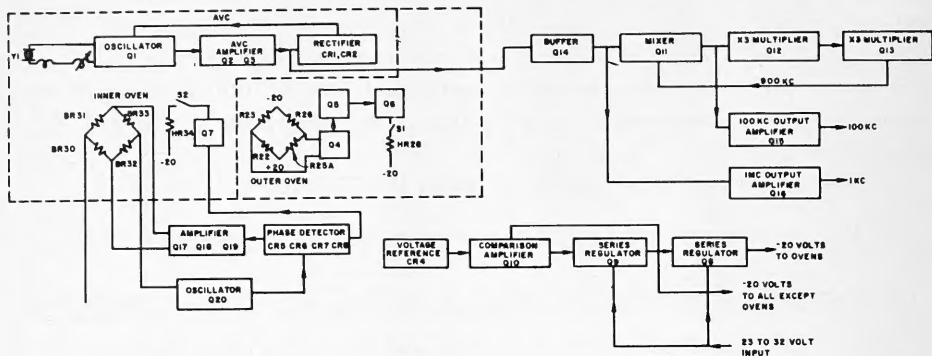


Figure 2 - Time Standard, Model FS-1100T

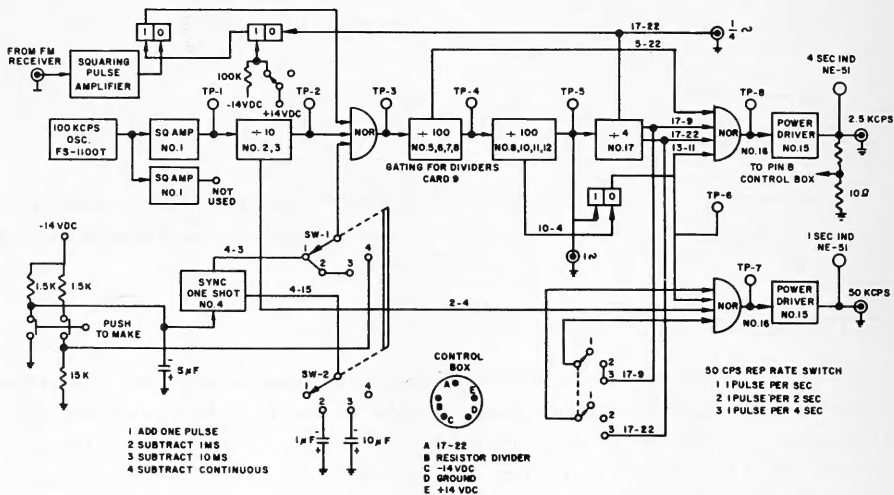


Figure 3 - Electronic Timing Package

one pulse so that the 1-cps pulse and the WWV pulse can be aligned. The second method is simpler and can be used when good radio reception is available between the submarine and the laboratory ship. A timing pulse is sent from the laboratory electronics to the submarine. Pushing a button interrupts the operation of the divider when it has reached the correct state for synchronization. A pulse from the laboratory electronics starts the divider chain again at the correct time.

The timing package also provides signals for driving both the AN/UQC-1A, which uses a 2.5-kc signal, and the 50-kc power amplifier. A pulse 20 msec wide at 2.5 kc is generated every 4 sec. Every 1, 2, or 4 sec, as preselected by the operator, a 20-msec wide, 50-kc pulse is generated.

CONTROL BOX

The function of the control box is to provide, on command, a predetermined number of pulses or a continuous pulsing which may be secured at the operator's discretion.

When in the automatic position, the control box, upon command of the operator, keys the AN/UQC-1A and begins gating pulses from the timing package into the AN/UQC-1A. When the number of pulses reaches two or four, as selected by the operator, the AN/UQC-1A transmission is stopped.

The sequence of events is as follows (see Logic Diagram, Figure 4): The operator depresses SW-1, putting a positive pulse at the "zero" side of Flip-flop Q-1; this pulse sets Q-1 to the "one" condition. With Q-1 in this position, two events take place. First, the transistor controlling the relay is forward biased, closing the relay; and second, the AND gate logic is so biased that the gate is opened and the 4-sec pulses are passed when they occur. Flip-flops Q-2 and Q-3 function as a counter; they count the 4-sec pulses, as they occur, to a count of two or four depending on the position of SW-2. When the proper count has been reached, a pulse is sent to Q-1, which resets it to the "zero" state, causes the relay to unlatch and the AND gate to close, and resets Q-2 and Q-3. In the "continuous" switch position (SW-3), the relay is closed, the AN/UQC-1A is keyed continuously, and a modulation signal is fed to it for a period of 20 msec once every 4 sec coincident with the 4-sec pulse.

50-KC POWER AMPLIFIER AND TRANSDUCER

The function of the 50-kc power amplifier and transducer (Figure 5) is to generate an acoustic pulse at 50 kc and to transmit this pulse through the water to a receiving hydrophone.

This function is accomplished through the use of a vacuum tube amplifier. The first section is a simple pulse amplifier which drives three cascaded Class C tuned amplifiers to develop a peak power of 200 w. The output of the power amplifier is matched to a coaxial line by Transformer T-1 and is matched from line to transducer by Transformer T-2.

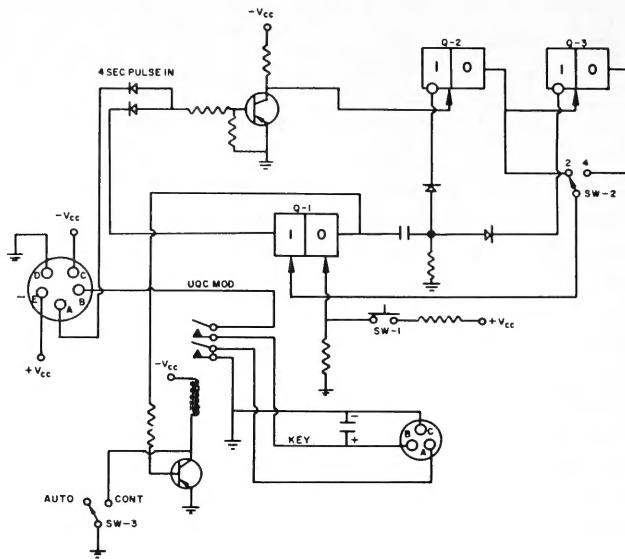


Figure 4 - Control Box

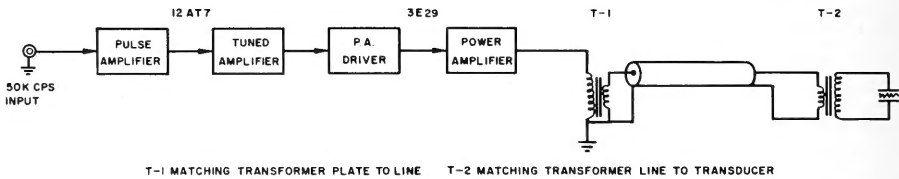


Figure 5 - 50-KC Power Amplifier

The transducer is Model LC-35, manufactured by Atlantic Research Corporation, with the housing manufactured by the David Taylor Model Basin. The transducer output is approximately 90 db (rel. 1 dyne/cm²) which, dependent upon sea conditions, gives reliable range readings to 2000 yd.

LABORATORY SHIP COMPONENT DESCRIPTION

The following ARMS equipment is employed by the laboratory ship.

TIME STANDARD (Ship)

The laboratory time standard is identical to the one used on board the submarine.

FREQUENCY DIVIDER

The frequency divider provides accurately timed pulses for the operation of the range counter. As shown in Figure 6, the FS-1100T 100-kc output signal is divided successively by five identical decade dividers; each decade divider consists of four flip-flops and associated gating circuits. The 1-cps output of the last decade is further divided to yield 1/2-cps and 1/4-cps repetition rate pulses. Any of the latter pulses plus the 1-sec pulse may be selected, as required, to provide a 1-, 2-, or 4-sec range readout rate. The 10-kc output of the first decade is also divided by 6 to obtain the 1.67-kc range-counting frequency.

A flip-flop and two AND gates are used to generate two 1-kc pulses of 20-msec duration; one with a 1-sec repetition rate and one with a 4-sec repetition rate. These two pulses drive lights for visual indication of their occurrence and show the time of transmission of the acoustic pulse.

RANGE COUNTER

The range counter measures the time of travel of the acoustic pulse from the submarine to the receiving hydrophones and reads out the corresponding range.

To read out this range in yards, pulses are counted at a 1.67-kc rate in a binary coded decimal register. Each decimal digit of the register is shown in the block diagram of Figure 7 and is marked in units, tens, etc. The count proceeds from zero to 1000, 3000, or 6000, depending on the position of the Switch SW₁. The switch sections SW₁-B and SW₁-C and the Gates G-1 and G-2 sense the desired highest number to be counted. When the desired number is reached, Flip-flop Q-2 is reset; this flip-flop resets the thousands digit to zero. Also, when Q-2 is reset, it stops the count through the action of G-3, which acts as an AND gate.

At the moment an acoustic pulse leaves the submarine, a synchronized pulse is generated by the laboratory frequency divider, which triggers Q-1 to the zero state. Ten msec later it is triggered back to the one state, which causes a pulse to trigger Q-2 to the one state.

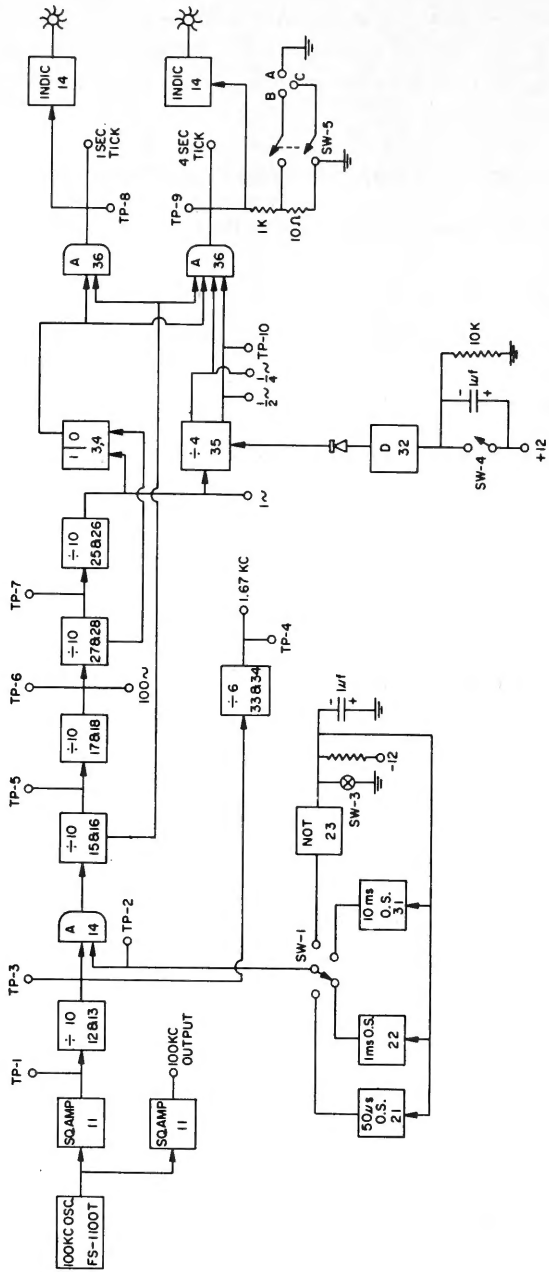


Figure 6 — Frequency Divider

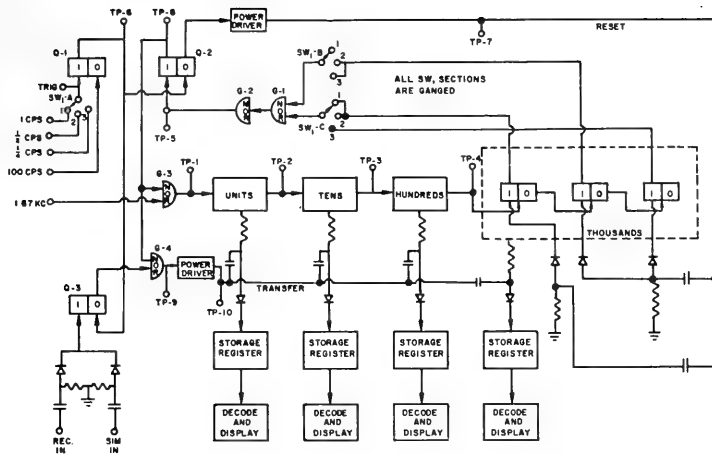


Figure 7 - Range Counter

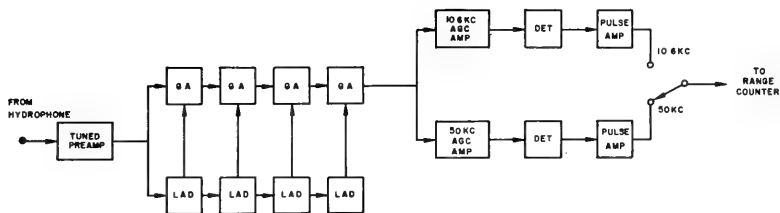


Figure 8 - Ranging Receiver

This action causes the counting register to count from zero, one count for each yard of travel of the acoustic pulse coming from the submarine. Ten msec after the acoustic pulse is received by the ranging receiver, a pulse is sent to the range counter, triggering Q-3 to the zero state and causing a transfer of the number in the counting register into the storage register. This number is decoded and displayed visually.

RANGING RECEIVER

This receiver is used to distinguish the ranging signal pulse from the accompanying background noise, a noise which may include transients similar to the signal.

This function is difficult to perform because of the complex nature of the signal-to-noise (S/N) ratio. One source of noise is sea ambient and its characteristics may vary with time; other noise is generated by the submarine and is a function of range and other factors.

Since both signal and noise vary by many decibels, a large amount of automatic gain control (AGC) is incorporated into the ranging receiver to enhance detection of the ranging pulse. Because this AGC action is slow, the gain is not reduced upon receiving a transient such as the signal pulse.

The signal flow is illustrated by Figure 8, which first shows a shielded preamp. This preamp is tuned to both 10.6 kc and 50 kc, and it may be manually varied in gain to compensate for various ambient conditions.

A stepped AGC amplifier, which consists of four cascaded gated amplifier (GA) stages, follows. Each stage has the capability to be switched electronically from 15-db gain to 0-db gain. As the input level rises or falls, a series of level amplifiers and detectors (LAD) sense the change and automatically switch the gain of the gated amplifiers accordingly. The stepped AGC amplifier maintains its output level between -23 dbv and -3 dbv for an input level variation of up to 75 db.

Following the stepped AGC is a tuned, continuously variable AGC which controls its output level within 3 db for a 30-db variation at the input. This AGC, as well as the stepped AGC, passes any short transient without attenuation.

The resulting transients, including the signal pulse, are measured for minimum level and minimum pulse length by an integrating energy level detector. Any pulse surviving these two checks is considered to be a signal pulse, and a data transfer signal is sent to the range counter.

CURRENT AND FUTURE DEVELOPMENT

As space is always a problem on board ship, plans are being formulated so that a substantial savings in space can be obtained for both portions of the system. Studies are being made of miniaturization techniques to determine which is best suited in terms of size and weight savings versus reliability and cost.

A twofold effort is presently directed toward improving the efficiency of the 50-kc portion of the system. First, a new projector that resonates at 50 kc is under design to provide a more efficient transfer of power. Second, a solid-state power amplifier is being designed with the net result being a smaller, more efficient, and more reliable 50-kc transmitting capability.

Future plans to improve the usefulness of the system for its intended applications, i.e., helping in data reduction and providing navigational aid, consist of expanding the laboratory portion of the system to a capability of handling data from six hydrophones simultaneously. To work in conjunction with the expanded system, plans are underway to provide an analog voltage that is proportional to range for each data hydrophone. This analog voltage will serve the prime function of supplying range information to the automatic data processing equipment so that on-line analysis may be accomplished. To increase the usefulness of the system in providing navigational aid, a range readout on the submarine would be of great value. To provide such a readout studies and tests are contemplated to determine the optimum frequency of operation, power required to transmit the information, and the best format of transmission for minimum error.

EVALUATION RESULTS

Numerous submarine acoustic trials and system evaluation tests have shown that the ranges obtained are both reliable and repeatable to ranges exceeding 5000 yd when using the submarine's AN/UQC-1A as the acoustic sound source. The capability of transmitting acoustic energy at 50 kc is a recent addition to the system, but preliminary field tests with surface and subsurface craft have shown that ranges can be obtained with the same degree of accuracy and reliability to a range in excess of 1500 yd.

Preliminary evaluation tests were made employing two surface ships. One of these ships simulated the target, the other the laboratory ship. The target ship made runs past the listening ship at various speeds to determine signal-to-noise ratios and true signal recognition ability. Static drifting tests were conducted where ranges were checked by a high accuracy, recently calibrated radar, and close ranges, i.e., less than 1000 yd, were checked with a statameter as well. The agreement between these methods was very good.

As with any system, the final evaluation must be conducted under actual working conditions. The ARMS was put aboard a submarine for test purposes during an actual acoustic test. The first results, although favorable, showed areas where improvements were needed. As the improvements were implemented, the dependability of the system was improved. The ranges from the system were then supplied to the submarine as an aid to navigation with the result that the quality of the acoustic trials was greatly increased. The greatest improvement was in the number of runs that did not have to be repeated because of navigational errors.

Several methods have been employed somewhat successfully to synchronize the two portions of the system. The two methods retained have the disadvantage of requiring the

submarine to be on the surface. An acoustic method would eliminate this disadvantage, but it would be less accurate and would require modification to the AN/UQC-1A.

Installation of ARMS, when used solely with the AN/UQC-1A, requires no modification of the submarine equipment. If the 50-kc transmitting capability is used, the transducer must be mounted on the outside of the hull and a cable must lead into the submarine.

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David Taylor Model Basin, Report 1754.

THE ACOUSTIC RANGE MEASURING SYSTEM, by Jay C. Brown and William G. Niner. Jul 1963. ii, 13p. illus., diagrs. UNCLASSIFIED

The Acoustic Range Measuring System (ARMS), with a range capability of 5000 yd, has been developed for radiated-noise trials. This system determines range by measuring the transit time of an acoustic pulse traveling from a submarine to a receiving hydrophone. The use of synchronized clocks requires the acoustic pulse to travel only one way, thus resulting in greater range capability. ARMS has been used on several radiated-noise trials with good results.

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2. Submarine noise--Measurement--Instrumentation
3. Acoustic ranges--Test facilities
4. ARMS (Acoustic Range Measuring System)
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- II. Niner, William G.
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