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Ultrasonic Shark Tag Monitoring System Technical Report

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ULTRASONIC SHARK TAG MONITORING SYSTEM

TECHNICAL REPORT

by

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The system described herein has been used in the Office of Naval Research Project No. NR-104-880 (a tagging study of the freshwater elasmobranchs of Central America), supported by ONR Contract No. N00014-66-C0161. Reproduction in whole or in part is permitted for any purpose of the U.S. Government.

2 June, 1969

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INTRODUCTION

The bull shark, Carcharhinus leucas, occurs in warm waters around the world, tends to congregate in shallow, brackish water around the mouths of large rivers and to make its way up rivers, sometimes for great distances. A large population of these sharks has long been known in Lake Nicaragua and the river which drains it, the San Juan. For many years it has been assumed that the sharks in the lake are landlocked by the occurrence of rapids in the river. However, evidence at hand suggests that this is not true: (1) sharks are common throughout the lake and river and are the same species throughout, as well as in the sea; (2) the rapids are navigable by barges and tugs with a draught of two feet; (3) sharks have been seen above and below the major rapids, as well as directly in some of the rapids. Although circumstantial evidence is strong that sharks move up the river into this lake, definitive proof would have to come from sharks tagged at the mouth of the river and recovered in the lake.

The project supported by ONR Contract No. N00014-66-C0161 (A tagging study of the freshwater elasmobranches of Central America) has as its objectives: (1) to demonstrate whether or not bull sharks move from the Caribbean Sea into Lake Nicaragua, (2) to establish their patterns of movement within the lake and the Rio San Juan, (3) to determine how long they stay in fresh water once they enter, and (4) to determine whether or not they return to the sea after having been in the lake.

Much of the study has been conducted by conventional tagging, but in 1967, eleven sharks were marked with sonic tags and tracked with portable hydrophones and receivers. Although they were tracked up to more than nine hours, for distances up to seven kilometers, the time and effort involved were more than the available manpower could sustain. More important, the extent of the river channels available to the sharks made it almost impossible to reestablish contact with a tagged shark once it was lost.

The monitoring system described herein became available in 1968. It had been thoroughly field-tested by the Bureau of Commercial Fisheries and has proven remarkably serviceable in the humidity and heavy rains of the tropical lowlands of Nicaragua and Costa Rica. Seven of the recording shore monitors were used for up to two months with only minor service problems. In 1969 eleven monitors will be used, installed at favorable points along the full length of the river, from its source at San Carlos, Nicaragua, to its mouth at Barra del Colorado, Costa Rica, and San Juan del Norte, Nicaragua.

DESCRIPTION OF SYSTEM

The fish monitoring system described here was designed and constructed by employees of the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington. The system comprises ultrasonic transmitter "tags", attached to the fish, and automatic recording monitors installed on the stream shoreline. Sonic tagged animals passing each monitor site are recorded as to time and direction of passage.

ULTRASONIC TAG

The ultrasonic tag consists of a pulsed oscillator, transducer, and mercury cell power supply. Oscillator and battery are housed in a polystyrene capsule 4.25 x 0.625 inches. The transducer is a lead zirconate disc (0.75 inch diameter) forming the flat base of a roughly hemispherical polystyrene dome. Capsule and transducer are connected by a two-wire lead. Weight of the tag in water is 11 grams.

The tag was designed to be used on adult salmon and trout, with the capsule inserted into the fish's stomach and the transducer affixed by stiff wire staple to the fish's snout. To modify it for use on sharks, the connecting wire lead was shortened and capsule and transducer were joined together with epoxy cement and a short plastic sleeve (Figure 1). This consolidated tag was fastened to the shark's first dorsal fin, near the base, by several turns of steel or plastic coated copper wire passed through holes punched in the fin and twisted together on the side opposite the tag.

The tag transmits a pulsed 134 kHz signal in a roughly spherical pattern. Each tag is preset at one of the following repetition rates:

Code	Pulse duration	Pulse interval
1.	10.5 milliseconds	350 milliseconds
2.	15.0 "	500 "
3.	24.0 "	800 "
4.	40.5 "	1350 "
5.	60.0 "	2000 "

The use of five distinct repetition rates permits identification of five individual tagged fish within a study area, or in mass tagging programs the identification of fish from five separate groups.

Tag circuit power requirement is approximately 4 milliamperes; duty ratio is 3%. A 7 volt, 160 MAH battery is used, providing the expected tag life of about 2000 hours, or 12 weeks.

Signal output is 45 db relative to 1 microbar at 1 yard in fresh water. With the receiving equipment described below this provides an effective tag transmission range of 1/4 to 1 mile, depending upon stream conditions.

ULTRASONIC TAG MONITOR

Basically, the ultrasonic tag monitor consists of two receivers, a recorder, and batteries, all housed within a weather-proof metal case, and two hydrophones connected to the receivers by electric cable (Figure 3). The receiver-recorder unit is installed on the stream bank, the two hydrophones in the water nearby.

HYDROPHONES

The hydrophones are usually placed 150-200 feet apart, at a depth of 4-6 feet, mounted about one foot above the stream bottom on galvanized steel stakes or on heavy steel plates. Hydrophones are shielded to produce a vertical reception pattern of approximately 60° at the half power point, sufficient to assure complete coverage from stream bottom to surface. Horizontally the reception pattern at the half power point is only 30° wide. The downstream hydrophone is set with the axis of its reception pattern pointing about 15° downstream; the upstream hydrophone points 15° upstream, with a slight overlap of the two reception patterns at the center. This configuration of reception patterns permits discrimination of the direction of movement of the passing fish. The distance offshore at which hydrophones are placed depends mainly upon the degree of bottom slope; it varies from a few feet to more than 25 yards. Although highly directional and pointed across the stream, the hydrophone is sensitive enough off the back that tagged fish cannot pass undetected between it and the near shoreline.[1/]

1/ Each monitor site must be chosen with care. Ideally, hydrophones should be placed on a sand or firm mud bottom, away from underwater vegetation and well away from rocks and gravel that create noise by shifting and rolling around in the current. A stream section with velocity less than 2 feet per second should be selected if available, though it is turbulence rather than velocity per se that reduces receiving range. Rapids are virtually impossible to monitor in because of the excessive background noise of turbulence and shifting rock, and also because of entrapped air which attenuates signal transmission. If possible the site chosen should also be protected from wave action, another source of background noise.

Channel configuration, submerged objects and thermal interfaces will affect the range, usually unfavorably. Hydrophone emplacement often requires much trial and error to achieve a satisfactory reception pattern and range. Range may then fall off abruptly if the stream water quality changes (e.g., if a heavy algae bloom occurs). Installations should be checked frequently.

RECEIVER-RECORDER UNIT

All components except batteries are mounted on three panels forming a flush deck in the receiver-recorder case. Two receivers are mounted at one side of the deck; a wide rear panel supports the tape transport and recording components; a clock, switches, and battery test meter are in a narrow front panel. Batteries are beneath the deck in the bottom of the case, secured by straps and metal retainers.

RECEIVERS

The two receivers are enclosed in metal shielding boxes mounted to the underside of a common panel. On the top side are gain controls, off-on switches, jacks for hydrophone cable plugs, and receiver output terminals. The terminals are used in adjusting noise levels and monitoring receiver output with an oscilloscope.

Receivers have two damped, stagger-tuned stages, followed by three untuned amplifiers, the second of which has a gain control. The output stage feeds a half-bridge rectifier, followed by a series-resonant LC carrier filter and an RC low pass filter. The output of the filter is a negative-going pulse train at the repetition rate of the tag signal; it saturates at 5 volts into a 47 kilohm load with a signal input to the receiver of less than 1 microvolt.

The output of the receiver is fed to the control circuitry, the first element of which is a signal conditioner. This consists of two Schmitt triggers in sequence; the output of the first is loaded with a capacitor and the capacitor voltage is the input to the second Schmitt trigger. The time constant and trigger levels

are adjusted so that the second trigger responds only to pulses longer than 10 milliseconds. This removes short fast pulses which can pass through the receiver and filter. The output of the second Schmitt is coupled to a one-shot multivibrator with a duration of 105 milliseconds. This prevents response to multiple signals caused by different signal path lengths and by echoes. The trailing edge of the one-shot pulse operates a pulse shaper and rotary solenoid-driver circuit to actuate the appropriate recorder stylus.

RECORDER

An event recorder with four data channels is used. Recording tape is black paper, one inch wide, with a white wax coating on the recording side, which is removed by recorder styli. Signals from the upstream and downstream hydrophones are recorded by styli on channels 1 and 2, respectively, in the upper half of the tape. The data marks appear as short vertical black lines of uniform height originating from a continuous base line. Reference marks (see below) of the same type are recorded by a stylus at one second intervals in a channel near the lower margin of the tape. Time marks on a fourth channel appear as circular punched holes slightly below the tape center line.

The tape is led from a 10-inch supply reel, which is not driven but has a drag brake on the periphery, around two idlers, forming an S-curve, and across a flat vertical metal place which is the backing surface for the recording styli. On a second vertical plate parallel to the first are mounted three rotary solenoids that actuate the styli. The two styli producing data marks on channels

1 and 2 are aligned vertically. The time mark punch, a stainless steel tube 0.073 inch O.D., is driven by a linear solenoid. The punch passes through a hole in the backing surface plate and perforates the tape from the back (non-recording) side.

After passing the recording styli and time mark punch, the tape moves around the drive capstan and another idler, forming another S-curve, and then to the take-up reel. The take-up reel is driven by a slip clutch and a motor, which also drives the capstan. Motor and gear train are mounted below the deck. Tape speed is 3/16 inch per second.

Time signals are triggered by a battery driven clock with hands removed. The minute hand is replaced by a metal disc with two alnico permanent magnets mounted radially at 180° intervals. These operate a reed switch every 30 minutes, producing a pulse which actuates the time punch through the driver.

The solenoid and stylus which produce reference marks at the bottom of the tape are actuated by a one-pulse-per-second pulse generator, which operates whenever the recorder is running.

BATTERIES

All batteries used are dry cell. The recorder operates on 24 volts supplied by six TW-2 (12-volt) batteries, two in one group in series, and four in a second group in series parallel, plus a TW-1 (6-volt) battery bias supply. Battery life is mainly dependent upon recording activity. A twenty percent usage rate results in usable battery life of about 60 days.

Receivers operate at 12 volts from two 4F4H (6-volt) batteries in series, and a TW-1 battery bias supply. The 12-volt receiver power supply is under constant load and lasts about 30 days; the 6-volt bias battery lasts a minimum of 90 days.

The clock operates on a single 1.5-volt D-cell battery, which lasts a minimum of 90 days.

OPERATION

To conserve tape, control circuitry is designed so that the recorder runs only when a signal pulse has been received, or after the time mark circuit has operated. When a signal or noise pulse is received the corresponding stylus records a mark and at the same time an enable voltage is switched on, actuating the recorder motor. When no more signals are received a reset timing circuit operates, switching off the enable voltage after 4 seconds. The reset timing circuit is inhibited so long as signals of any kind are received at less than 4-second intervals.

The pulse generator that triggers 1-pulse-per-second reference marks is also operated by the motor enable voltage.

Time marks are recorded every 30 minutes, whether signals from the receiver are being recorded or not. If the tape is not running when the time punch operates, the motor and reference marker are switched on, run for 4 seconds, and stop. If signals are being received the tape and reference marker will be running, and the punch operates without any other effect. The punch action is so fast that it does not noticeably affect the movement of the tape.

A typical recording of a tagged shark moving upstream past a shore monitor shows signal marks appearing initially on channel 2, intermittently for the first minute or two, then with increasing regularity as the animal moves toward the center of the hydrophone reception pattern. At this point the tag pulse rate, compared with the 1-pulse-per-second marks in the reference channel, is seen to be (for example) one pulse every two seconds and is identified as a Code 5 tag.

Within three or four minutes (depending on how fast the shark is moving) after the first signals are recorded on channel 2, the first intermittent signals appear on the upstream channel (ch. 1), and for a minute or two signals are recorded on both channels, indicating the tagged shark is roughly between the two hydrophones in the area of overlapping reception. As the shark continues upstream signals disappear first from channel 2, and eventually become intermittent and disappear from channel 1. A time mark check indicates the shark came into receiving range at approximately 0918 and was monitored a total of 13 minutes.

Occasionally two or more tag signals may be recorded simultaneously. In this event tape interrogation obviously becomes complicated, especially if the tags have different pulse rates. However, with the help of dividers and much patience it is possible to separately identify as many as three tags recorded at the same time.

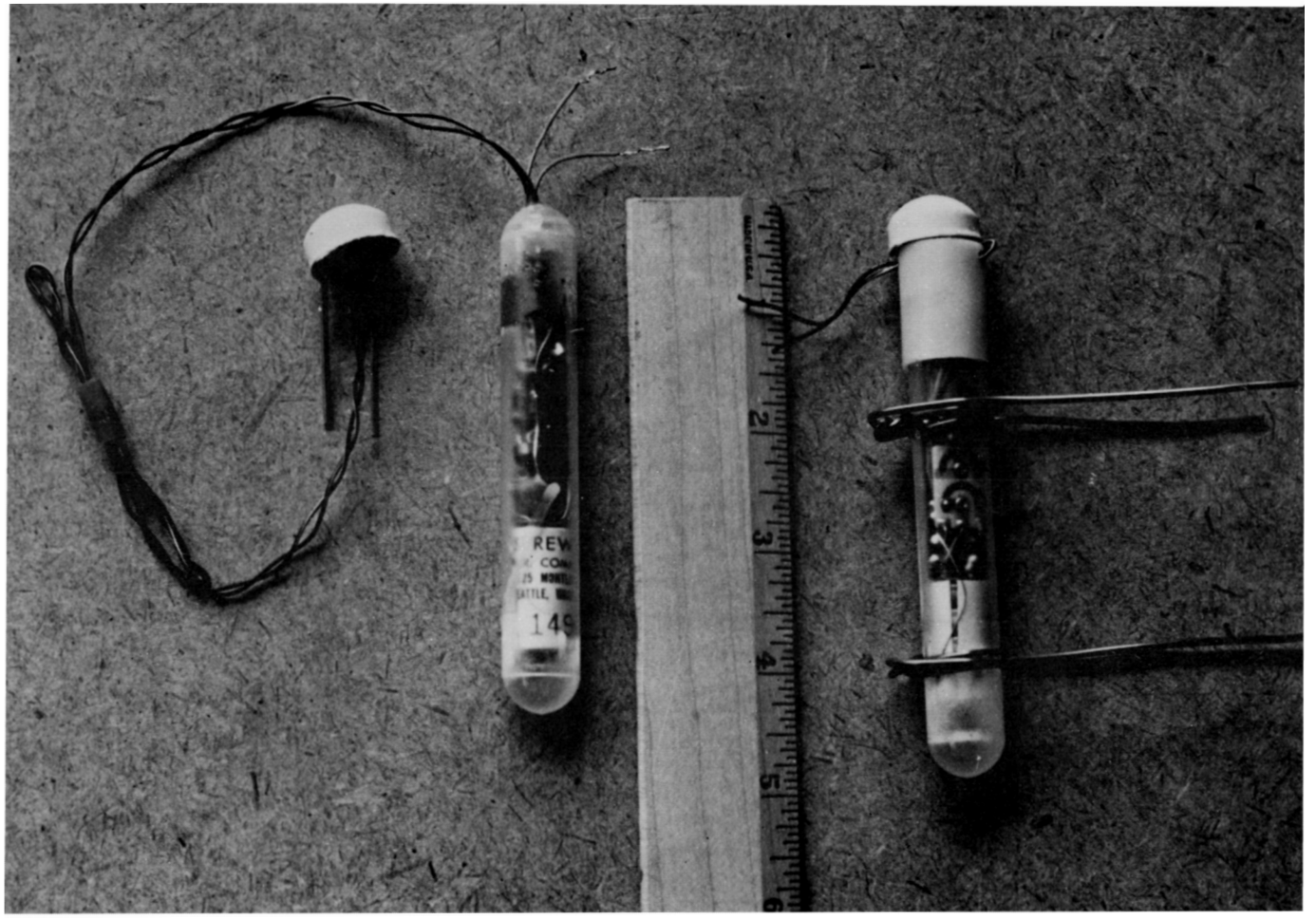
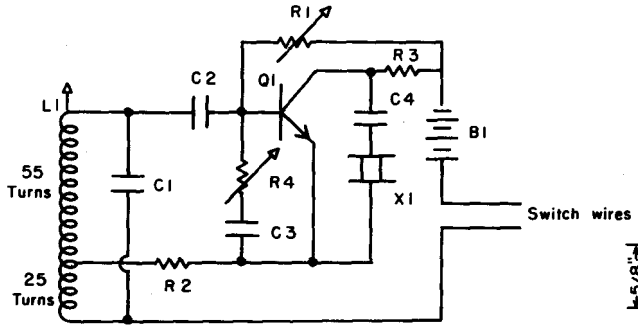
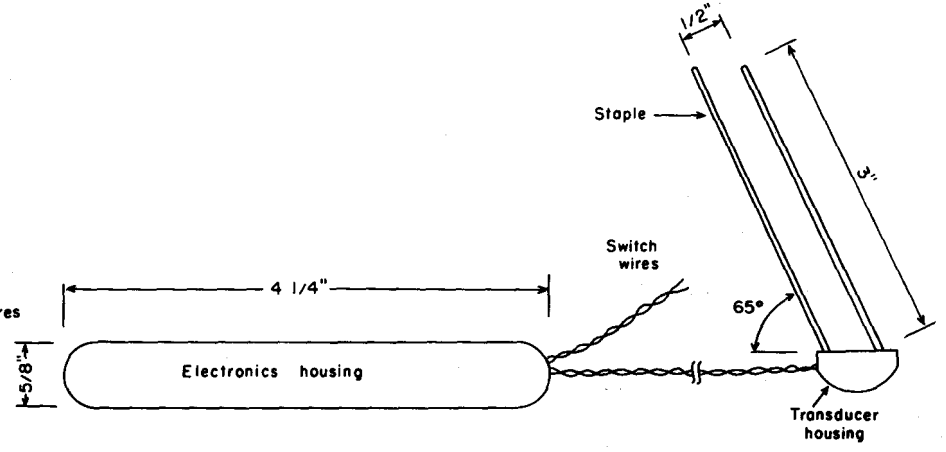


Figure 1. Ultrasonic Fish Tags. Salmon tag at left; tag modified for use on shark at right.

Figure 2.

TAG SCHEMATIC AND PARTS LIST

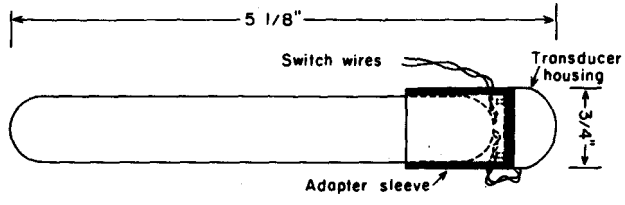




SALMON TAG

R1 5 megohm max. Adjusts pulse period
R2 120 ohm
R3 750 ohm
R4 10 K ohms max. Adjusts pulse duration

C1 .001 MFD
C2 .001 MFD
C3 4.7 MFD codes 1,2,3; 0.82 MFD codes 4,5
C4 .1 MFD
Q1 2N 2924
L1 Iron core adjustable inductor
X1 Lead zirconate crystal disk 134 Khz
B1 7V 160 MAH 5 Burgess 675 cells or equiv.



TAG MODIFIED FOR USE ON SHARK

Figure 3. Ultrasonic Tag Monitor (shown with single hydrophone).

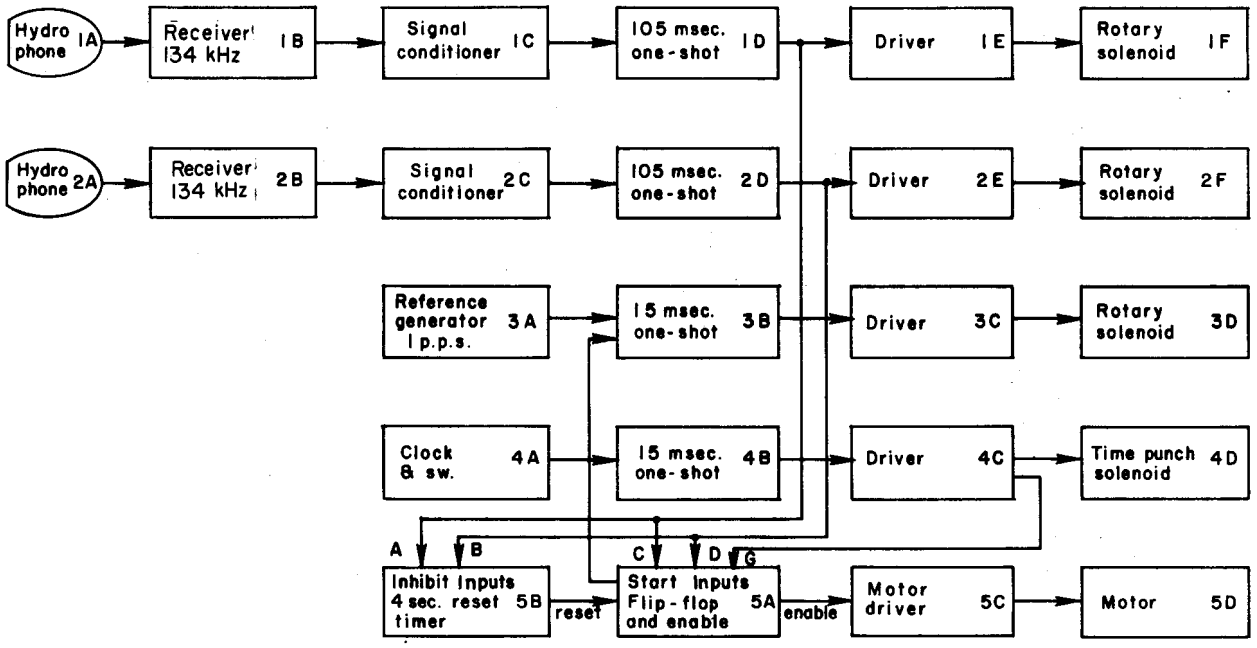
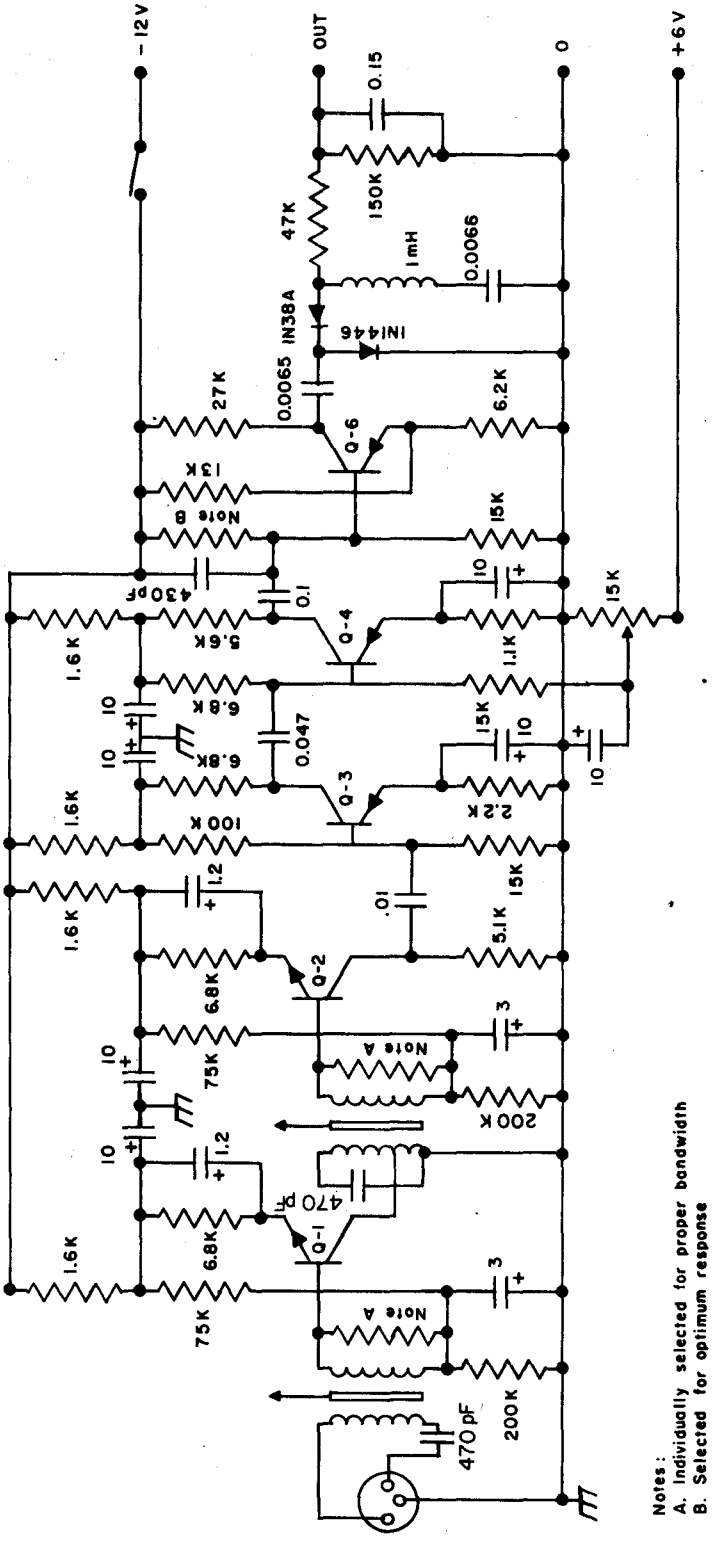


Figure 4. Ultrasonic Fish Tag Monitor (134 kHz), Block Diagram



Notes:
A. Individually selected for proper bandwidth
B. Selected for optimum response
C. Capacitances in microfarads except as noted
D. Transistors Q-1 & Q-2 are 2N930; Q-3, Q-4, Q-6 are 2N3702

Figure 5. Receiver Schematic, (134 kHz), Ultrasonic Fish Tag Monitor

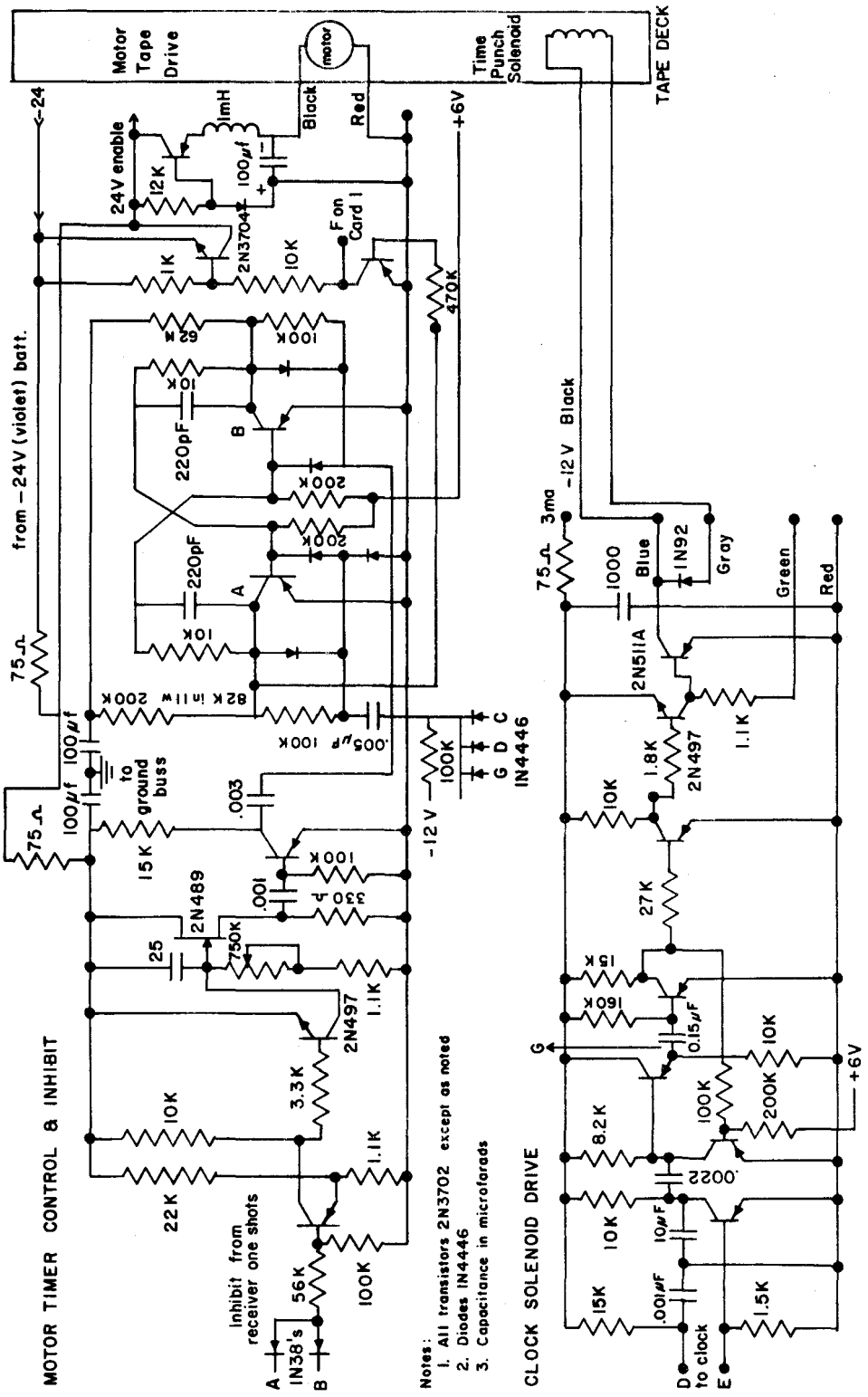


Figure 6. Cicuit Schematic, Ultrasonic Fish Tag Monitor I

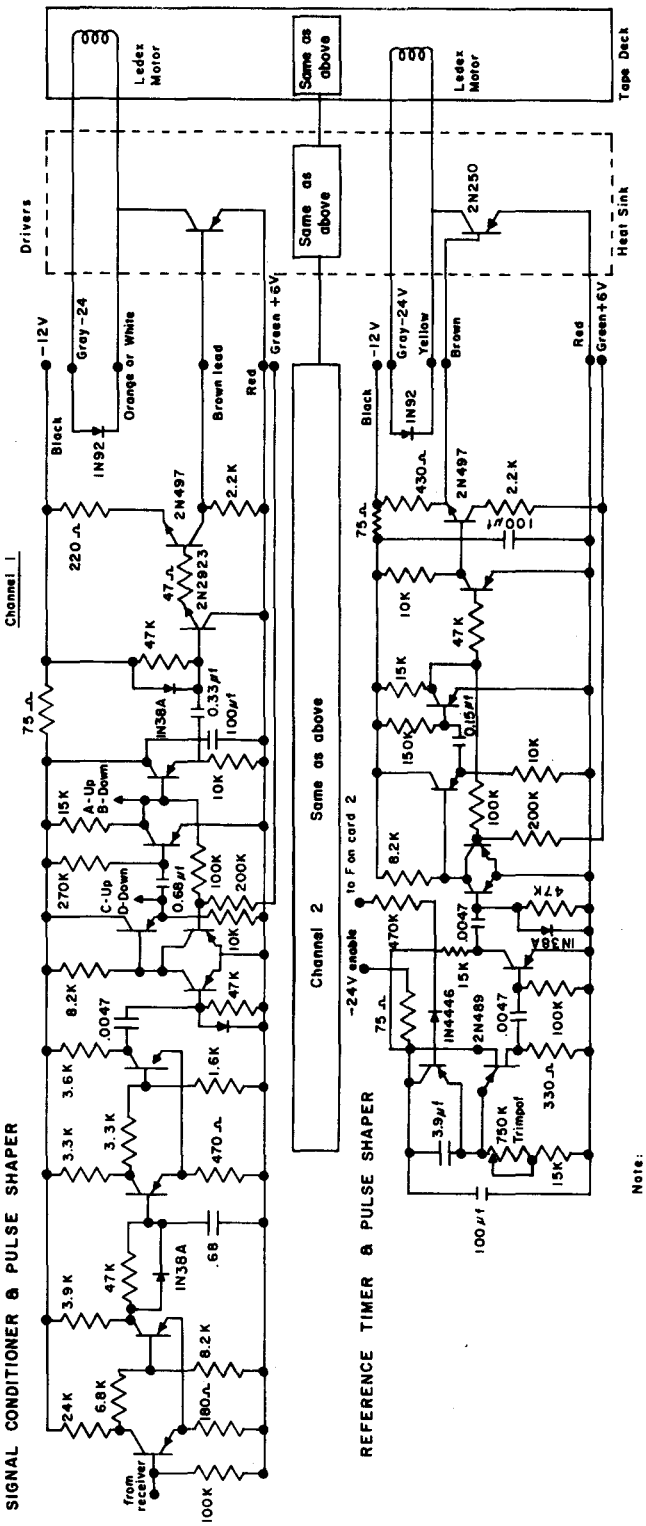


Figure 7. Circuit Schematic, Ultrasonic Fish Tag Monitor II

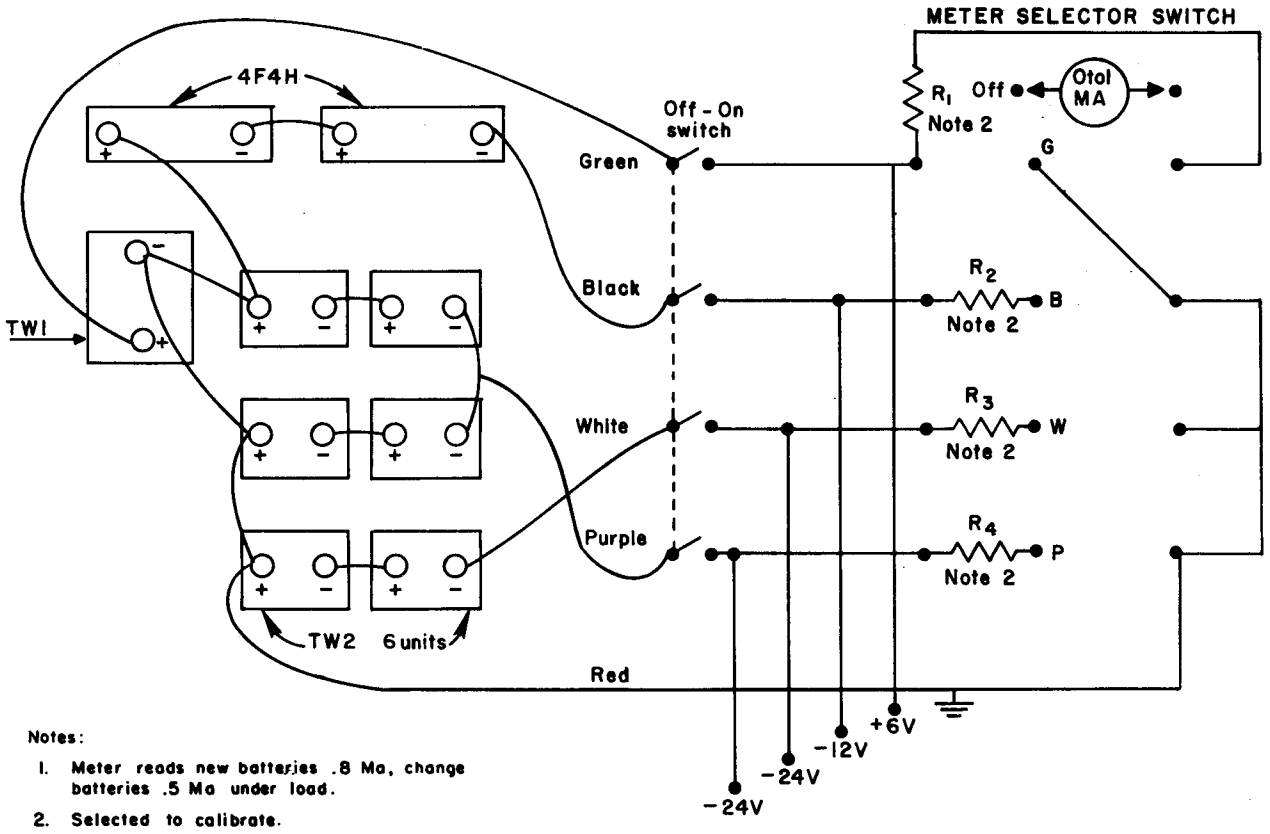


Figure 8. Battery Pack and Meter Selector Switch, Ultrasonic Fish Tag Monitor

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Thomas B. Thorson, Gordon F. Esterberg and James H. Johnson

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TRACT

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KEY WORDS	LINK A		LINK B	
	ROLE	WT	ROLE	WT
c tags				
c Monitoring System				
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