ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

TECHNICAL NOTE No: T.D.40

TELEMETRY CONVERTER UNIT

A METHOD OF CONVERTING A TIME INTERVAL BETWEEN TWO PULSES INTO A D.C. VOLTAGE CHANGE

by

J.S.WHITALL, B.Sc. & P.C.DENCH, Grad. Inst.P.

APRIL, 1959

SUBJECTS

1. Pulses - measurement

2.

3.

4.

5.

ADDED ENTRIES

I Title

II Whitall, J. S.

III Dench, P. C.

IV

V Project No.

VI Contract No.

MODIFIED HANDLING A[redacted]

CONFIDENTIAL CONFIDENTIAL CONFIDENTIAL

U.S. ARMY STANDARDIZATION GROUP, U.K.
Box 65, USN 100, F.P.O.
New York, N.Y.

7911

OC/GM-RP-2226 1 July 1959

SUBJECT: Telemetry Converter Unit (U)

TO: Commanding Officer
Ordnance Technical Intelligence Agency
United States Army
Arlington Hall Station
Arlington 12, Virginia

1. Forwarded herewith as Inclosure No. 1 for your retention is Royal Aircraft Establishment Technical Note T.D.40, entitled, "Telemetry Converter Unit - Amethod of Converting a Time Interval Between Two Pulses Into a D.C. Voltage Change" dated April 1959.

2. (C) <u>Summary of Inclosure No. 1</u>

"The circuits described are designed for full scale measurements, of 1 μsec, 10 μsecs and 100 μsecs.

"The time interval between two pulses is measured by using them to gate a pentode so that it discharges a capacitor. The voltage change across the capacitor during the gating interval will be proportional to the length of the interval. The voltage change is maintained sufficiently long on a capacitor to enable the subsequent circuits to either record or transmit the information using a system which can have a frequency response or bandwidth very much lower than that required for direct recording or transmission of the two pulses.

"Also described in this Note are the circuits used for calibration of the above method of measurements."

Dudley B. Selden
DUDLEY B. SELDEN
Lt Colonel, Ord Corps
Ord Corps (GM) Representative

1-Incl.
a/s

Copies furnished:
w/Incl: ARGMA(5 cys incl); BRL; JPL; ABMA; WSMR; OCSigO(R&D)USASEL; Frankford Asnl; Picatinny Asnl; DOFL; Air Def.Bd.
w/oIncl: ORDTU; Air Def.Schl; File; OArmA London for ACS, Intel.
N.44840/B
Reg 009104

MODIFIED HANDLING [redacted]

CONFIDENTIAL

CONFIDENTIAL

US ARMY STANDARDIZATION GROUP, UK
Box 65, USN 100, F.P.O.
New York, N.Y.

OC/GM-LR-712 28 July 1959

SUBJECT: Downgrading of U.K. Report (U)

TO: Commanding Officer
Ordnance Technical Intelligence Agency
United States Army
Arlington Hall Station
Arlington 12, Virginia

c69867

1. This office has been advised by Ministry of Supply that Royal Aircraft Establishment Tech Note T.D.40, entitled, "Telemetry Converter Unit - A Method of Converting a Time Interval Between Two Pulses into a D.C. Voltage Change" dated April 1959, has been downgraded from 'CONFIDENTIAL' to 'RESTRICTED' (U.S. CONFIDENTIAL - MODIFIED HANDLING).

2. The above report was transmitted your office under file reference OC/GM-RP-2226, dated 1 July 1959. Request you downgrade your copy/copies of report and/or copy of OC/GM-RP-2226 accordingly.

DUDLEY B. SELDEN
Lt Colonel, Ord Corps
Ord Corps (GM) Representative

Copies furnished:
ARGMA;
BRL;
JPL;
ABMA;
WSMR;
OCSigO(R&D);
USASEL;
Frankford Asnl;
Picatinny Asnl;
DOFL;
Air Def.Bd.;
ORDTU;
Air Def.Schl.;
OArmA London for ACS-Intel;
File.

Reg # 009446

U.D.C. No. 621.398:621.314.5:621.317.787.2

Technical Note No. TD.40

April 1959

ROYAL AIRCRAFT ESTABLISHMENT

(FARNBOROUGH)

TELEMETRY CONVERTER UNIT

A METHOD OF CONVERTING A TIME INTERVAL BETWEEN TWO PULSES INTO A DC VOLTAGE CHANGE

by

J.S. Whitall, B.Sc.
and
P.C. Dench, Grad. Inst.P.

SUMMARY

The circuits described are designed for full scale measurements, of 1 µsec, 10 µsecs and 100 µsecs.

The time interval between two pulses is measured by using them to gate a pentode so that it discharges a capacitor. The voltage change across the capacitor during the gating interval will be proportional to the length of the interval. The voltage change is maintained sufficiently long on a capacitor to enable the subsequent circuits to either record or transmit the information using a system which can have a frequency response or bandwidth very much lower than that required for direct recording or transmission of the two pulses.

Also described in this Note are the circuits used for calibration of the above method of measurements.

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

---

1 INTRODUCTION

The time interval between two separate pulses, one positive and the other negative is measured by using them to gate a short-base suppressor pentode so that it discharges a capacitor. The positive pulse opens the gate and the negative pulse closes the gate, thus the voltage change across the capacitor will be some function of the length of the time interval.

The voltage change is maintained sufficiently long on a capacitor to enable the subsequent circuits to either record or transmit the information using a system which can have a frequency response or bandwidth very much lower than that required for direct recording or transmission of the two pulses.

This method is being used for full scale measurements of 1 μsec, 10 μsecs and 100 μsecs with a normal error of ±3 per cent of full scale. Careful choice of components should make it possible to increase the range.

For full scale measurements of 1 μsec and 10 μsecs the Calibration Unit provides a pulse from a triggered blocking oscillator to feed into a chain of accurate lumped constant delays. The pulses providing the calibrating time intervals are selected from the delay line and are shaped to the form required to operate the converter.

For a full scale measurement of 100 μsecs the Calibration Unit provides two negative pulses, the second of which is obtained by passing the first an integral number of times around a loop containing an 8 μsec delay line. The required interval for calibration is selected by a variable calibrated phantastron triggered by the first pulse, which gates open the loop during its rundown and, on recovery, selects the last pulse by allowing another gate to open which was held closed during the rundown. The two negative pulses then trigger a bistable circuit which provides a positive pulse that is used to open the gate of the converter for the duration of the interval.

2 TELEMETRY CONVERTER UNIT

2.1 Circuit description

The circuit is given in Fig.1. The short base suppressor pentode V1 is normally cut off by a negative bias of 15 volts applied to its control grid. The suppressor is returned to earth through a resistor R2. The anode potential is therefore at 150 volts. The voltage across capacitor C4 will charge to this value via the diode leak R7. The circuit is then ready for operation.

A positive pulse of approximately 50 volts applied to the control grid will open the gate and cause anode current to flow when the amplitude of the pulse reaches 15 volts. The grid potential will remain at zero, the current being limited by R3, for a maximum time of approximately C1 R3 at which time C1 will be charged. C1 R3 must be longer than the maximum interval to be measured. The capacitor C4 will now be discharged via the forward impedance of the silicon junction diode D1 shunted by R7.

The gate will be closed by a negative pulse of 50 volts applied to the suppressor. The anode current will be cut off when the suppressor reaches between 5 and 15 volts. The anode voltage will rise to HT discharging stray capacitance via the anode load R6. The capacitor C4 will now again charge via the diode leak and the input impedance of V2 with a time constant of at least 100 μsecs.

This sawtooth waveform will now be inverted by the second valve V2 to be passed as a positive going sawtooth to the third valve V3 which is a cathode-follower. The output of V2 is attenuated by the feedback, R10 and R8, to provide a maximum output for a full scale reading of 4 volts, that being the requirement. For no appreciable loss in the decay time of the waveform the time C8 R13 must be at least ten times as large.

The low output impedance of V3 is now utilised to charge, via diode D2, a large capacitor C9 to the peak voltage of the output from V2. The potentiometer RV1 is adjusted so that in the quiescent condition D2 is just open. R17 and R18 are chosen to satisfy a requirement that the quiescent level of the output should be negative. The output, then, is taken across C9 where the voltage change will be a function of the gating interval. The decay time of this voltage change in the absence of any external load will be C9 (R15 + R16) which is approximately 200 millisecs. If this voltage is sampled n times per revolution of a 24-way Telemetry Switch feeding a modulator with an input impedance of Z M ohms then the time constant will be modified since the effective discharge resistance will now be R15 + R16 in parallel with (24Z/n) M ohms.

2.2 The required shape of gating pulses

2.2.1 The pulses should be equal in amplitude and have equal and fast rise times.

2.2.2 For accurate results the pulses must be repeatable in rise time and amplitude.

2.2.3 Great care must be taken to ensure that the pulses are clean. Small pre-pulses or noise can result in spurious answers.

2.2.4 The duration or time constant of the positive pulse must be longer than the interval to be measured and the duration or time constant of the negative pulse must be longer still.

2.2.5 For full scale measurements of 100 μsecs the input to the suppressor is earthed and a positive rectangular pulse of 50 volts whose duration is equal to the time interval to be measured is applied to the control grid through a capacitance C1 equal to 0.02 μF. The rectangular pulse is obtained from a bistable circuit.

2.3 Time-voltage conversion laws

2.3.1 Since the pentode is a constant current device, the peak voltage change across the capacitor C4 should be directly proportional to the time interval measured provided that the anode potential does not fall too low. The calibration curves of Fig.2, 3, and 4 shows the departure from linearity experienced in practice.

2.3.2 Due to the nature of the pentode, the reciprocal of the output voltage change should be directly proportional to the capacitance of C4. Fig.5 shows that this law is obeyed reasonably well down to a capacitance value of 50 pf.

Examination of Fig.5 reveals that an equation can be fitted to the curve which is of the following form $(1/V) = P\,C4 + Q\,\ln\,(R/C4)$ where P, Q and R are constants. The first part of this expression is as anticipated, and the error, represented as a logarithmic function of C4, is mainly due to sharing the charge on C4 with C5 with a time constant of [R8 C5 C4/(C4+C5)]. This, due to the relatively slow rise time of the output at C9, causes the error to become large for low values of C4. Other causes of error are likely to be:

(a) Residual capacities

(b) Hole storage and the capacitance of D1

(c) The knee of the pentode characteristic.

The storage capacity C4 should be sufficiently large to overcome these effects.

2.4 Stability

2.4.1 Temperature

An ambient temperature change of ±20 deg C gives an error of ∓0.02 μsec for an interval of 0.6 μsec and is less for smaller intervals.

2.4.2 HT variation

A variation of ±3 volts on 150 volts gives an error or ±0.02 μsec for an interval of 0.6 μsec, and is approximately proportional to the interval.

2.4.3 LT variation

A variation of ±0.5 volts on 6.3 volts gives an error of ±0.015 μsec for an interval of 0.6 μsec and is approximately constant for all intervals.

2.4.4 Vibration

With a vibration of ±5g between 30 c/s and 500 c/s the maximum variation obtained is ±0.01 μsecs for an interval of 0.4 μsecs.

2.4.5 Random variations

One unit, with a life to date of over 100 working hours, has revealed during a period of 6 months a maximum random variation of ±2.5 per cent of the interval i.e. ±0.01 μsecs at an interval of 0.4 μsecs.

2.5 Power supplies

The power requirements for the Telemetry Converter are as follows:

(a) HT +150 volts at 5 mA

(b) LT +6.3 volts at 550 mA

(c) Bias -23 volts at 2 mA

2.6 Mechanical design

The unit, illustrated in Fig.6 has overall dimensions of 2.75, 1.75 and 1.75 inches. Its weight is 7 oz.

The three valves are housed in a duralumin block which acts as a heat sink and also provides four 6 BA tapped holes to enable the unit to be mounted.

The components are encapsulated in a block of epoxy resin fixed to the valve block by four insulating strips. An air gap between the two blocks provides heat insulation of the components from the valves.

2.7 Measurements

2.7.1 Calibrations are made using a Solatron Oscilloscope Type CT 316 using the calibrated Y shift. Sweep speed is about 2 m secs.

2.7.2 If the output is sampled by a telemetry switch then due to the decay of the output and the fact that the actual time of occurrence of the time interval to be measured relative to the samples will probably not be known, an error is introduced which is a maximum of half the decay between successive samples. Using a 24-way 100 c/s switch and sampling four times per revolution to feed a Modulator input impedance of 3 m ohms, the error will be approximately ±1 per cent of full scale.

2.8 Applications

2.8.1 The time interval between two pulses can be converted to a voltage step which is proportional to the time interval, providing that the polarities of the pulses are modified to conform with 2.2.

2.8.2 If either pulse may occur first then it is still possible to measure the separation by delaying the negative pulse so that the positive pulse will always reach the converter first. The sensitivity is then designed so that the new zero interval measurement is in the middle of the curve.

2.8.3 It is also possible to use this converter to measure the width of a positive going rectangular pulse if it is applied to the control grid in place of the first pulse, and if the suppressor input is returned to earth.

3 TELEMETRY CONVERTER CALIBRATION UNIT - 1 μSEC AND 10 μSECS

The calibration unit is considered in two parts. The circuit diagrams are given in Fig.7.

3.1 Pulse generator

The pulse generator consists of a blocking oscillator V3 V4 which is series triggered from an asymmetrical astable multivibrator V1 V2. A positive pulse is taken from the blocking oscillator and is fed via the cathode followers V3b and V5 V6 to the delay lines from which the intervals for calibration are selected.

3.1.1 The multivibrator uses the rear edge of its narrow pulse to trigger the blocking oscillator so that the front edge provides a convenient trigger point for the oscilloscope used for calibration or examination of the waveforms. Its frequency may also be switched from 200 c/s where it is used to examine waveforms of the calibrator or converter, to 1.5 c/s which since the time constant of the output voltage change is about 200 millisecs, is the maximum frequency that can be used for calibration.

3.1.2 The blocking oscillator transformer is wound on a $\frac{5}{8}$" x $\frac{5}{8}$" core of 0.004 in Mumetal laminations Interservice Type 524. Each of the three windings, consisting of 20 turns of 30G enamelled copper wire, are wound side by side to form a single layer.

3.1.3 The delay lines for the short interval are A.R.W. Types A 01 and 02/02/10P and those for the long interval are A.R.W. Type 10/10/10. The peak current required to drive these necessitates the use of two CV858 in parallel.

3.2 Pulse shaper

The calibrating time interval is obtained from the delay between two positive pulses picked off the delay line. These are now shaped in accordance with 2.2.

The first pulse is fed into the cathode-follower V7 and from there to a stretching network. The time constant of the output with this circuit is approximately 20 μsecs. This is now fed via the cathode-follower V8, to form the positive pulse to open the gate of the Telemetry Converter.

The second pulse, likewise, is fed into a cathode-follower V9 and stretching network to give a time constant of approximately 80 μsecs. This is coupled to the inverter V11 via the cathode-follower V10 which is to prevent shortening of the timing constant due to shunting the timing components by the input impedance of the inverter. The negative pulse so formed provides the waveform to shut the gate of the converter.

3.3 Power supplies

The power requirements for the Calibration Unit are as follows:

(a) HT +250 volts at 20 mA

(b) LT +6.3 volts at 4 amps

(c) Bias -23 volts with negligible current drain.

4 TELEMETRY CONVERTER CALIBRATION UNIT - 100 μSECS

A block diagram is given in Fig.8.

The circuit is triggered from a free running multivibrator.

The output of the multivibrator after passing through a Schmitt-trigger and a cathode-follower is inverted to form the first of the two negative calibration pulses P1.

The positive pulse from the cathode-follower also triggers the screen-coupled variable calibrated phantastron and is also fed through one half of a cathode-follower pair to the loop at the beginning of the 8 μsec delay line.

The output of the delay line is reshaped by a Schmitt-trigger and fed through a cathode-follower to Gate 1 and through a second cathode-follower to Gate 2.

The delayed pulse is allowed to pass through Gate 1 while the phantastron is running down and is inverted, to compensate for inversion by the gate, so that it may be fed through the other half of the cathode-follower pair into the loop again.

The pulse continues around the loop, adding each time a delay of 8 μsecs, until the phantastron bottoms where-upon Gate 1 is closed.

Gate 2 is closed during the rundown of the phantastron. The bottoming of the phantastron allows Gate 2 to open so that the last pulse is permitted to leave the loop and become the second of the two negative calibration pulses, P2.

P1 and P2 are available separately and are used to trigger a bistable circuit which provides the calibrating positive rectangular pulse of 50 volts whose width is an integral multiple of 8 μsecs.

P1 and P2 are also available mixed so that the unit may be compared to a crystal calibrator.

5 CONCLUSIONS

5.1 It is shown here that the Telemetry Converter Unit provides a means whereby the interval between two pulses can be converted to a DC voltage change. This enables transmission of remote information using a normal telemetry system of very much lower bandwidth than that required for direct transmission of the pulses. In telemetry applications, for intervals of less than 1 μsec, there is a saving in the RF power required for any given range.

5.2 The error in measurement can be within ±3 per cent of full scale providing certain repeatability of pulse shape is maintained.

5.3 The Telemetry Converter Unit can also be used to measure pulse widths.

ATTACHED:

Drawings Nos.TD/P.419-425
Negative Nos.141,279
Detachable abstract cards

ADVANCE DISTRIBUTION LIST:

MOS Headquarters

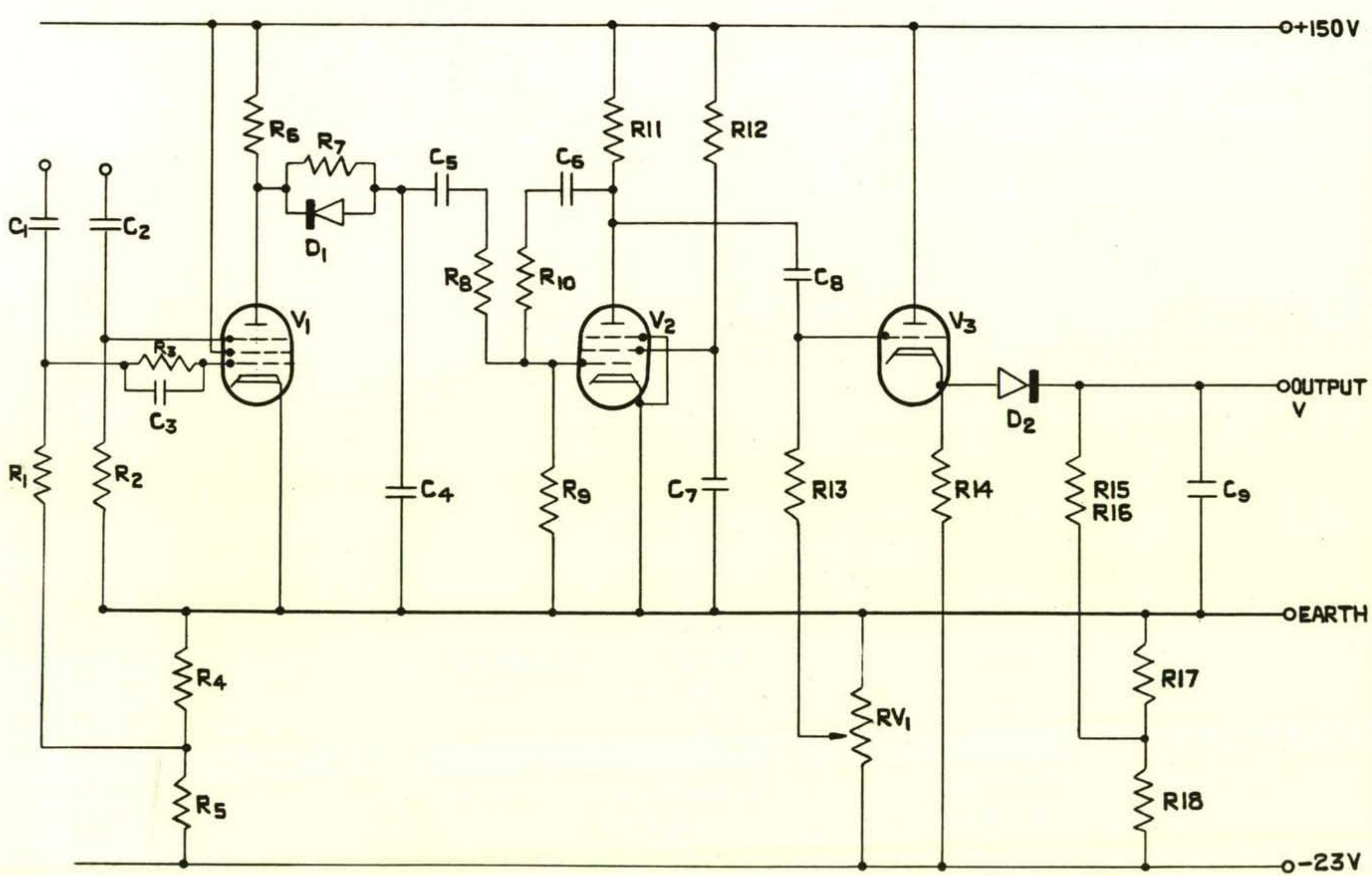
Chief Scientist	
DG/GW	60
TIL	60

Air Ministry

Science/Library

Royal Aircraft Establishment

Director
DD(E)
Library
Patents Dept



R_1	100K	R_{10}	AS REQD.
R_2	1M	R_{11}	47K
R_3	10K	R_{12}	150K
R_4	68K	R_{13}	1M
R_5	33K	R_{14}	12K
R_6	47K	R_{15}	4·7M
R_7	10M	R_{16}	4·7M
R_8	680K	R_{17}	33K
R_9	1M	R_{18}	AS REQD.
RV_1	250K		
C_1	0·002 μF		
C_2	0·01 μF		
C_3	10pF		
C_4	AS REQD. S. MICA		
C_5	470pF		
C_6	0·01 μF		
C_7	0·002 μF		
C_8	0·005 μF		
C_9	0·02 μF		
D_1	ZS 21		
D_2	ZS10B		
V_1	VX8125		
V_2	VX8122		
V_3	VX8156		

FIG. 1. CIRCUIT DIAGRAM OF TELEMETRY CONVERTER UNIT.

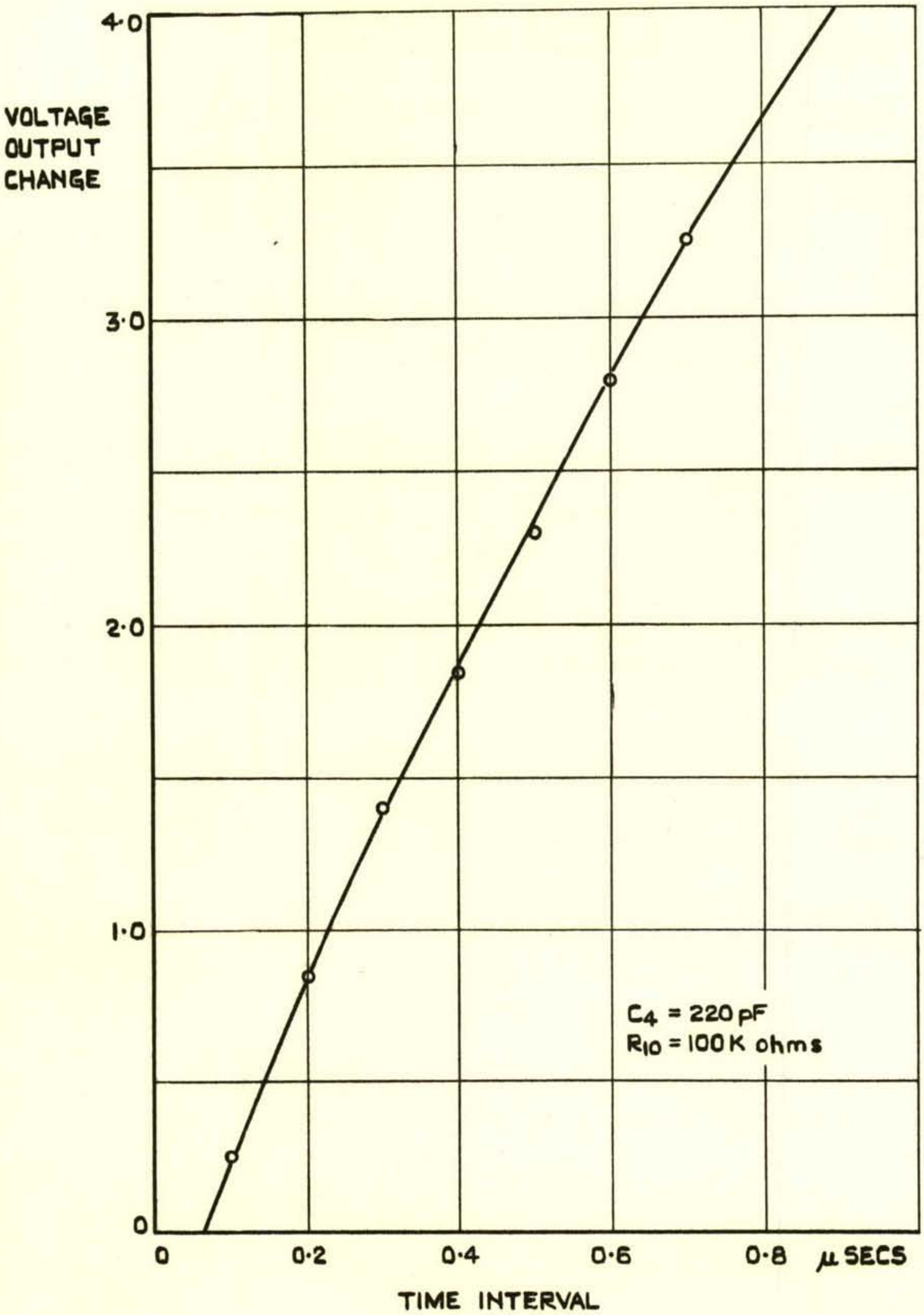


FIG. 2 CALIBRATION CURVE FOR FULL SCALE MEASUREMENT OF 1μ SEC.

TD/P/421

FIG. 3

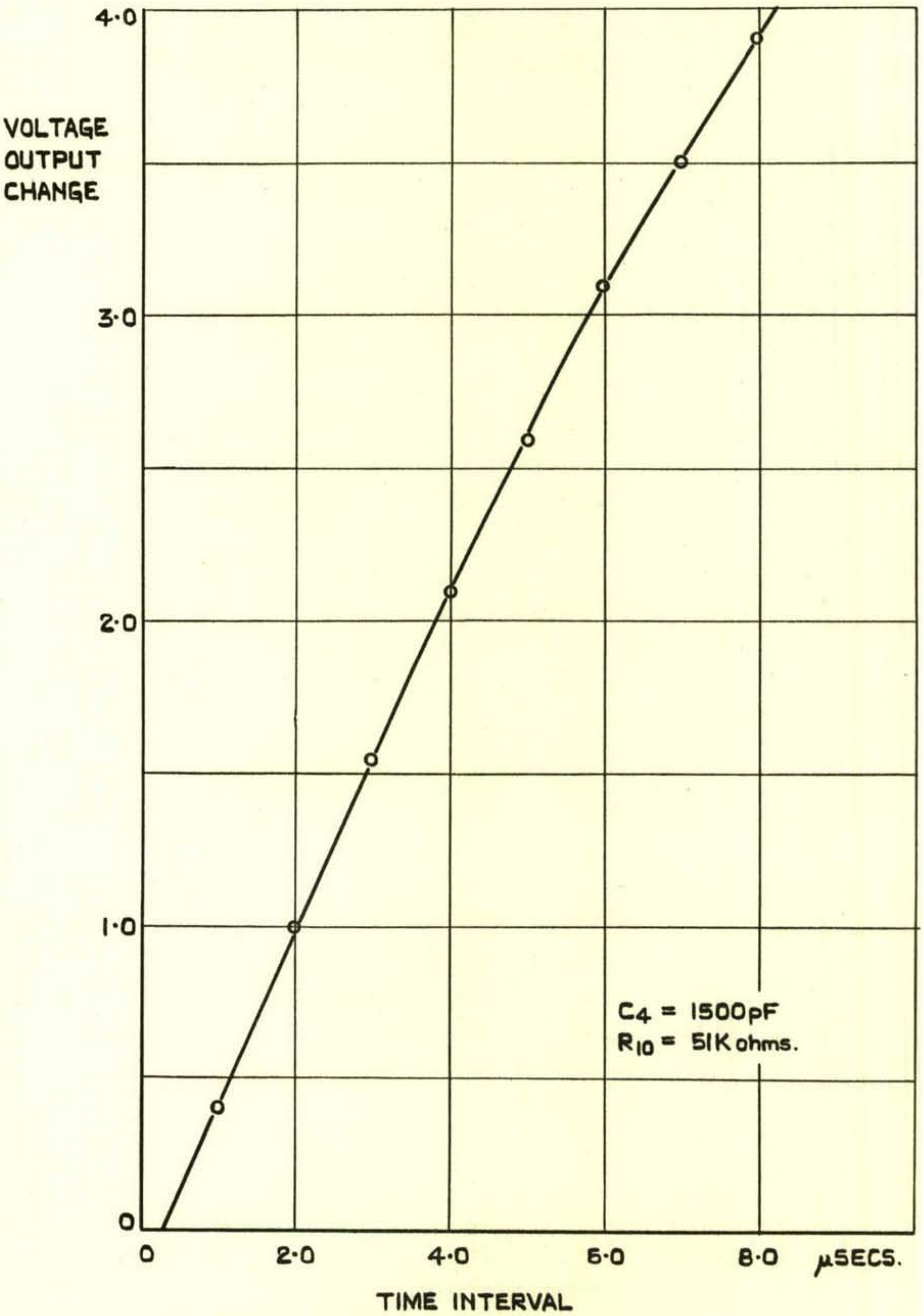


FIG. 3 CALIBRATION CURVE FOR FULL SCALE MEASUREMENT OF 10μ SECS.

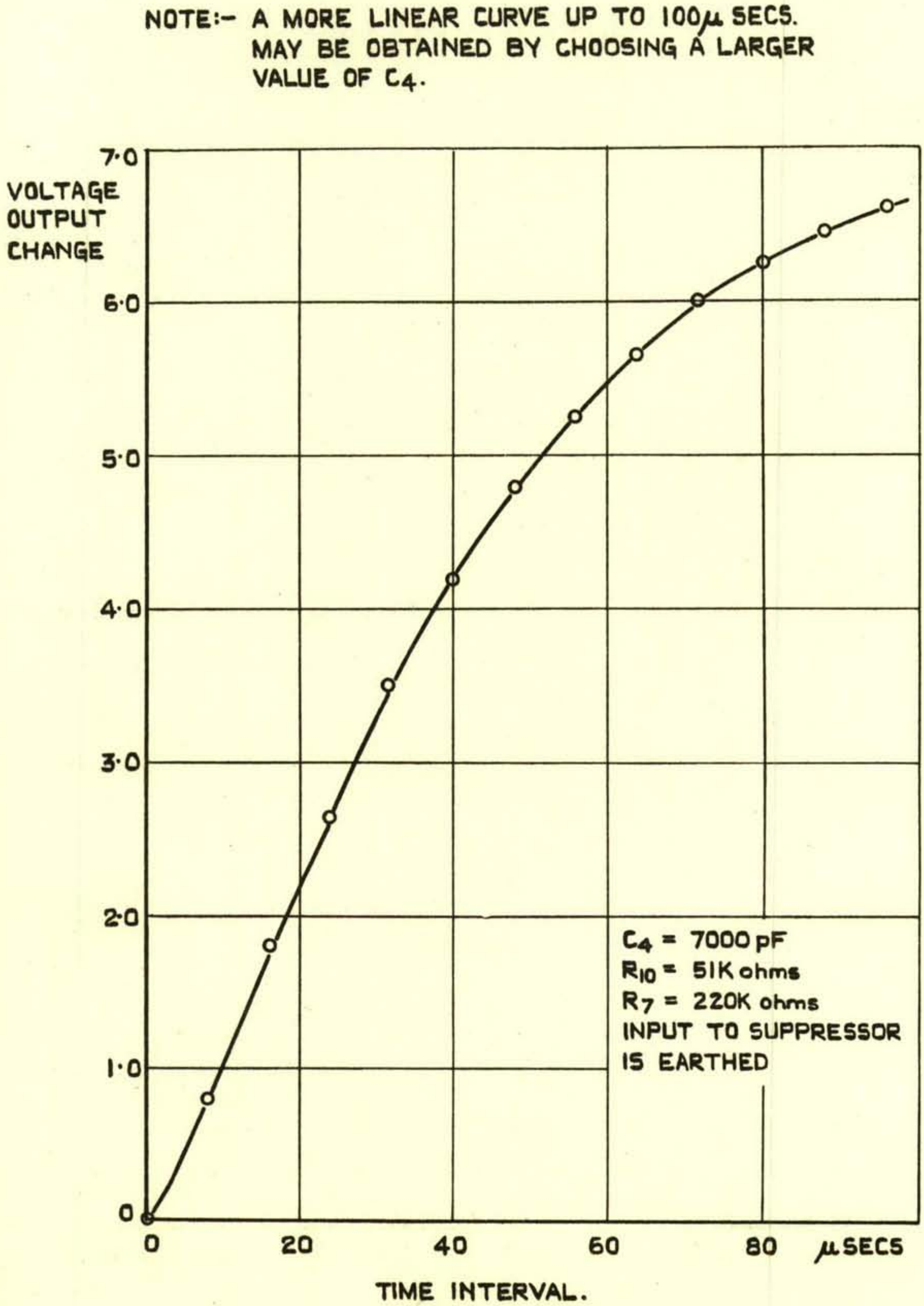


FIG. 4 CALIBRATION CURVE FOR FULL SCALE MEASUREMENT OF 100μ SECS.

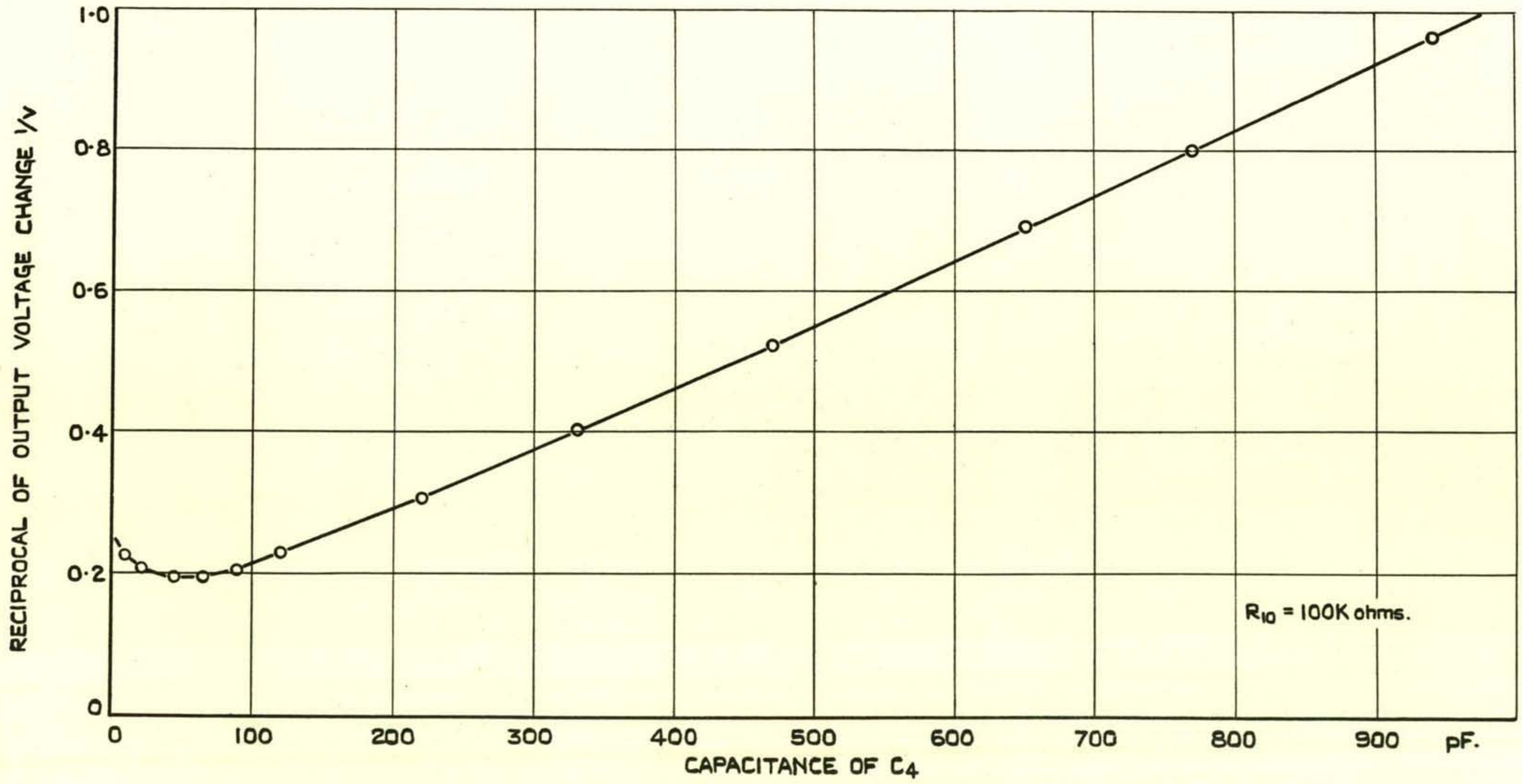


FIG. 5 LAW OF OUTPUT VOLTAGE CHANGE FOR CAPACITANCE OF C_4.

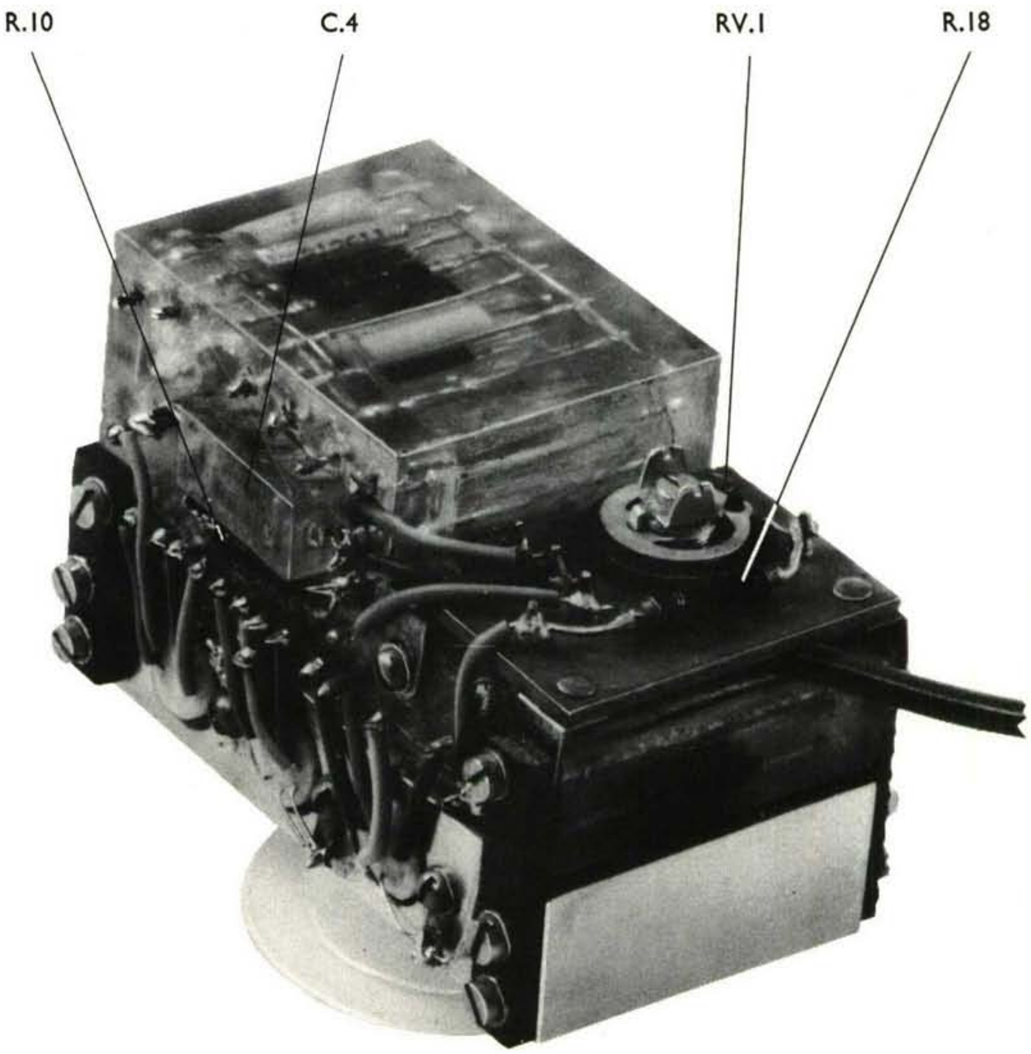
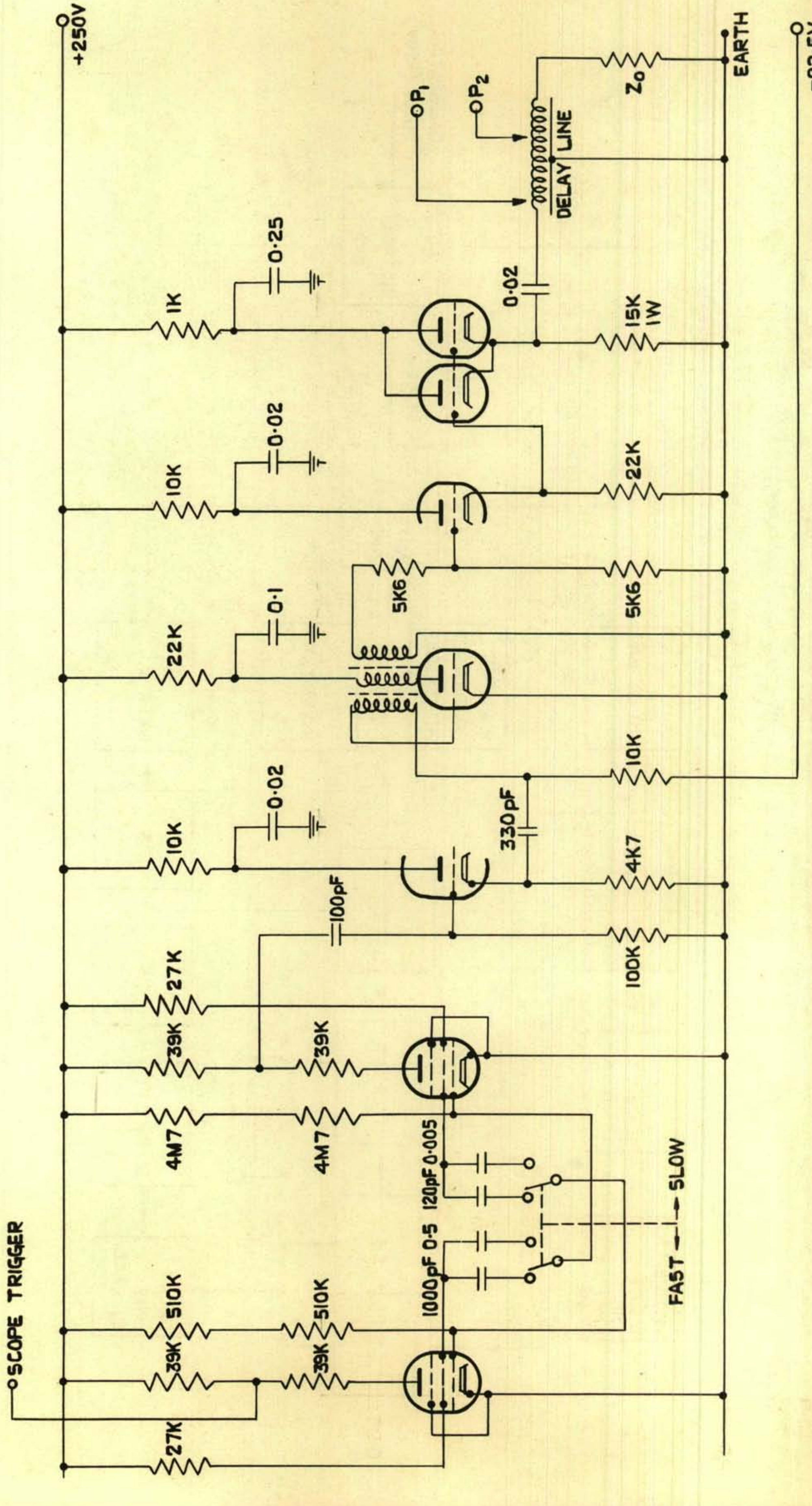


FIG.6. TELEMETRY CONVERTER UNIT


+250V
EARTH
−22·5V
P1
P2
DELAY LINE
Zo
1K
0·25
0·02
15K 1W
10K
0·02
22K
22K
0·1
5K6
5K6
10K
0·02
10K
330pF
4K7
100pF
100K
27K
39K
39K
4M7
4M7
120pF 0·005
1000pF 0·5
FAST — SLOW
SCOPE TRIGGER
510K
510K
39K
39K
27K

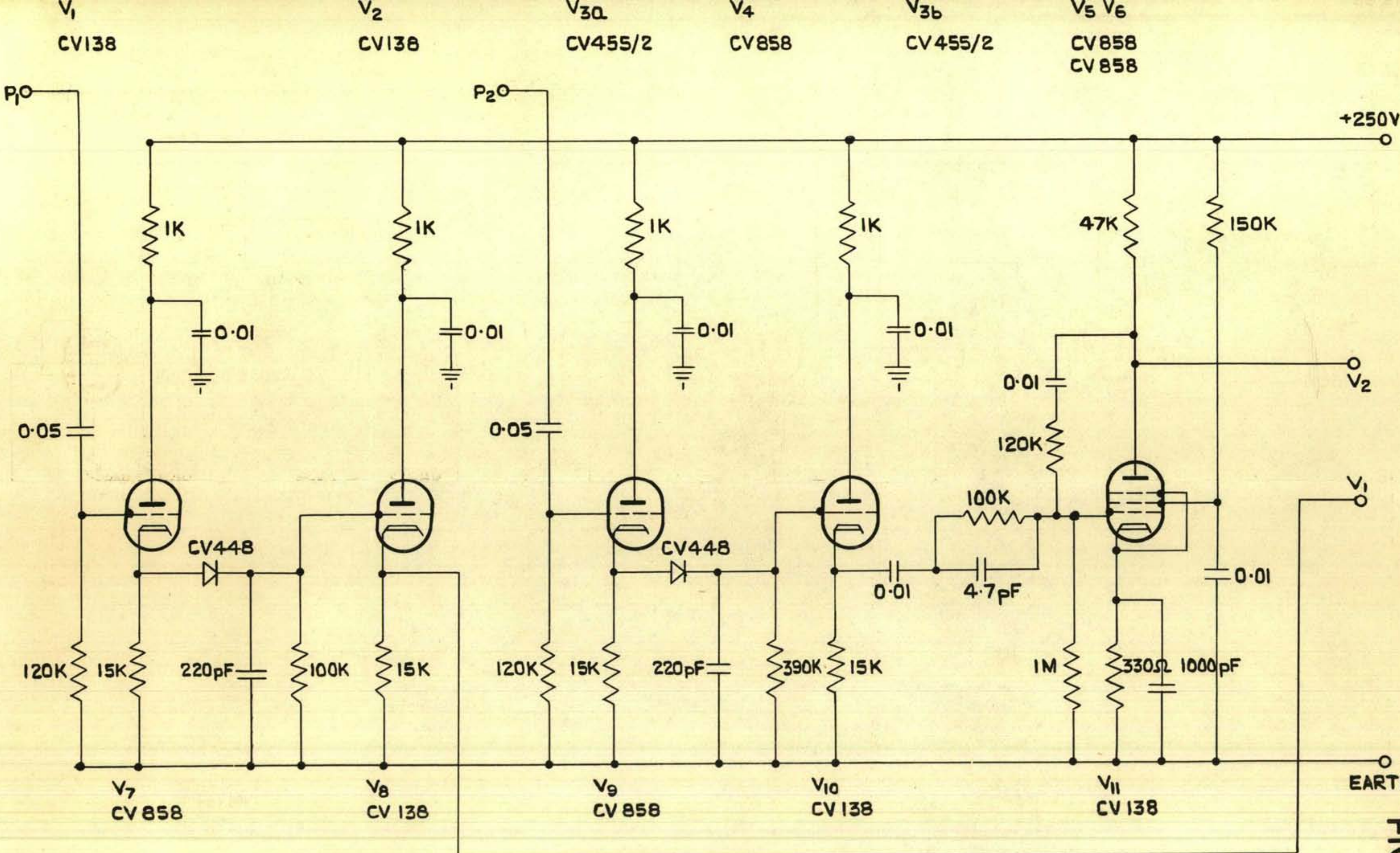


FIG. 7 TELEMETRY CONVERTER CALIBRATION UNIT.

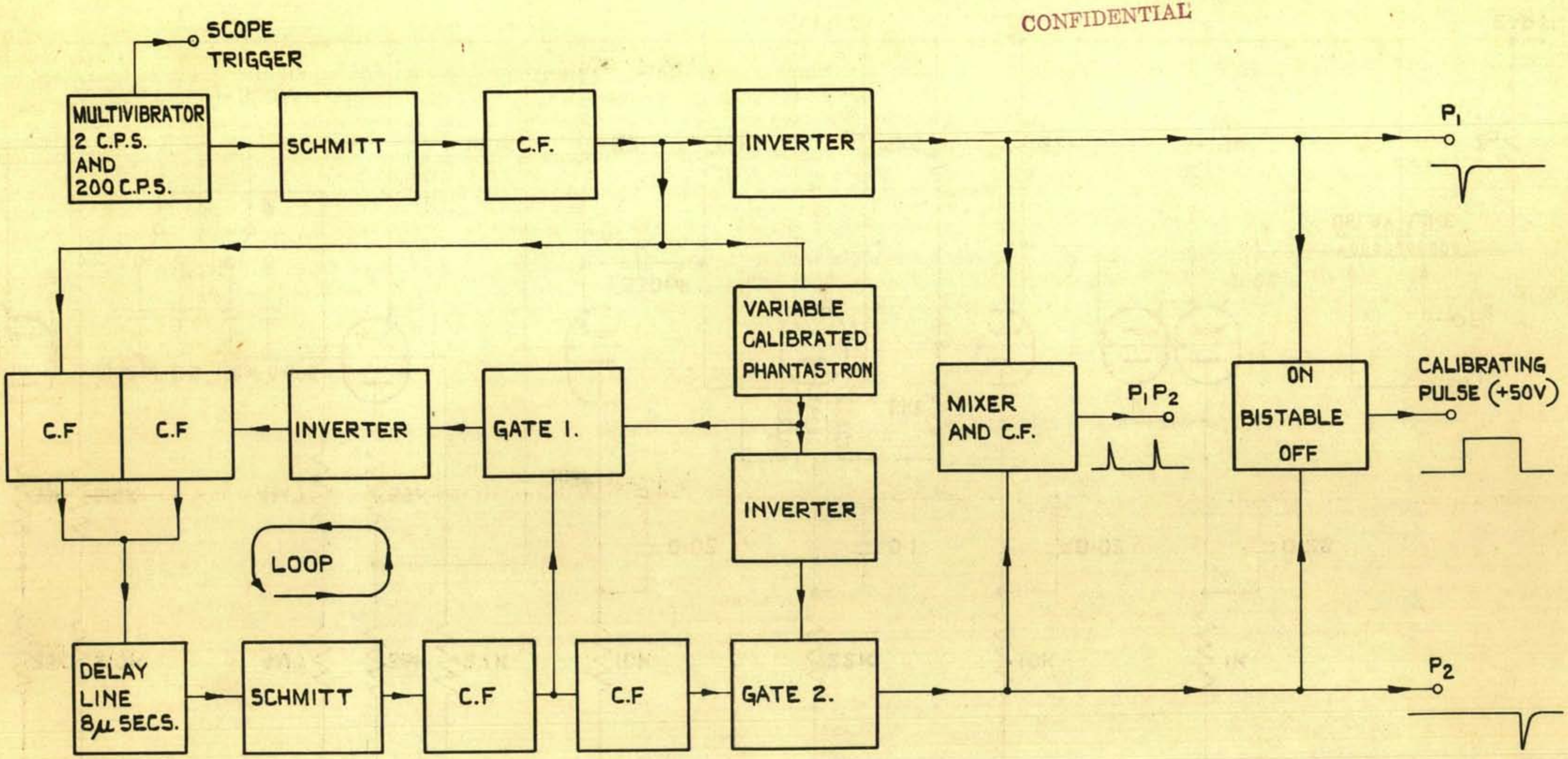


FIG. 8 BLOCK DIAGRAM OF TELEMETRY CONVERTER CALIBRATION UNIT — 100μ SECS.