ATLANTIC OCEANOGRAPHIC LABORATORY

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Internal Note 68-4-I

THE DIGIBRIDGE: INSTRUMENTAL DETAILS OF A.O.L. MARINE SEDIMENT TEMPERATURE PROBE.

by

D.R. Harvey and C.S. Mason

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INTRODUCTION

The digibridge is an instrument designed to measure the temperature gradient in the sediment on the ocean floor. The digibridge is mounted in an Ewing piston corer or a gravity corer. Except for the three temperature sensing probes, the instrument is self-contained in a pressure case approximately 41" long and 4" in diameter. The three probes are spaced along the core pipe on fins while the pressure case is mounted on the weighted head of the corer.

The photos show the pressure case and two views of the instrument with the case removed. A view of one probe and fin is provided as is a photo showing the test box and battery charger.

From the temperature data, as measured by the digibridge, and the thermal conductivity of the recovered core, a measure of the heat flowing through the earth's crust at that point, may be calculated. This report describes the digibridge temperature recorder and probes. Field operation and results are described separately. (Ref. 1)

The digibridge is a wheatstone bridge that is electronically self-balanced over a small range by digital shunts. The balancing process is serial starting with the largest digit and completing the 11 bit number in 1 1/2 seconds. Pulses from the balancing process are recorded on magnetic tape by a stepping magnetic tape recorder. The magnetic tape is recovered from the instrument and fed into a tape reader for consumption by a computer which will plot the 3 temperature profiles on an X-Y plotter. (Ref. 2 and 3)

The bridge can measure the resistance of an unknown over a range of 4 per cent with a resolution of 0.0020 per cent. Using a Texas Instrument Sensistor Type P-100 with a nominal 2 K ohm resistance, the instrument measures temperature to 0.0028°C over a 5.8°C range.

THE WHEATSTONE BRIDGE. Circuit B-D-32-2

The wheatstone bridge is comprised of the sensistor, a selected reference resistor equal to the sensistor resistance at +3°C, a fixed resistor of 500 ohms and a tapped resistor of 512.8 ohms which is shunted to obtain balance. All resistors in the bridge and shunts (except R82, the least significant shunt) are Shallcross type VA14 precision resistors with a temperature coefficient of ±10 PPM or better.

The five largest digits correspond to direct shunts in binary progression, while the remaining digits are taken off a tap in the bridge arm. This arrangement has the advantage that only five switching transistors are directly connected across the reference arm in the "off" condition.

The signal applied to the sensor has an effective frequency of about 30 cycles per second, so that the digibridge is relatively insensitive to cable capacity in the sensor leads.

The effect of the cable capacity is an apparent drop in resistance of the sensor and a scattering of readings. A capacity of 100 pF, equivalent to 4 feet of co-axial cable does not affect the reading, but 200 pF causes a drop of two digits and a start of scattering (see table #1). Therefore, capacitors C1 and C2 are added across the shorter probes to equalize cable capacity and C3 is put across the other side of the bridge. The ratio between cable capacity and C3, is the inverse of the resistance ratio of the arms at +3°C.

The signal applied to the bridge is a ramp voltage that increases until the discriminator triggers, either positive or negative, which turns off the ramp. The signal then decays to zero. Therefore the signal applied to the sensor, and the dissipation in it, is least when the bridge is far from balance and greatest when it is near balance. The average dissipation in the sensor is less than 10 micro watts. (Ref. 4)

<u>BASIC OPERATION BLOCK DIAGRAM CIRCUIT B-D-32-1</u>

The sequencing for inserting the shunts across the wheatstone bridge is provided by an 11 stage ring counter plus terminator. This circuit also includes the memory transistors to hold the appropriate shunts in circuit until balancing is complete.

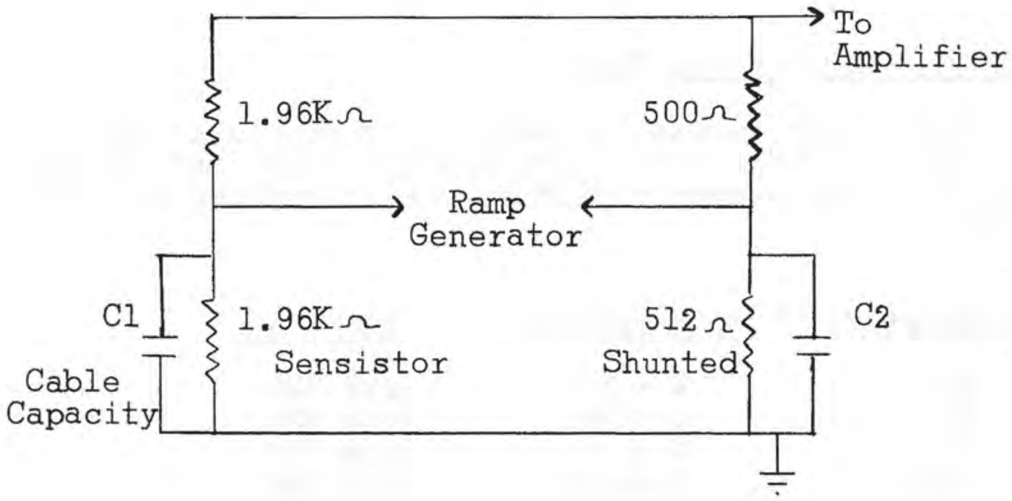
A clock oscillator provides the timing pulses to operate the digibridge. This circuit provides pulses to the solinoid drive circuit, the signal generator and the ring counter. (See Waveform Diagrams)

The signal generator provides a ramp voltage to the bridge circuit. The error signal from the bridge goes through the amplifier to the discriminator. The discriminator resets the memory transistors as required and feeds pulses to the digital pulse generator for recording on magnetic tape.

The cycle pulse delay circuit and the cycler switch the three probes into the bridge at the proper time.

The timing pulse generator and the marker pulse generator put identifying pulses on the magnetic tape.

TABLE #1 Effect of Cable Capacity on Bridge



Test circuit for effect of cable capacity

C1	C2	COUNT	NUMBER OF TRIES
0pF	0pF	1041	10
100pF	0pF	1041	10
200pF	0pF	1038 1039	2 8
390pF	0pF	1015 1016 1017 1018	1 4 2 3
390pF	390pF	1029 1030 1031 1032	1 1 5 3
390pF	1000pF	1039 1040	2 8
390pF	1500pF	1041 1042	7 3

The test box is a separate unit which may be connected to the digibridge for testing purposes.

CLOCK OSCILLATOR. Circuit B-D-32-6

A unijunction relaxation oscillator provides timing pulses for the system. The nominal clock rate is 480 pulses per minute. The second digibridge built had the following characteristics:

Temperature	Battery Volts	Clock rate
26°C	± 6.5V	458 PPM
26°C	± 4.6V	464 PPM
0°C	± 6.5V	464 PPM
0°C	± 4.6V	475 PPM

Transistor Q21 allows the test box to stop the clock oscillator by shorting the unijunction base. Output CP operates the solinoid drive circuit.

The point A momentarily grounds the common anodes of the ring counter, turning off whichever silicon controlled switch happens to be on, and allowing a shift to the next digit. A reasonably well controlled pulse length is required for stable operation, hence the shaping network.

A simple monostable flip flop provides a pulse at V that is delayed by about 100 miliseconds. This starts the signal generator after the amplifier has had time to recover from the line switching transients which are inevitable in a battery powered system. This delay also allows time for the magnetic tape to move and completely stop before the pulse is applied to the tape.

RING COUNTER. Circuit B-D-32-9

The ring counter has 11 similar stages plus a terminator. Each stage has a switching transistor Q36, shunt resistance R82, the digital memory Q35, and a segment of the ring counter that searches the digits. The ring counter uses the silicon controlled switch Q33 and is operated by momentarily grounding the common anode, point A. Connections T and T^1 pass the "on" condition from one digit to the next and at the same time turn on the memory S.C.S., Q35. This last biases the switching transistor Q36 "off", and because the point T^1 is at a low potential, is susceptible to turn off if the current supply to A^1 is interrupted. If the discriminator input is positive (see below), the memory is turned off and finally the sequencing S.C.S. is turned off by the next clock pulse. If the memory is still "on", it is latched by the current from Q34. When balancing is completed the reset supply is interrupted simultaneously with that at A^1 and all the memories turn off.

The output P provides a parallel output for connection to the test box. This operates indicator lamps to show the state of each memory.

RING COUNTER TERMINATOR. Circuit A-D-32-10

When the bridge balancing has been completed, the digits must be reset and the sensing cycled to the next sensistor probe. The outputs E and Reset, reset the digits and memories. Output T^1 initiates the ring counter cycle, and after going through the cycle pulse delay circuit, advances the cycler to connect the next sensor.

The terminator actually starts the ring counter. When all the ring counter S.C.S. are off, the potential at A rises and turns Q77 on via the resistance leading to the cathode gate.

SIGNAL GENERATOR. Circuit A-D-32-8

A negative going pulse at V starts the ramp generator by turning off the two-transistor loop Q30 and Q31. The ramp condenser C29 charges up toward 12 volts through R74 and R75, and the signal is applied to the output transformer via an emitter follower Q32. When the condenser reaches about 2 volts, Q31 turns on and the loop goes back into the conducting state, discharging C29 through R75.

The ramp is usually stopped by applying a positive pulse at V from the discriminator. The output W turns the discriminator on during the signal pulse.

The output transformer reduces the ramp voltage 2:1 (1 volt peak) and has a secondary isolated from ground. The floating potential is applied symetrically to the bridge, so that the error voltage appears relative to ground.

AMPLIFIER. Circuit B-D-32-3

The amplifier consists of 2 stages with A.C. coupling. Each stage is a differential amplifier with constant current load and an output transistor inside the feedback loop. The first stage inverts the signal while the second does not.

R9 and R14 are set for zero offset with no signal. The passband is 5 to 150 cps and the gain is 2.5×10^5. The amplifier recovers from gross overload during switching before the error signal arrives. (Ref. 5)

DISCRIMINATOR. Circuit B-D-32-4

This is the most complex circuit in the instrument because it contains almost all the logic circuitry. The signal from the amplifier arrives via C11. This is normally shorted to ground by Q12. When the ramp generator is triggered, the point W rises from its low potential turning on Q11, thus turning Q12 off. The amplifier signal may then reach the input of the flip flop trigger Q13 and Q15 and the diode ballasted Q14.

If the amplifier goes negative, Q14 conducts and turns off the ramp generator. But if amplifier output goes positive by 1 volt, the flip flop triggers, producing a positive pulse at D, and a large negative pulse at A^1. This turns off the digit memory being sampled. The signal generator is also turned off via D2 and Q14 to V.

The input E allows A^1 to be given a negative pulse when the ring counter terminator resets the digital memory.

DIGITAL PULSE GENERATOR. Circuit A-D-32-5

The positive pulse from D of the discriminator triggers a flip flop Q18 and Q19 which turns Q20 on for approximately 5 miliseconds. This pulse is applied to track 3 of the 4 track magnetic tape record head.

CYCLE PULSE DELAY. Circuit B-D-32-11

The pulse from T^1 of the ring counter terminator is delayed approximately 40 miliseconds by the flip flop Q80 and Q81. Transistor Q83 is turned off briefly to cause the cycler to advance one step.

CYCLER. Circuit B-D-32-12

A simple 3 element ring counter is used to switch the reed relays in sequence. It differs from the digit ring counter in that cycling is accomplished by interrupting the anode supply instead of grounding the common anode. The reed relays require 10 mA to operate and are slugged with diodes to damp out the turn off transients.

The relays are intended to connect one side of the signal generator output winding to each measuring arm of the bridge in turn. They do not have a low enough contact resistance to be made part of the measuring circuit.

SOLINOID DRIVE. Circuit B-D-32-7

The pulse from point CP of the clock oscillator operates a flip flop Q26 and Q27. This turns Q29 on for a 30 milisecond pulse which operates the solinoid to step the tape recorder at the clock rate.

MARKER PULSE GENERATOR. Circuit B-D-32-13

Pulses from the cycler outputs H and K operate transistors Q87 and Q88 to put pulses on tracks 1 and 4 respectively of the magnetic tape head. When a pulse comes at point L, it causes both transistors to operate and put pulses on both tracks simultaneously. These pulses identify the particular sensistor being sensed at that time. The identifying code is: A pulse on track 1 indicates probe A is being sensed, a pulse on track 4 indicates probe B is being sensed, while pulses on both tracks 1 and 4 indicate that probe N.L. is being sensed.

TIMING PULSE GENERATOR. A-D-32-14

The timing pulse generator produces a continuous sequence of pulses corresponding to the clock pulses. The pulse at W, from the signal generator, operates the flip flop Q89 and Q90 and thus puts a pulse on track 2 of the magnetic tape head.

MAGNETIC TAPE RECORDER.

A miniature stepping tape recorder (Ref. 6) is operated by momentarily pulsing a solinoid which causes the tape to advance in steps past a Nortronics Type 5601 four track record head. The solinoid is pulsed once every clock pulse by the solinoid drive circuit. The solinoid operates the capstan which pulls the tape from the supply reel past the tape head. The supply reel is coupled to the take up reel by a slipping clutch which causes the larger diameter take up reel to keep tension on the tape.

The tape steps at approximately 8 steps per second (see section on clock oscillator) and moves approximately 0.020 inches per step. After the tape has had time to come to rest, the information pulses are applied to the tape head.

The tape reels hold 120 feet of 1/4" magnetic tape which provides a running time of about 2 1/2 hours.

A timer may be set to turn the digibridge on with a delay of up to 2 hours. This can be set so the instrument will turn on when lowering is almost complete, saving magnetic tape and battery life.

TEST BOX. Circuit B-D-32-15

The test box is a separate unit which may be plugged into the digibridge for testing the digibridge. The points in the ring counter marked P are connected to transistors Q6 to Q16 and turn on the associated lamp B4 to B14 when the memory is "on". Diodes D1 to D11 and switch S3 allow the testing of the bulbs for continuity.

Similarly, points H, K and L of the cycler are connected to bulbs B1 to B3 to show which sensistor probe is in the measuring circuit.

The flip flop Q1 and Q2 allow the stepping of the ring counter through one complete count and stopping leaving the memories and the lights in the state required for balance. Switch S4 puts this "one cycle" circuit into operation. Switch S2 resets the flip flop thereby starting another single cycle of the ring counter.

BATTERY CHARGER. Circuit B-D-25-1

The nickle cadmium batteries used in the digibridge need recharging after two or three hours use. The batteries can be removed from the digibridge and plugged into the battery charger. The charger can charge two battery packs at one time.

The charger has an automatic current limit when the battery is charged. When the battery voltage is below approximately 13.5 volts, the battery charges at a high rate via the 200 ohm resistor R2 or R5. When the battery voltage is above 13.5 volts, the transistor is cut off and a trickle charge flows via the 2.2K ohm resistor R3 or R6.

The batteries may be left indefinitely on charge.

FUTURE DEVELOPMENTS.

An attempt to gather data rather than improve instrumentation is anticipated. However, because of the failure of the external probes (Ref. 1), and the difficulty of construction, some changes are required. The sensistor probes will be replaced with thermistors, which can now be obtained with excellent stability of resistance with time. As the temperature coefficient of the probes will thus be increased by nearly an order of magnitude, the co-axial cable will no longer be required, simplifying the problem of interconnections. Modification of the binary shunt resistor values will be required. No further changes to the existing instruments are planned.

Design of a new instrument, intended to monitor bottom temperature for several months in one location will be commenced.

It is hoped this installation will consist of up to six platinum resistance thermometers sampled at hourly intervals by an instrument very similar to the recording bridge described in this report.

DIGIBRIDGE OPERATING PROCEDURE.

The digibridge is used on a modified core head. A 4" diameter hole parallel to the axis of the head holds the instrument case.

The steps in setting up and using the digibridge follow.

1) Never at any time leave connectors, on case or probes open without dummy plugs on them. The probe is very fragile and pulls apart easily. After pulling apart, the probe must be refilled with oil.

2) Load the tape onto the smaller of the two tape reels. The first end is held by the machine screw in the reel. Observe the direction of tape winding so that the oxide surface goes next to the tape head. Wind about 120 feet of tape on the reel. Do not completely fill reel.

3) Assemble the reel assembly and feed the tape around the tape head, guides, capstan, etc. See photo of tape recorder. The free end of the tape may be stuck to the take-up reel by a small piece of sticky tape.

4) Put fresh battery pack in instrument (Power switch in OFF position) and put instrument in pressure case. Inspect "O" ring and seat for dirt nicks etc. Put silicone grease on "O" ring.

5) With corer on racks and rigged for lowering, insert pressure case in core head with cap and connectors either at top or bottom depending on cable length required. The instrument is held by putting 2 large hose clamps on the case to keep it from sliding out.

6) Connect the 3 probes to the proper connectors and clamp with hose clamps to the core pipe. Clamp the fins in position to receive the probes (set by cable length) and carefully insert the probes. Tighten set screw on fin into slot of probe. Clamp the cables securely with hose clamps. The coiled up lowering wire must not foul the fins or cables when it is tripped.

7) When corer is ready for lowering, remove cap of pressure case, and set timer for required delay, TURN POWER SWITCH ON, and replace cap. Make sure that cap fits snugly. The timer should be set so that the instrument turns on when the instrument is near bottom.

8) Hold the corer approximately 100M off the bottom for about 5 minutes so that the probes can record temperatures in what should be uniform temperature water for calibrating purposes. Then lower corer until it trips in the normal way. Leave the corer in the bottom for at least 5 minutes, paying out line slowly so that corer is not disturbed by ships drift. Then haul in.

9) When back on deck, disconnect cables from case, and without opening, remove case from corer and warm it in hot water. This is to prevent condensation on cold parts. Wash salt water from case and around connectors. Then open and turn off power switch.

10) Remove tape from recorder for processing.

11) Do not leave cables and probes on corer when corer is taken inboard from rail, or for extended periods between lowerings.

ACKNOWLEDGEMENTS

The digibridge was conceived and designed for B.I.O. by C.R.B. Lister. The design has been adapted for recording on magnetic tape and modified in detail where field trials showed this to be necessary. The instruments herein described have been changed only in a few details from the original supplied by Dr. Lister, with the addition of a suitable recorder.

The Marine Geophysics group has generously supplied ship time to test the equipment at sea.

REFERENCES

1) The Measurement of the Temperature Gradient in Marine Sediments. First Progress Report, D.R. Harvey and C.S. Mason, 1968.

2) A Playback System for a Special Purpose Digital Tape Recorder. D.R. Harvey and C.S. Mason, 1968.

3) Digi Plot: An Interrupt Program for PDP-8 Data Processors. Plots Resistance Readings for 3 Temperature Probes on Incremental Calcomp Plotter. A.S. Bennett, 1968.

4) Self-Heating and Temperature Coefficient of Fenwal Thermistors and Texas Instrument Sensistors. H. MacPhail and C.S. Mason, 1968.

5) A Low Noise Amplifier used with Digibridge Temperature Recorder. A.S. Bennett and D.R. Harvey, 1968.

6) The Design of a Miniature Incremental Magnetic Tape Recorder. P.F. Kingston and D.R. Harvey, 1968.

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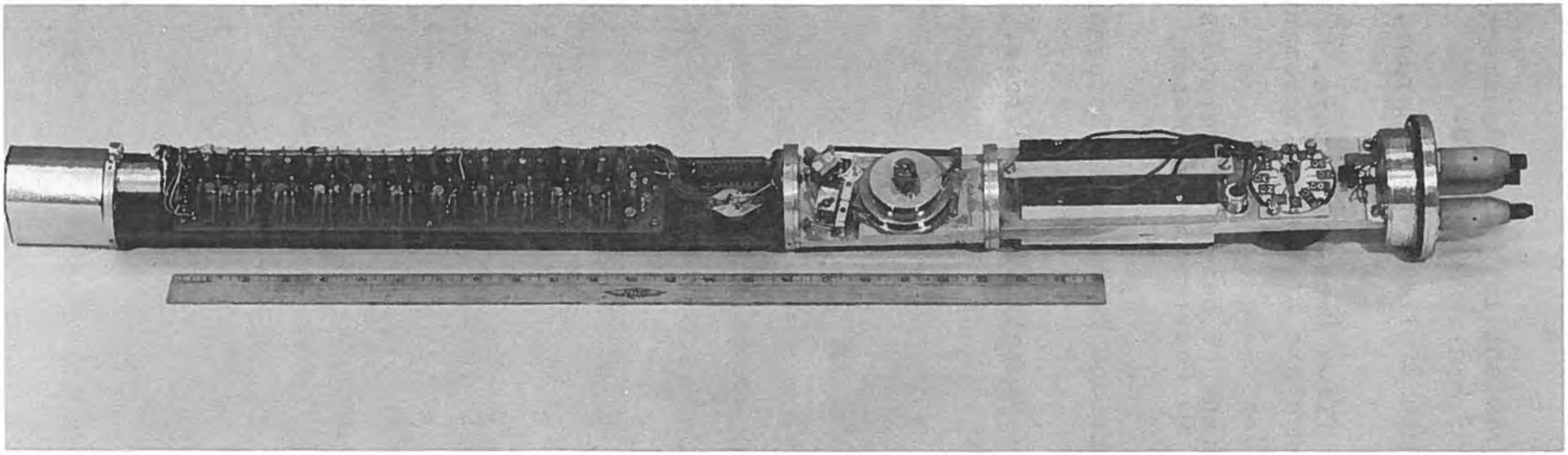
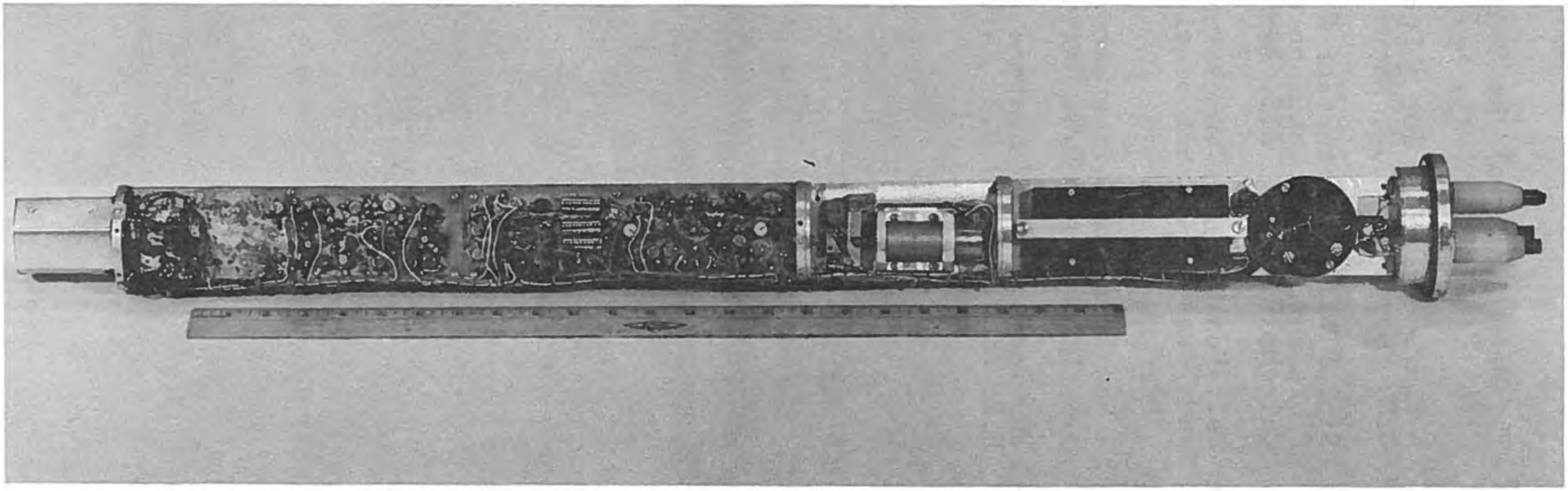


Figures #1 and #2



Two views of the bridge showing electronics, recorder, battery, timer and end cap.

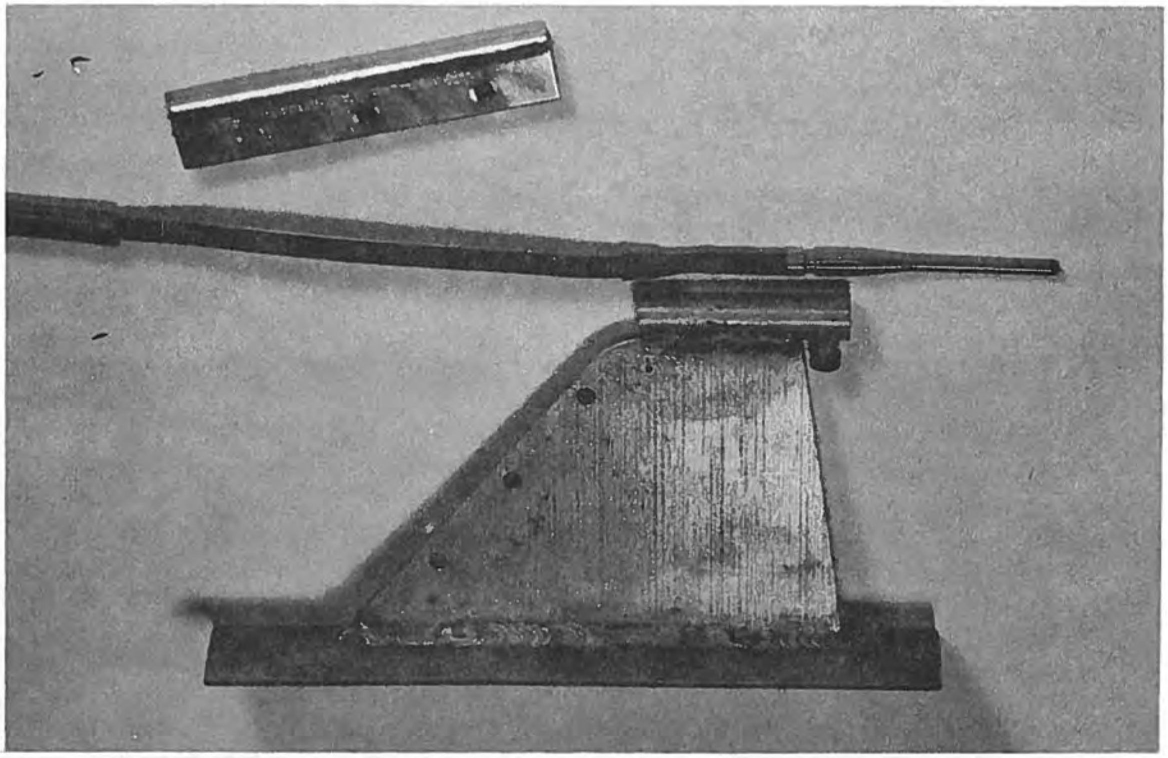


Figure #3. Sensistor probe housing and fin.

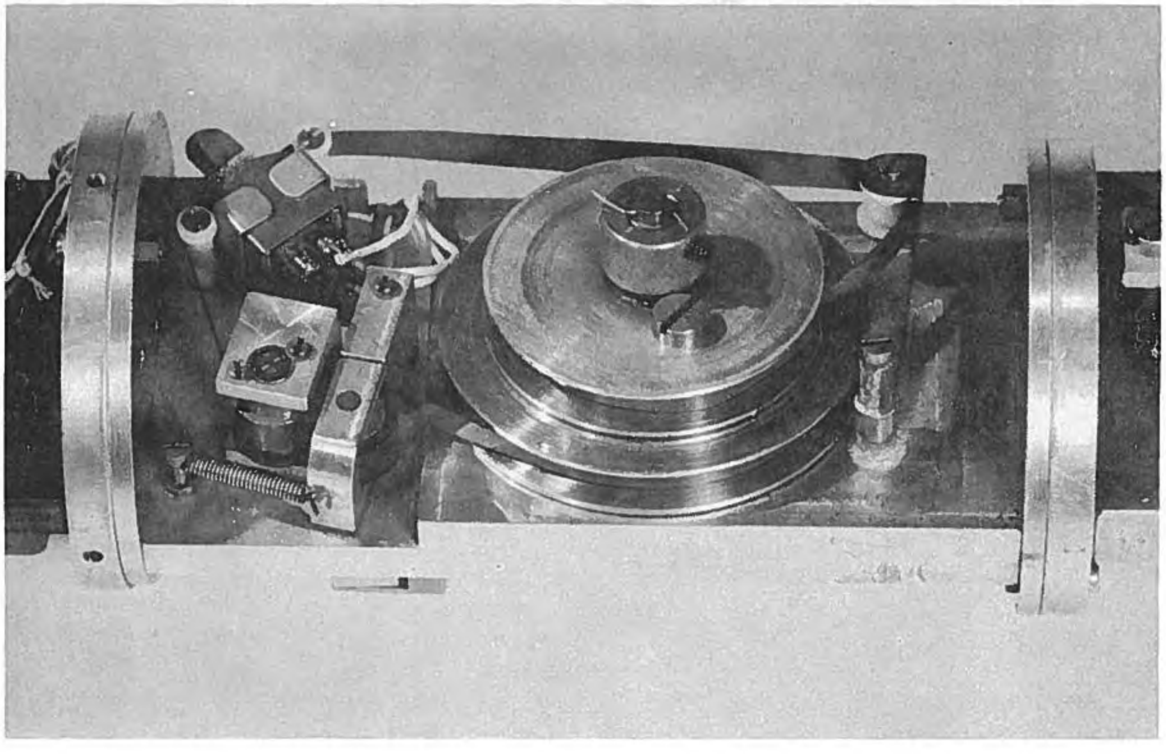


Figure #4. Tape recorder showing tape position.

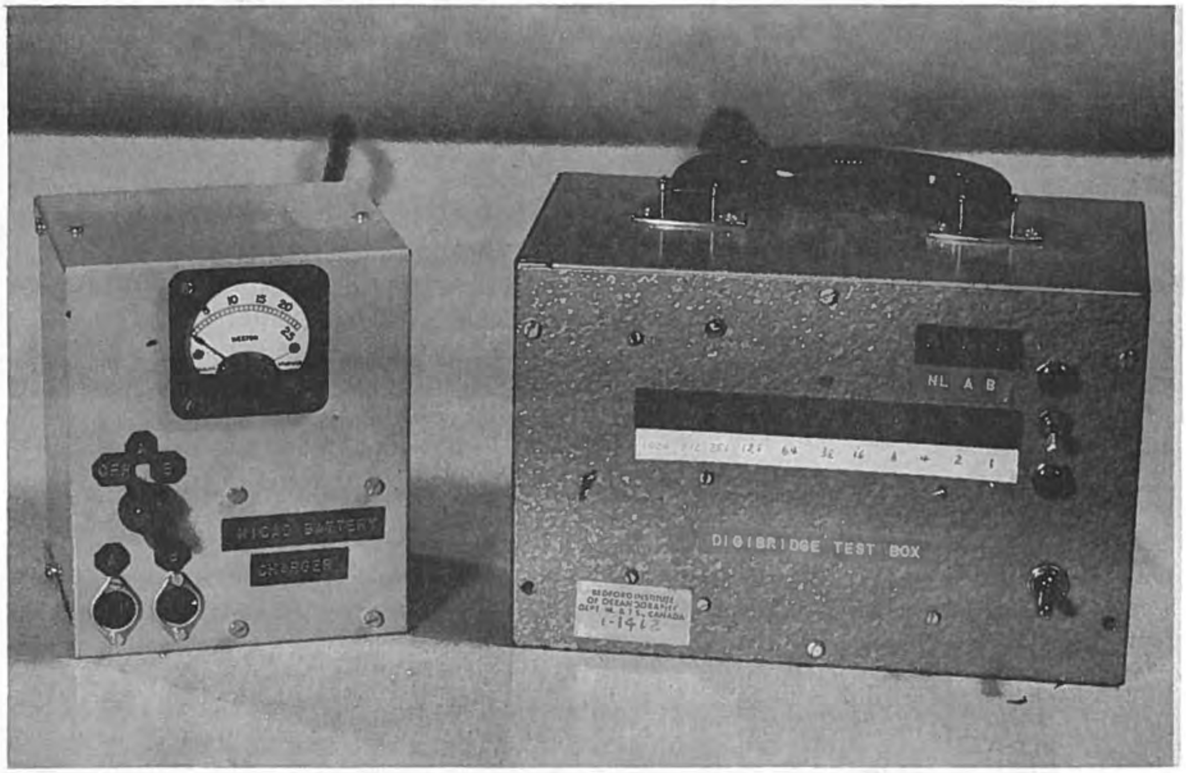
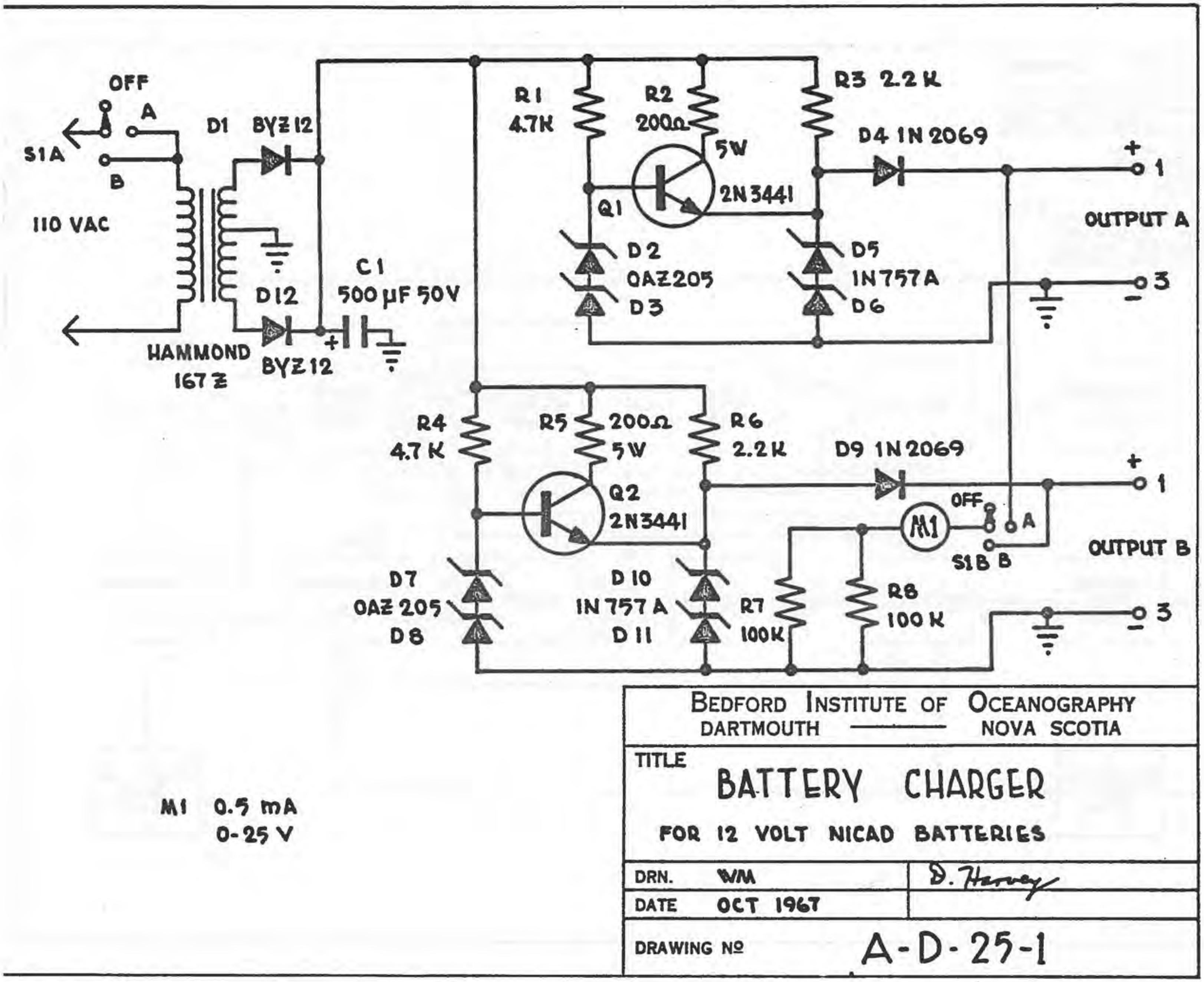


Figure #5. Battery Charger and Test Box.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A
S1A
B
110 VAC
D1 BYZ12
HAMMOND
167 Z
D12
BYZ12
C1
500 µF 50V
R1
4.7K
R2
200Ω
5W
Q1
2N3441
R3 2.2K
D4 1N2069
D2
OAZ205
D3
D5
1N757A
D6
+ 1
OUTPUT A
– 3
R4
4.7K
R5
200Ω
5W
Q2
2N3441
R6
2.2K
D9 1N2069
D7
OAZ205
D8
D10
1N757A
D11
R7
100K
R8
100K
M1
OFF
A
S1B B
OUTPUT B
+ 1
– 3
M1 0.5 mA
0-25 V
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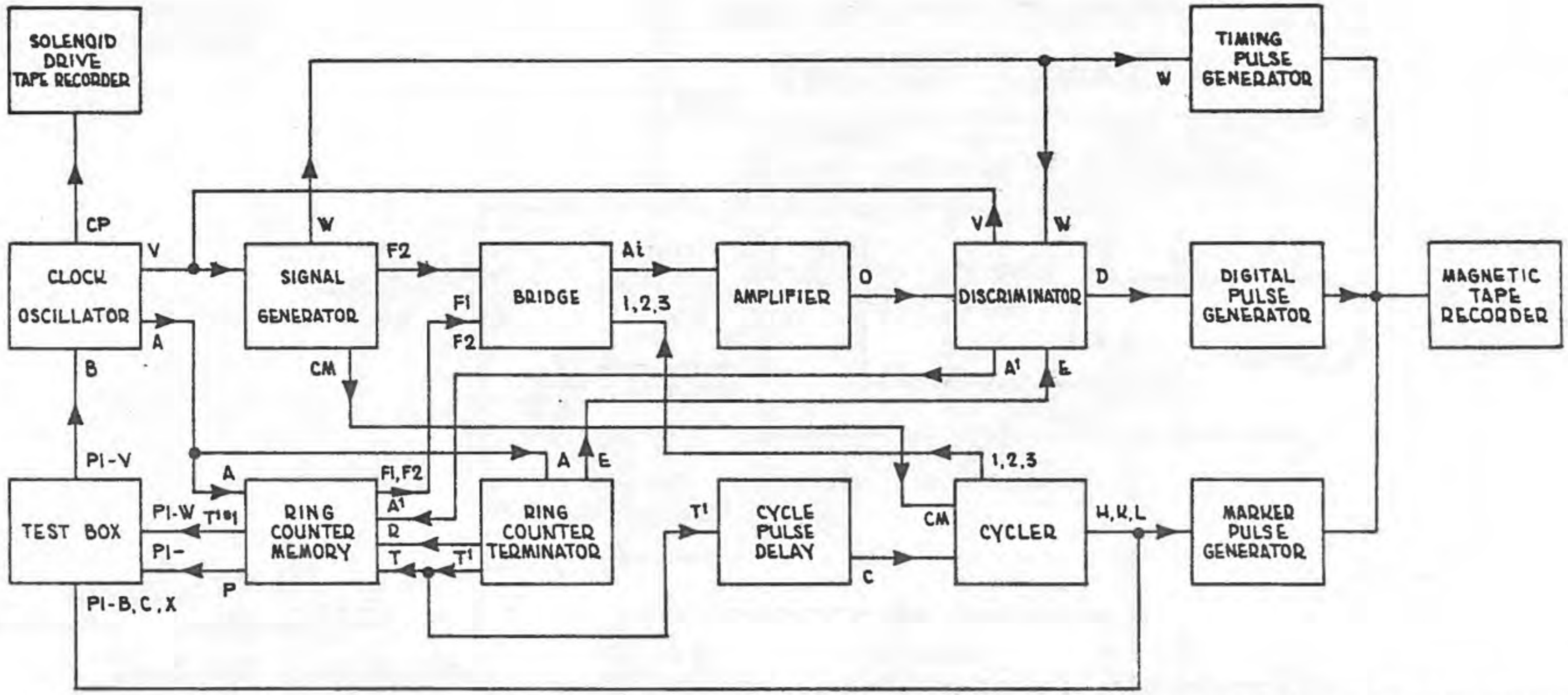
DARTMOUTH —— NOVA SCOTIA
TITLE
BATTERY CHARGER
FOR 12 VOLT NICAD BATTERIES
DRN. WM
D. Harvey
DATE OCT 1967
DRAWING No A-D-25-1



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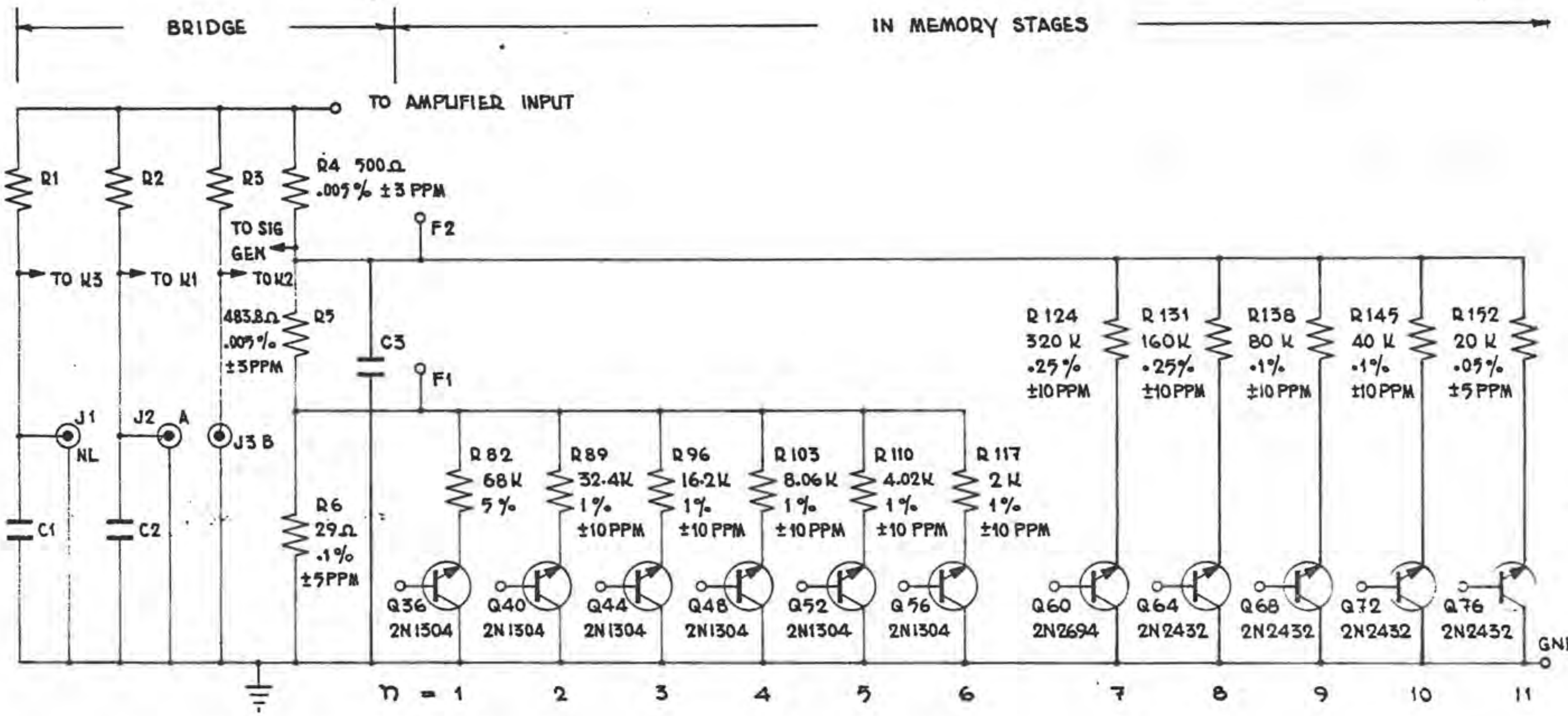
TITLE

DIGIBRIDGE
BLOCK DIAGRAM

DRN. W G MILO	D. Harvey
DATE NOV 1967	METROLOGY SECTION
DRAWING Nº B-D-32-1	



NOTES:

C1, C2, & C3 TO EQUALIZE CABLE CAPACITIES

R1, R2, & R3 ARE .025% AND ± 5PPM : SELECTED TO MATCH SENSISTORS

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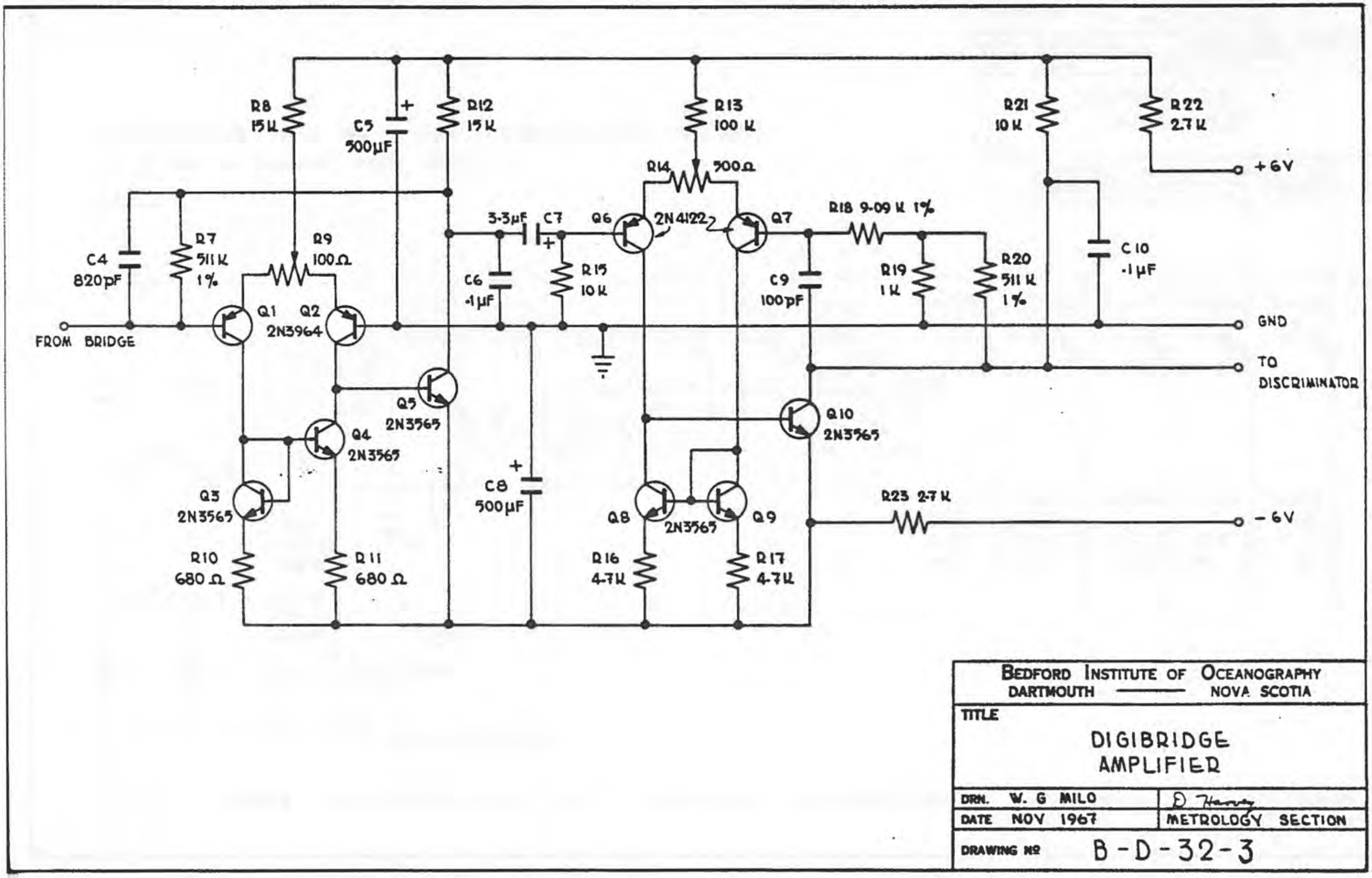
DARTMOUTH — NOVA SCOTIA

TITLE
DIGIBRIDGE
BRIDGE CIRCUIT

DRN. MILO | D. Harvey
DATE NOV / 67 | METROLOGY SECTION

DRAWING No B - D - 32 - 2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15K
C5
500µF
R12
15K
R13
100K
R21
10K
R22
2.7K
+6V
R14
500Ω
3.3µF
C7
Q6
2N4122
Q7
R18 9.09K 1%
C4
820pF
R7
511K
1%
R9
100Ω
C6
.1µF
R15
10K
C9
100pF
R19
1K
R20
511K
1%
C10
.1µF
Q1
Q2
2N3964
FROM BRIDGE
GND
TO DISCRIMINATOR
Q5
2N3565
Q4
2N3565
Q10
2N3565
Q3
2N3565
C8
500µF
Q8
2N3565
Q9
R23 2.7K
-6V
R10
680Ω
R11
680Ω
R16
4.7K
R17
4.7K
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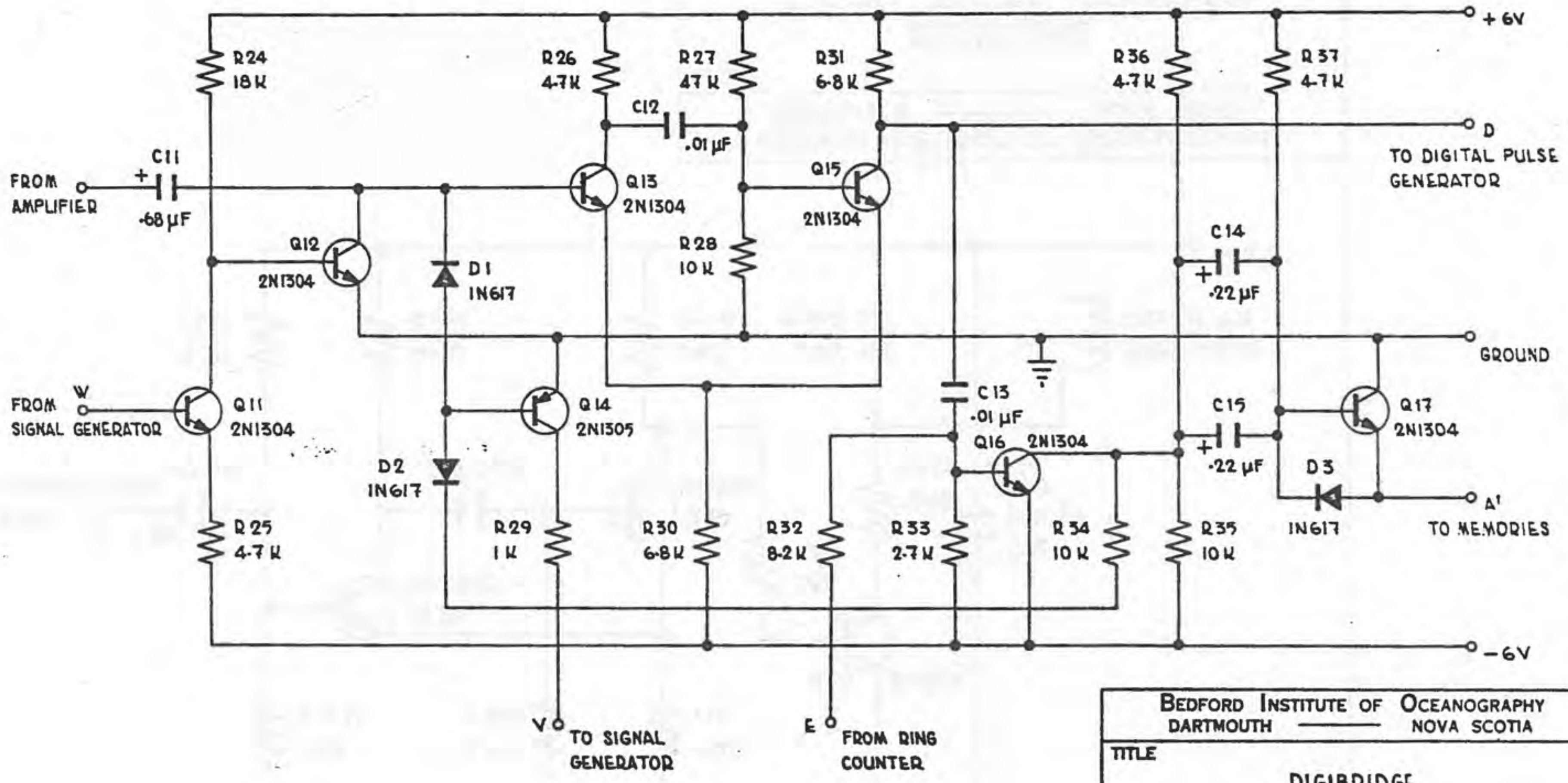
TITLE
DIGIBRIDGE
AMPLIFIER
DRN. W. G MILO
DATE NOV 1967
METROLOGY SECTION
DRAWING No
B-D-32-3



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TITLE

DIGIBRIDGE DISCRIMINATOR

DRN. W. G. MILO	D. Harvey
DATE NOV 1967	METROLOGY SECTION
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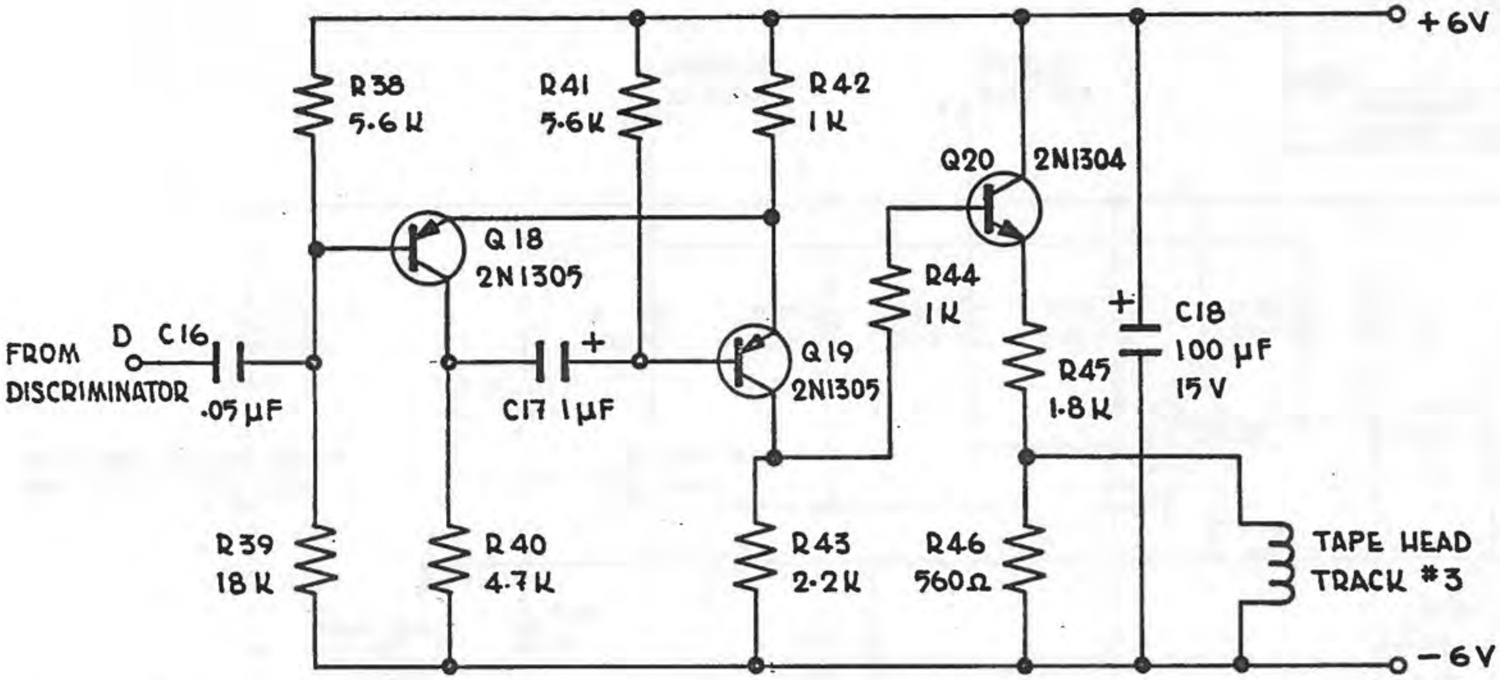

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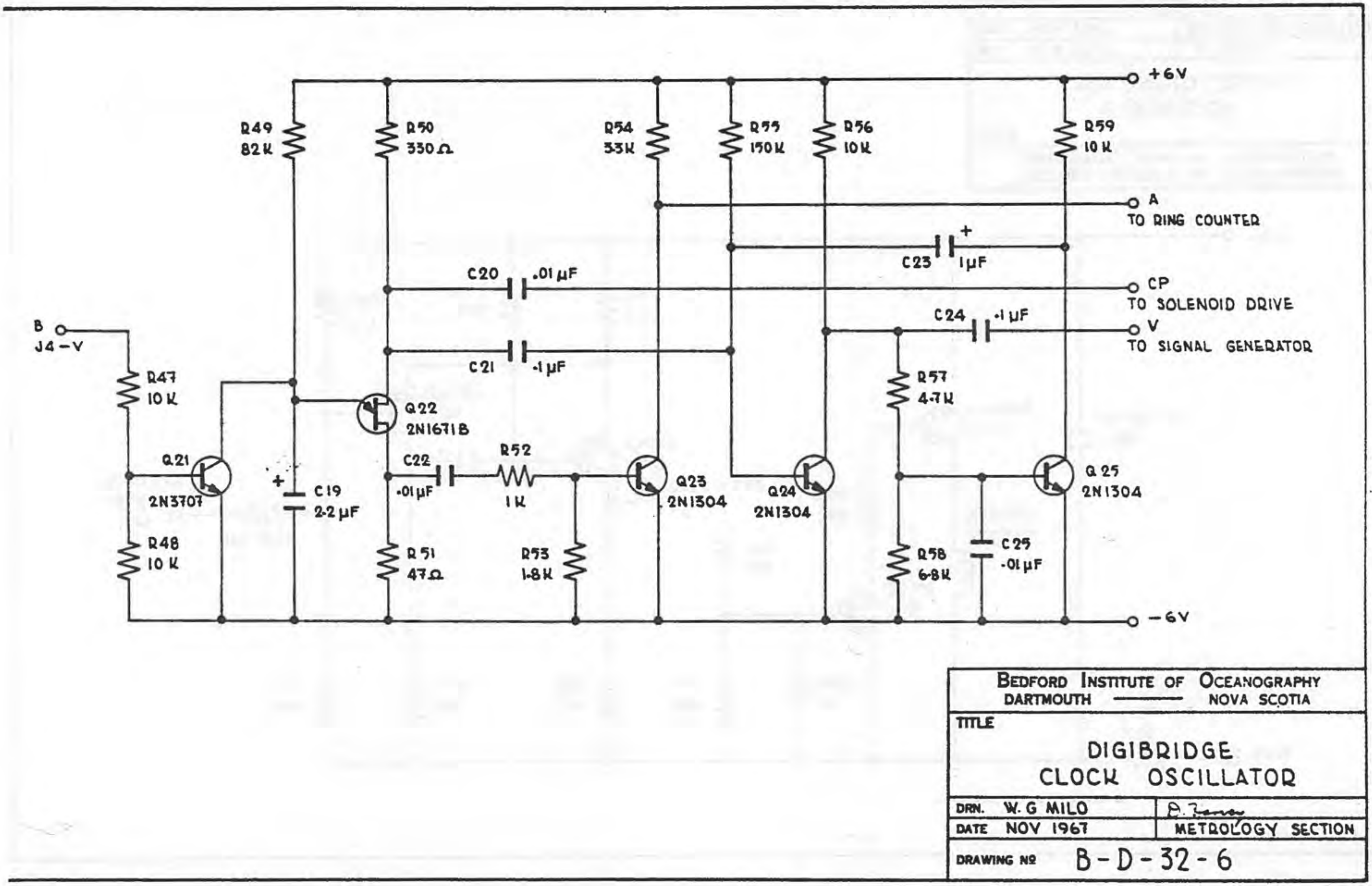
TITLE
DIGIBRIDGE
DIGITAL PULSE GENERATOR

DRN. W. G MILO — D. Harvey
DATE NOV 1967 — METROLOGY SECTION

DRAWING № A-D-32-5



+6V
R49
82K
R50
330Ω
R54
33K
R55
150K
R56
10K
R59
10K
A
TO RING COUNTER
C23
1µF
C20
.01µF
CP
TO SOLENOID DRIVE
C24
·1µF
V
TO SIGNAL GENERATOR
B
J4-V
C21
·1µF
R47
10K
Q22
2N1671B
R57
4.7K
Q21
2N3707
C19
2.2µF
C22
·01µF
R52
1K
Q23
2N1304
Q24
2N1304
Q25
2N1304
R48
10K
R51
47Ω
R53
1.8K
R58
6.8K
C25
·01µF
−6V
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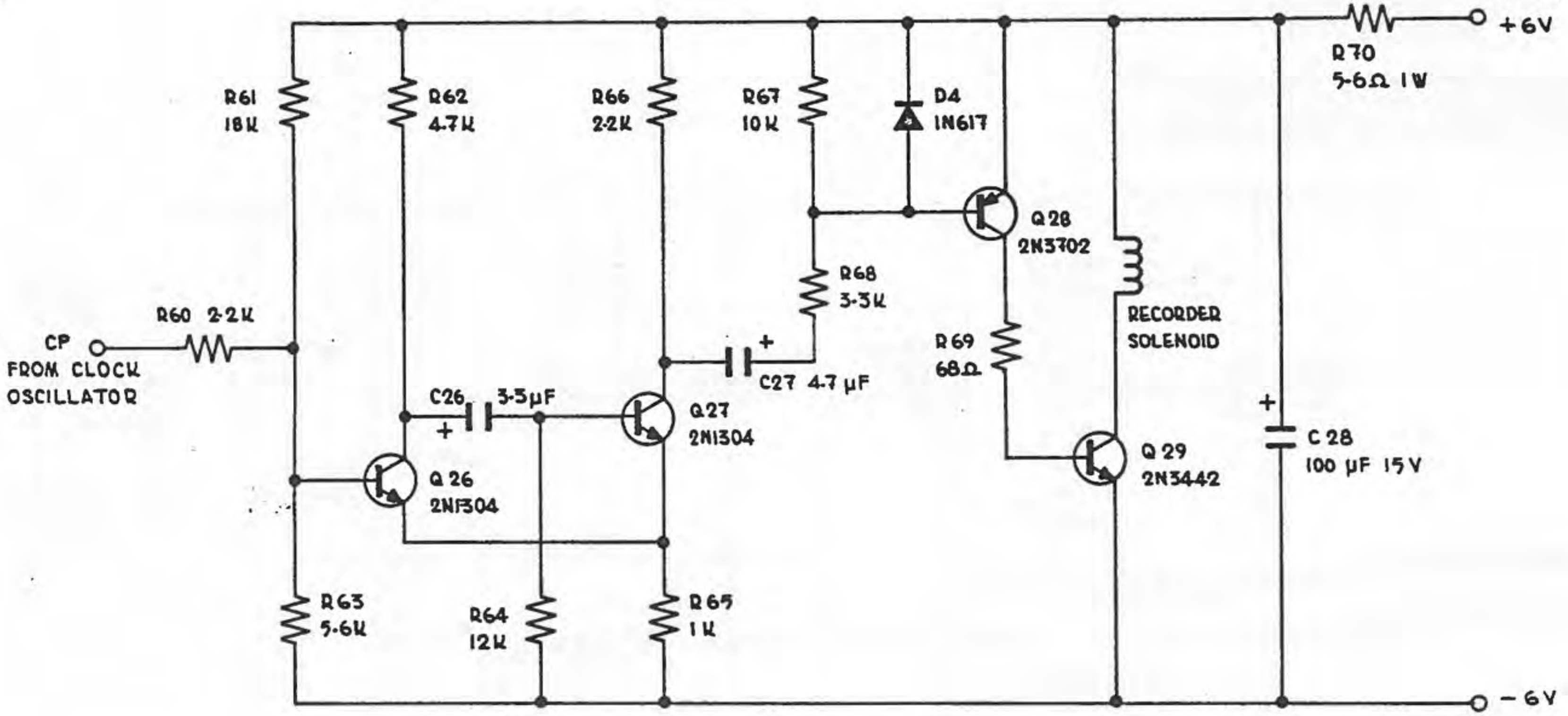
DARTMOUTH NOVA SCOTIA
TITLE
DIGIBRIDGE
CLOCK OSCILLATOR
DRN. W. G MILO
DATE NOV 1967
METROLOGY SECTION
DRAWING Nº B-D-32-6



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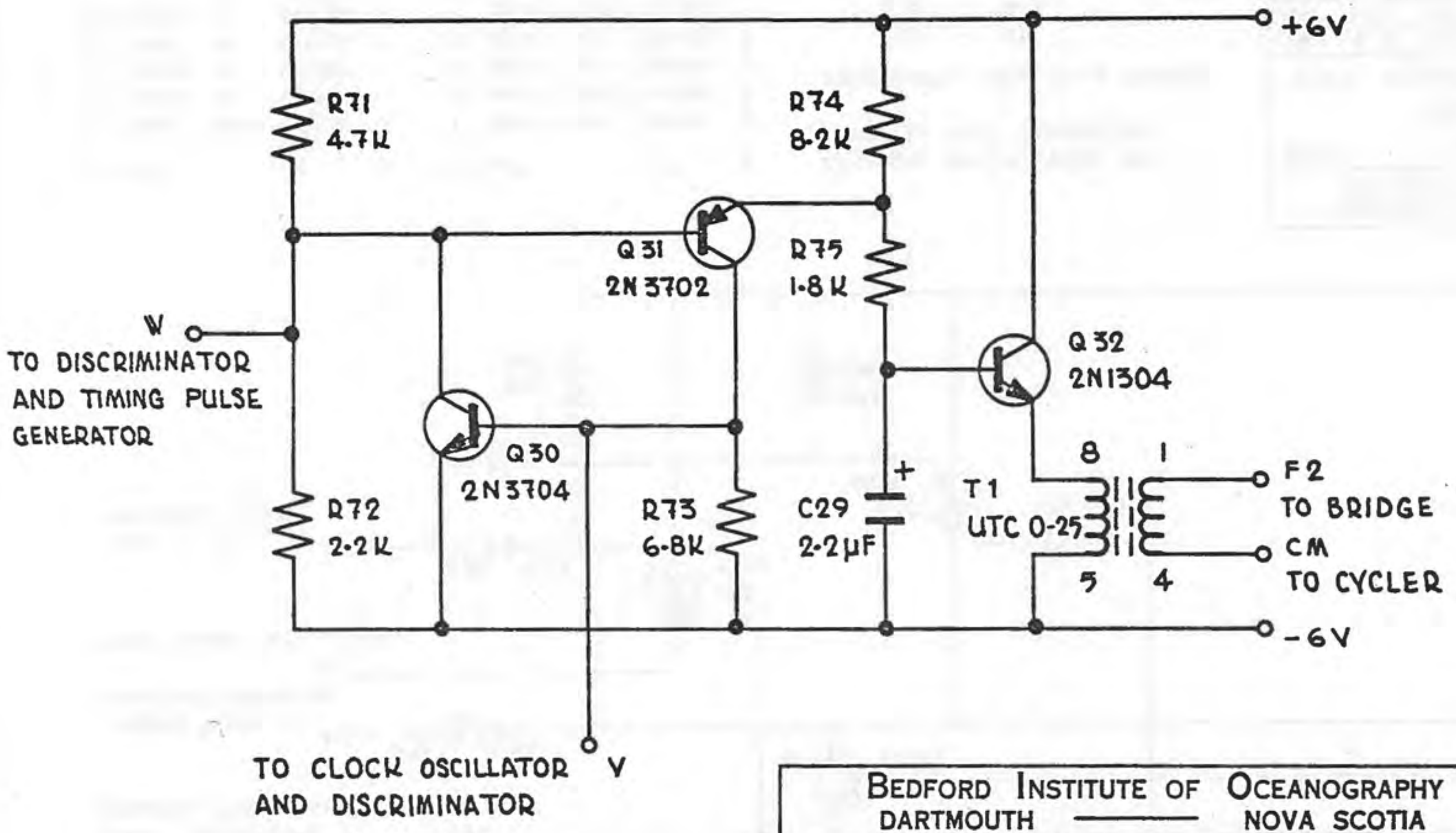
DARTMOUTH ——— NOVA SCOTIA	
TITLE: DIGIBRIDGE SOLENOID DRIVE	
DRN. W. G. MILO	D. Harvey
DATE NOV 1967	METROLOGY SECTION
DRAWING Nº B-D-32-7	



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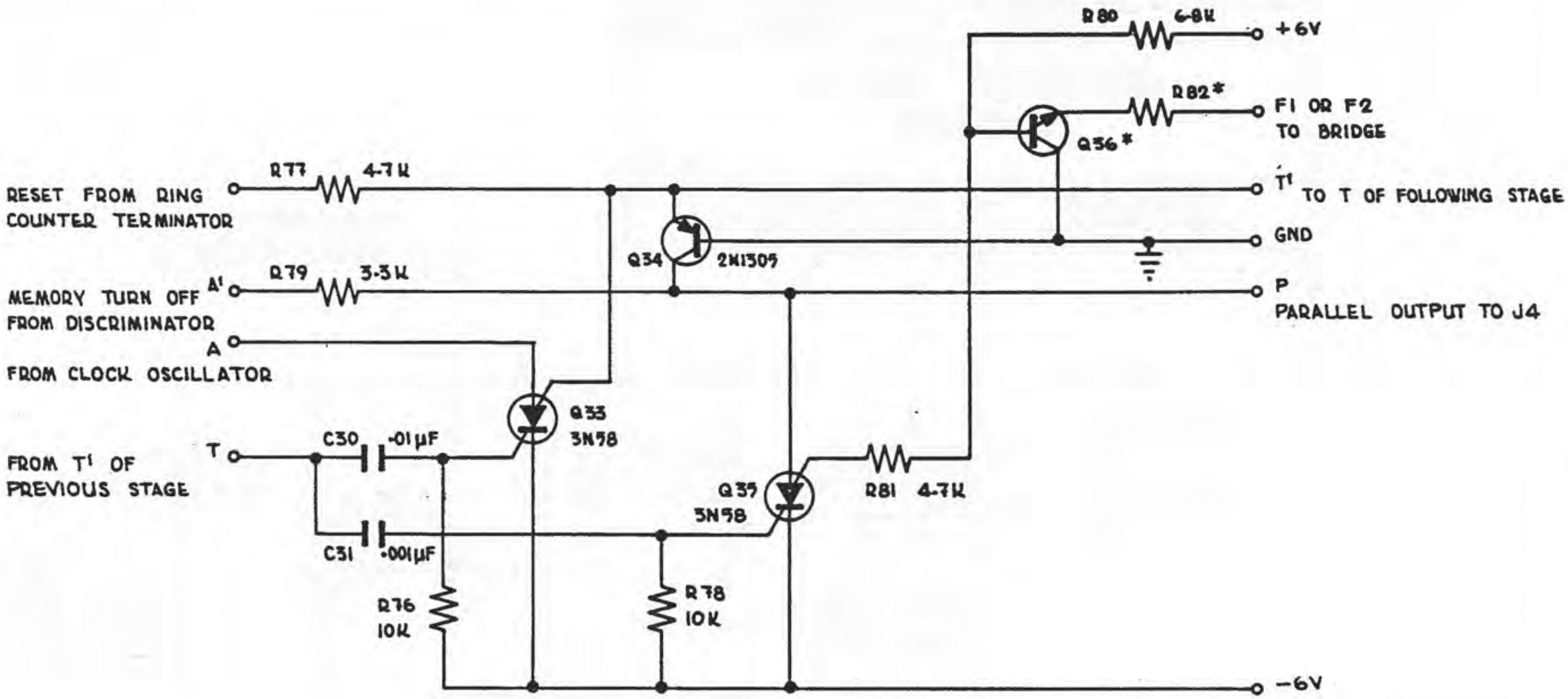
TITLE DIGIBRIDGE SIGNAL GENERATOR	
DRN. W G MILO	
DATE NOV 1967	METROLOGY SECTION
DRAWING No A - D - 32 - 8	



N	R*		Q*	F	N	R*		Q*	F
1	68K	10%	2N1304	1	7	320K	0.25%	2N2694	2
2	32-4K	1%	2N1304	1	8	160K	0.25%	2N2432	2
3	16-2K	1%	2N1304	1	9	80K	0.1%	2N2432	2
4	8-06K	1%	2N1304	1	10	40K	0.1%	2N2432	2
5	4.02K	1%	2N1304	1	11	20K	0.05%	2N2432	2
6	2K	1%	2N1304	1					

COMPLETE RING COUNTER USES
11 STAGES PLUS TERMINATOR

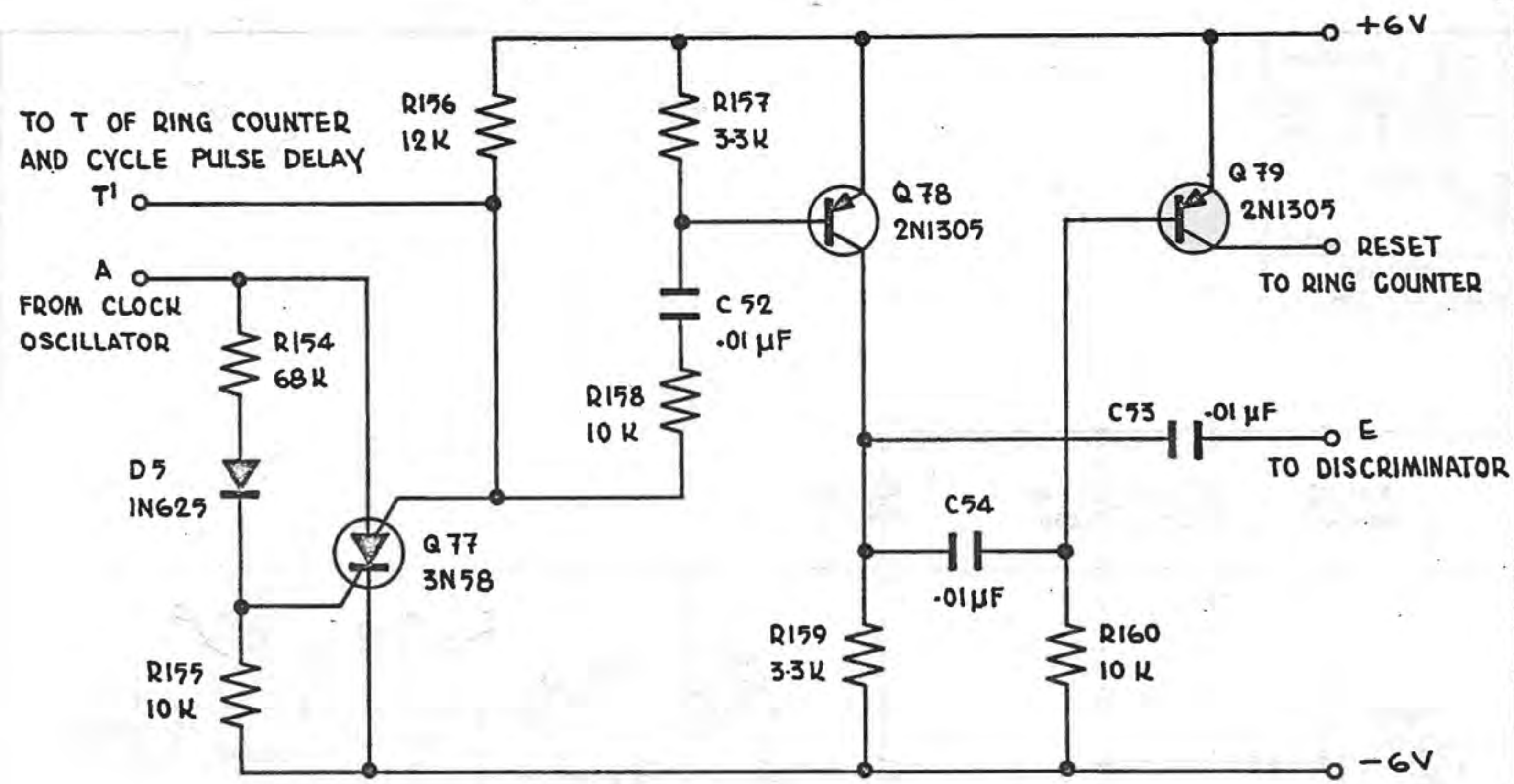
COMPONENTS USED IN 11 STAGES

C30 – C51
Q33 – Q76
R76 – R153

BEDFORD INSTITUTE OF OCEANOGRAPHY
DARTMOUTH — NOVA SCOTIA

TITLE DIGIBRIDGE
ONE STAGE OF
RING COUNTER AND MEMORY

DRN.	W. G. MILO	D. Harvey
DATE	NOV 1967	METROLOGY SECTION
DRAWING NO	B-D-32-9	

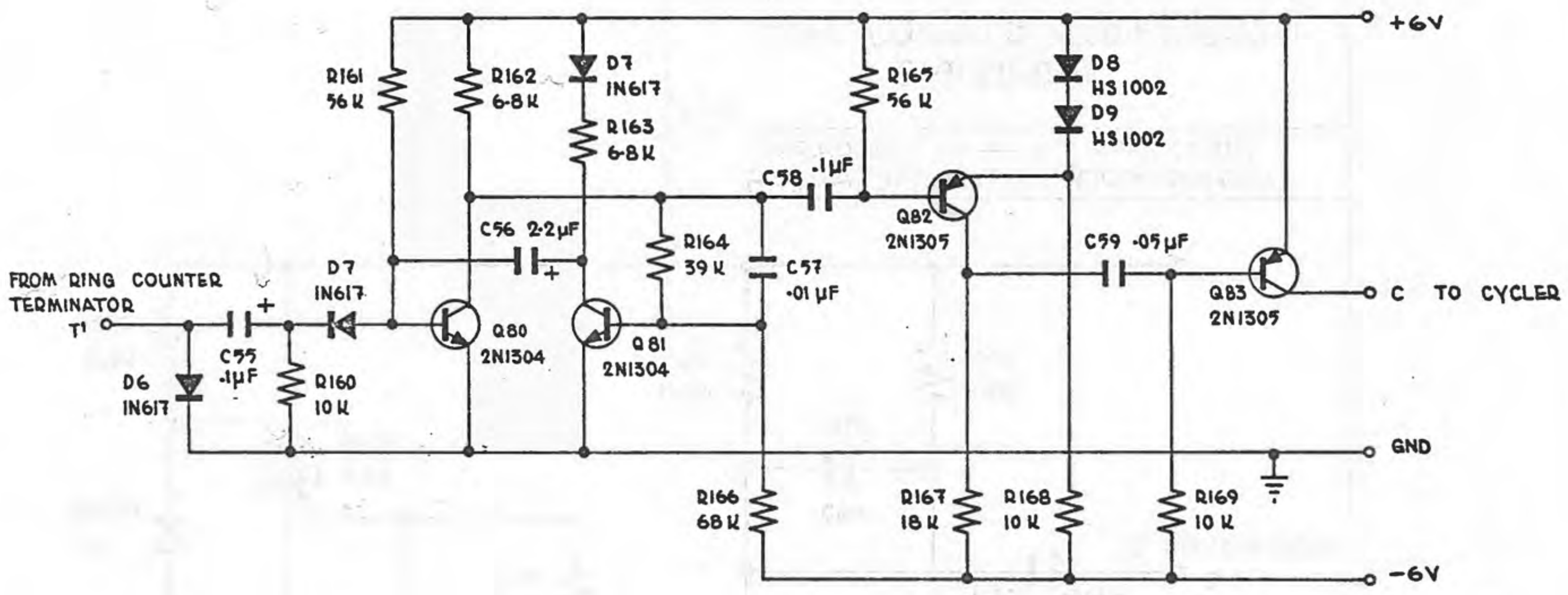


BEDFORD INSTITUTE OF OCEANOGRAPHY
DARTMOUTH —— NOVA SCOTIA

TITLE

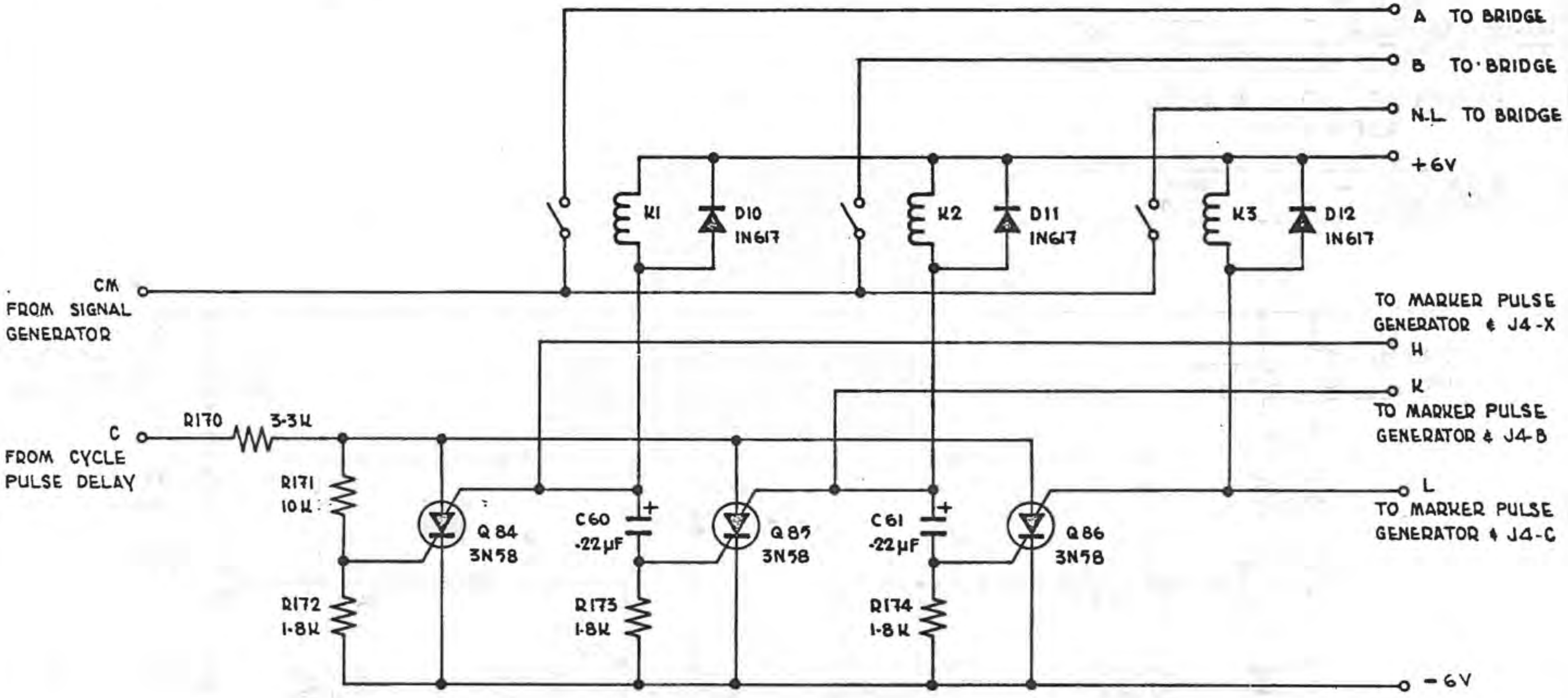
DIGIBRIDGE
RING COUNTER TERMINATOR

DRN. W. G MILO	D. Harvey
DATE DEC 1967	METROLOGY SECTION
DRAWING № A - D - 32 - 10	



BEDFORD INSTITUTE OF OCEANOGRAPHY
DARTMOUTH — NOVA SCOTIA

TITLE	DIGIBRIDGE CYCLE PULSE DELAY
DRN. W. G MILO	D. Harvey
DATE DEC 1967	METROLOGY SECTION
DRAWING Nº	B-D-32-11



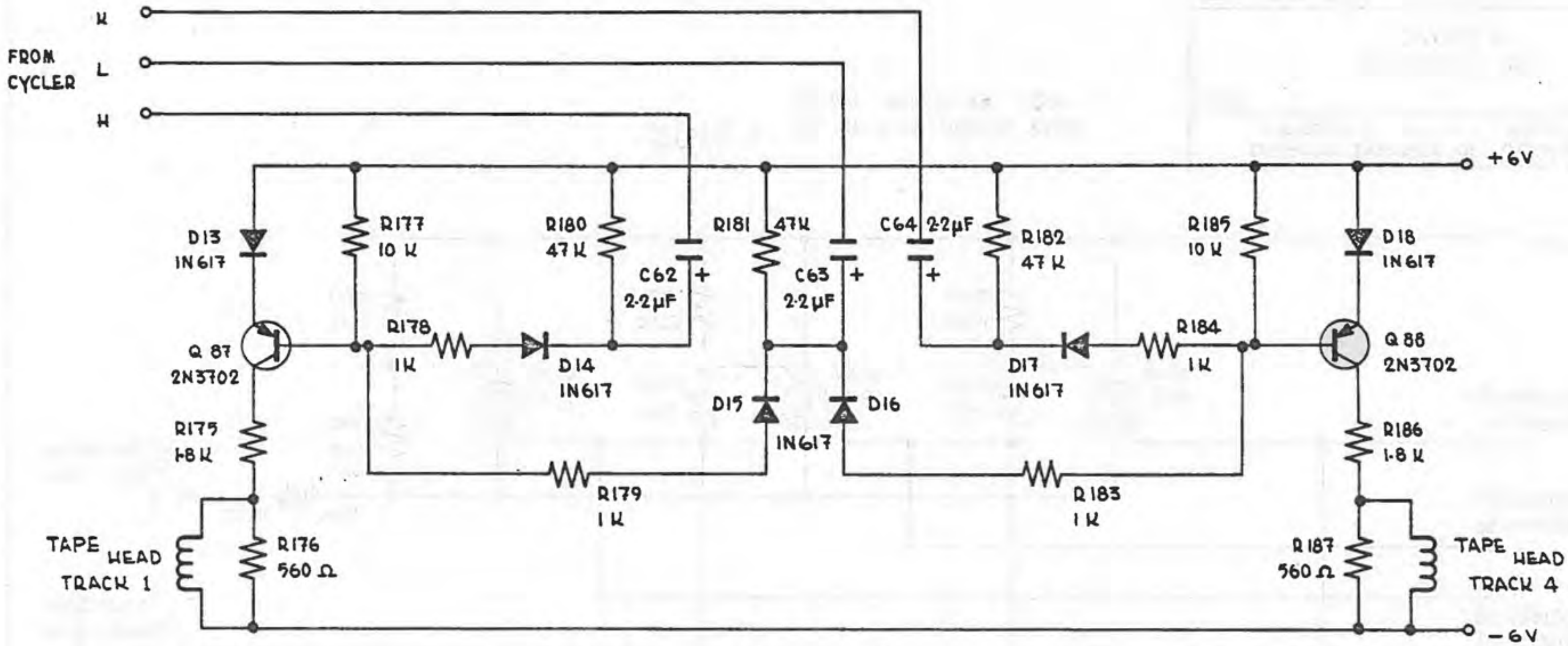
NOTE: K1, K2 & K3 DUNCO REED RELAY MMR-1A 12V

BEDFORD INSTITUTE OF OCEANOGRAPHY
DARTMOUTH — NOVA SCOTIA

TITLE

DIGIBRIDGE CYCLER

DRN.	W. G. MILO	D. Harvey
DATE	DEC 1967	METROLOGY SECTION
DRAWING No	B-D-32-12	



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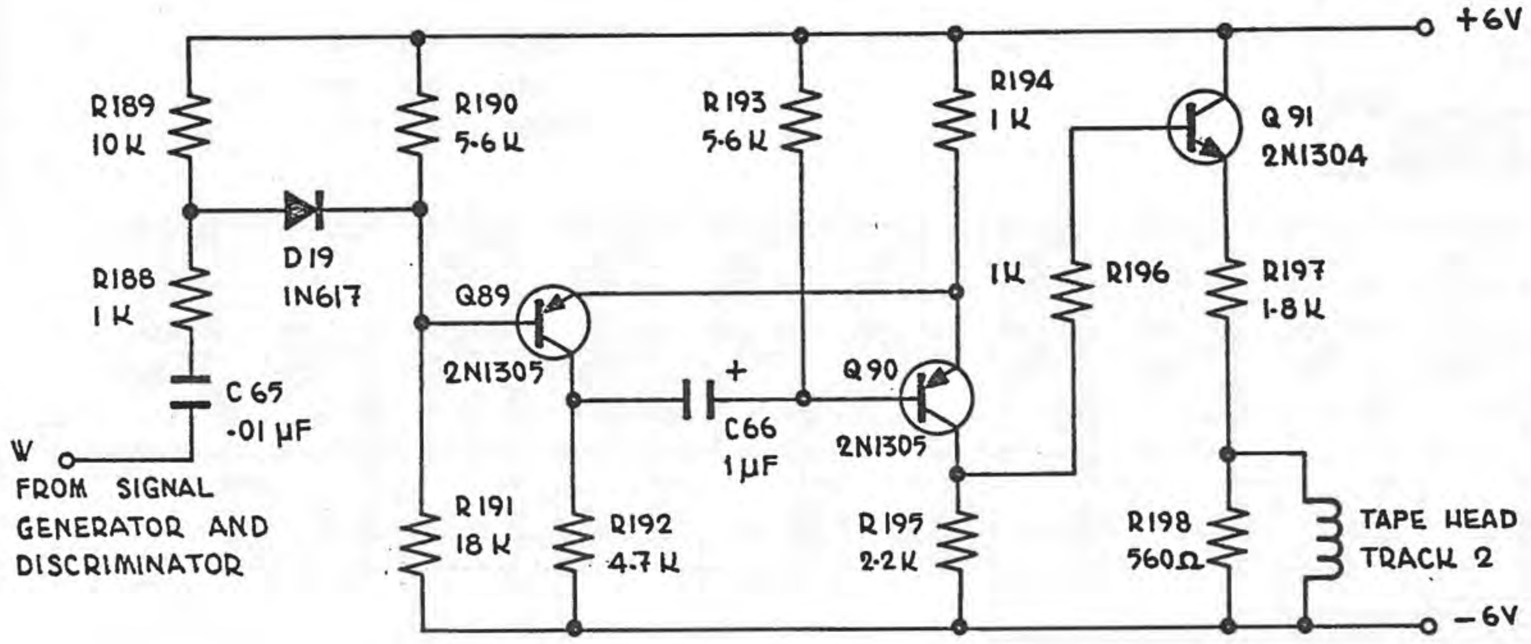
DARTMOUTH —— NOVA SCOTIA

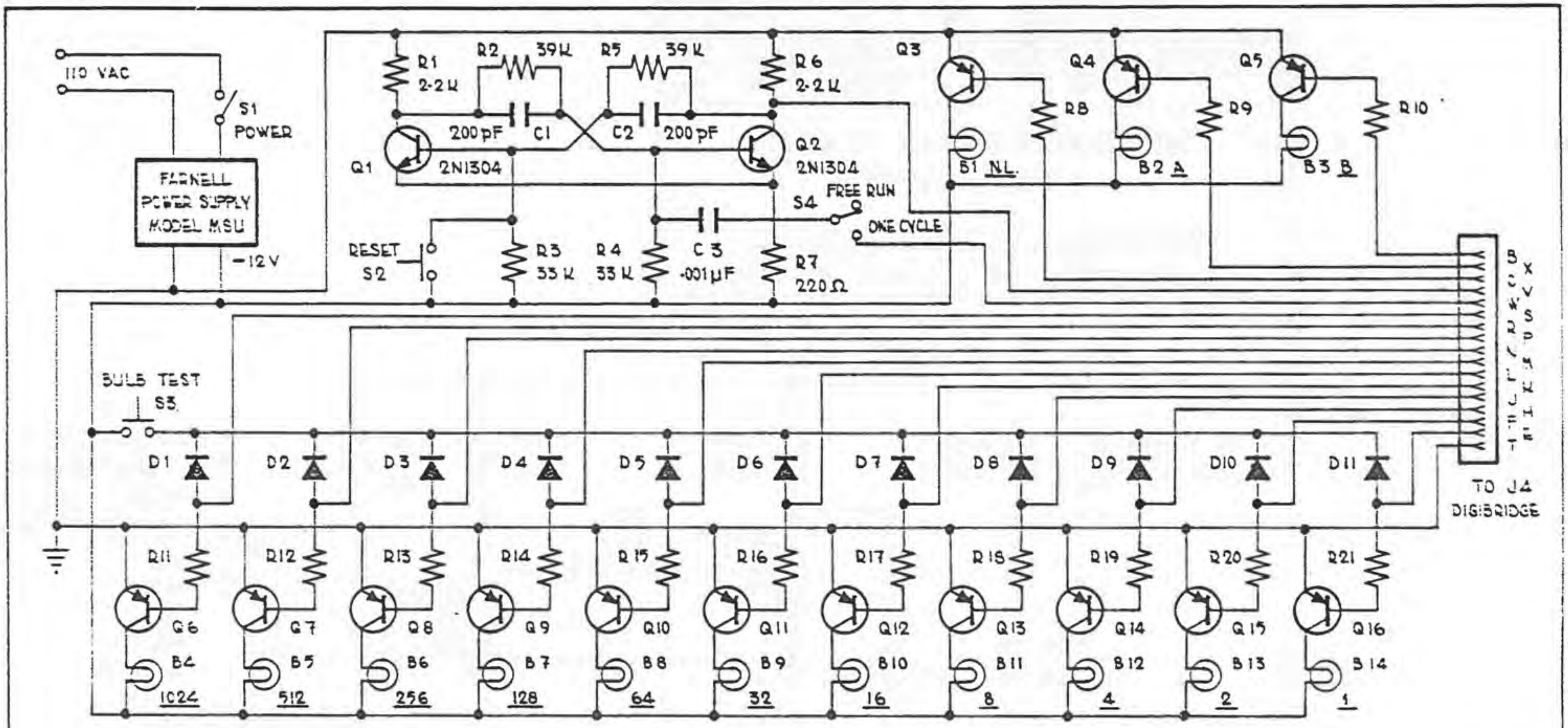
TITLE

DIGIBRIDGE
MARKER PULSE GENERATOR

DRN.	W. G. MILO	
DATE	DEC 1967	METROLOGY SECTION
DRAWING No	B-D-32-13	



BEDFORD INSTITUTE OF OCEANOGRAPHY DARTMOUTH —— NOVA SCOTIA	
TITLE DIGIBRIDGE TIMING PULSE GENERATOR	
DRN. W. G. MILO	D. Harvey
DATE DEC 1967	METROLOGY SECTION
DRAWING Nº A - D - 32 - 14	



Q3 - Q16	2N1305
R8 - R21	22K
D1 - D11	IN617

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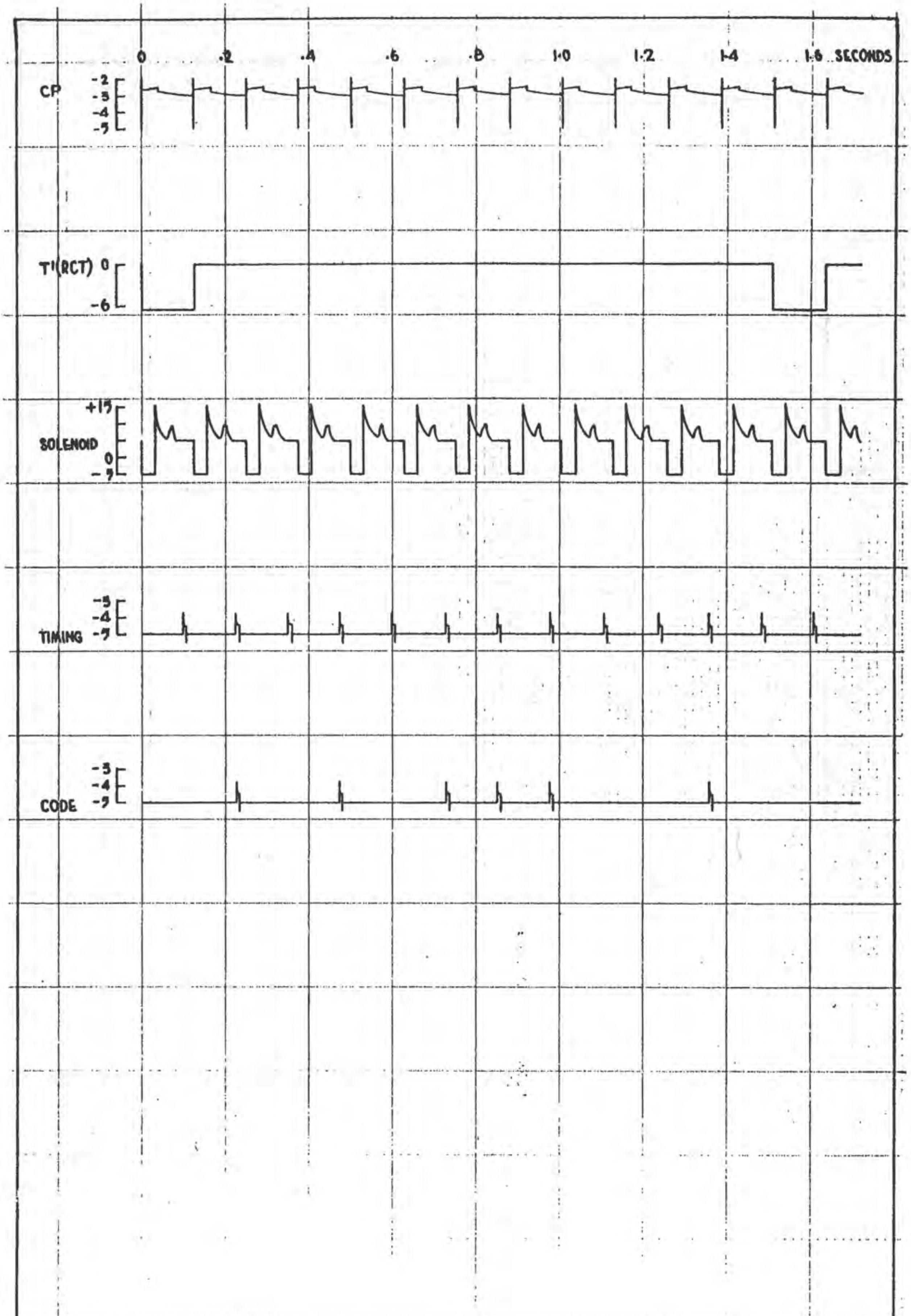
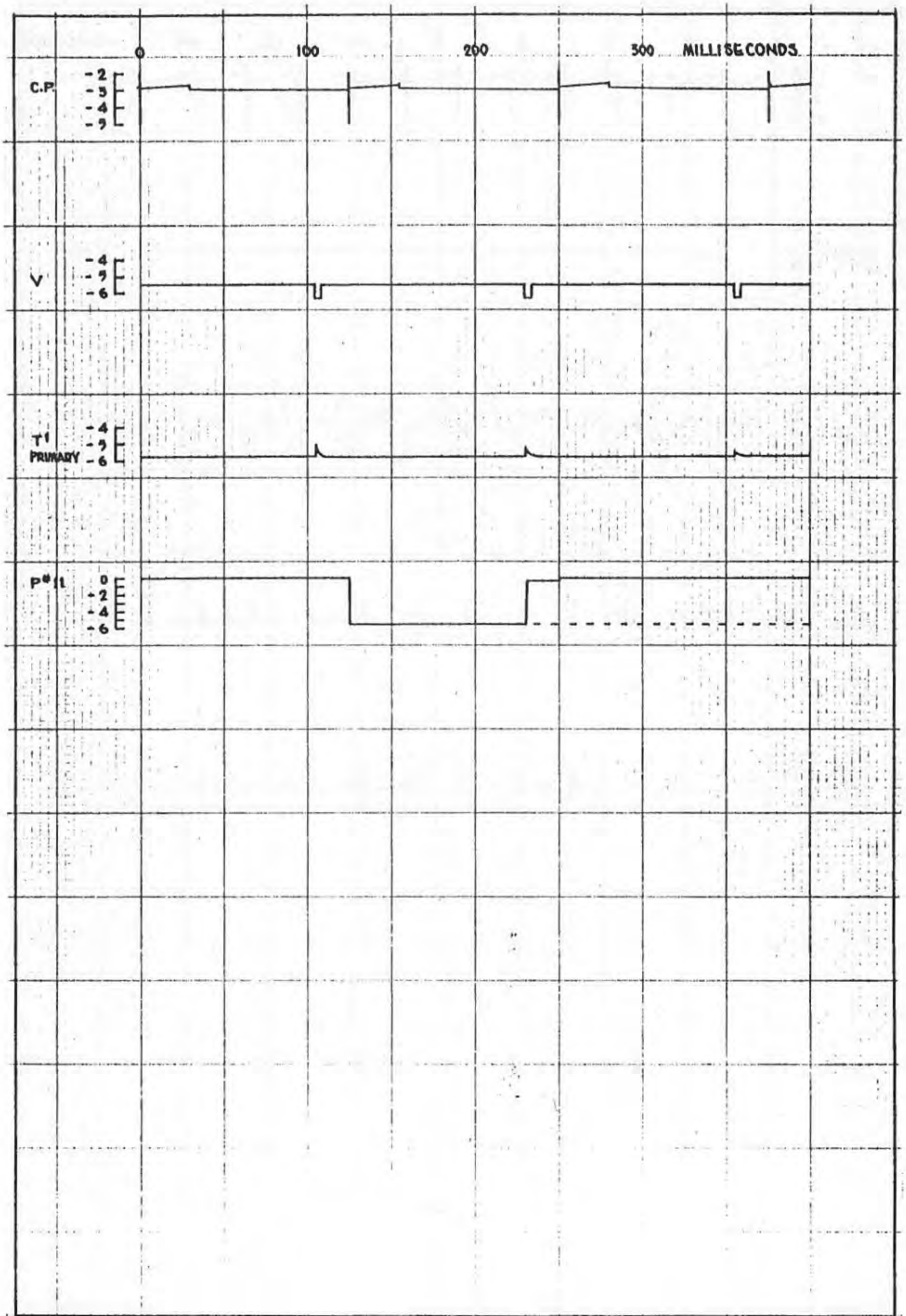
DARTMOUTH ——— NOVA SCOTIA

TITLE
DIGIBRIDGE
TEST BOX

DRN. W G MILO — D Tovey
DATE DEC 1967 — METROLOGY SECTION
DRAWING No B-D-32-15



BEDFORD INSTITUTE OF OCEANOGRAPHY		DIGIBRIDGE WAVE FORMS	DRAWING NUMBER B-D-32-16
DRWN W. G. MILO	CHKD D. Harvey		
DATE DEC. 1967	METROLOGY SECTION		



BEDFORD INSTITUTE OF OCEANOGRAPHY		DIGIBRIDGE WAVE FORMS	DRAWING NUMBER
DRWN W. G. MILO	CHKD D. Harvey		B-D-32-17