

19



COMPUTATION NOTE BOOK

43-648

Course

EMG Densitometer

Name

Wth Thornton, M.D.

June '65

1 June 65

25

Because of the apparent impossibility of obtaining sizable items through supply a much reduced version of the densitometer will be attempted.

The pulsed light arrangement using two λ will be used. Called Novey of Baird Atomic who has in stock a 1" x 1" 6350 Å + on 8065 Å unit which he can block to ∞ on "high side" (I.R. side.) Talked to Maj. Melbar (#5242) who agreed that small items could be expedited + talked to Sgt. Barker () who agreed to walk thru + otherwise expedite.

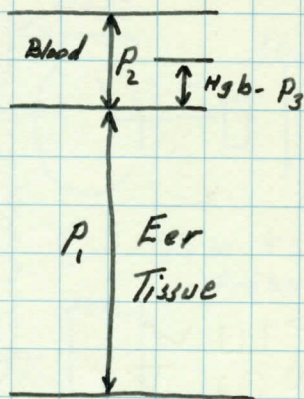
Still order the filters, one 1/2 pin-lites and LS-400 S.D. photodetector + read type relays.

The exact curve and density of EVANS blue are needed + will be run tomorrow.

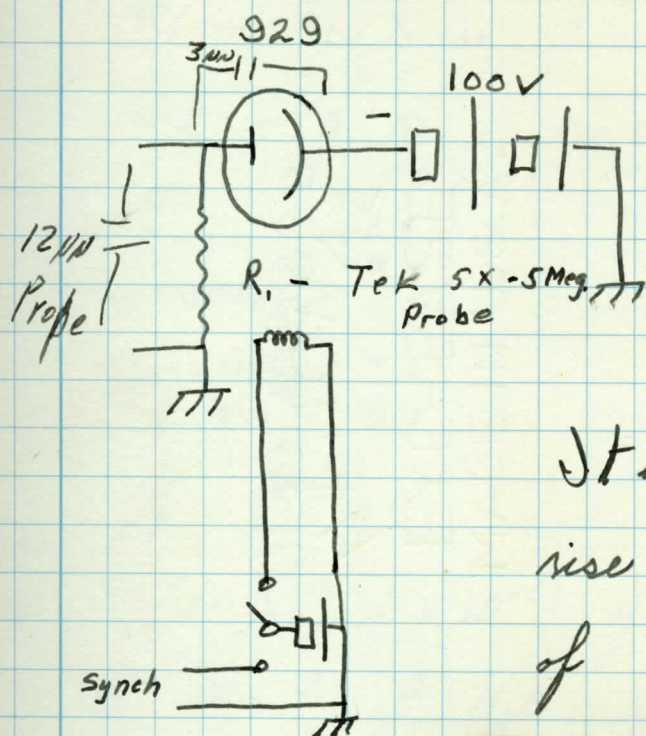
There is little question that dye curves from an easypiece densitometer can be obtained however the basic problem of calibration of path length and comparison remain to be solved in that order.

2 June Orders apparently placed for filters at 635 + 805 m μ , Hg Wet Reed relays, LS 400 Si sensor + Pinlites. Lockland supply has a quote for evaluation or rather sent me 1/2 of it.

? 6 June - Novey will send copy of bid filters shipped.



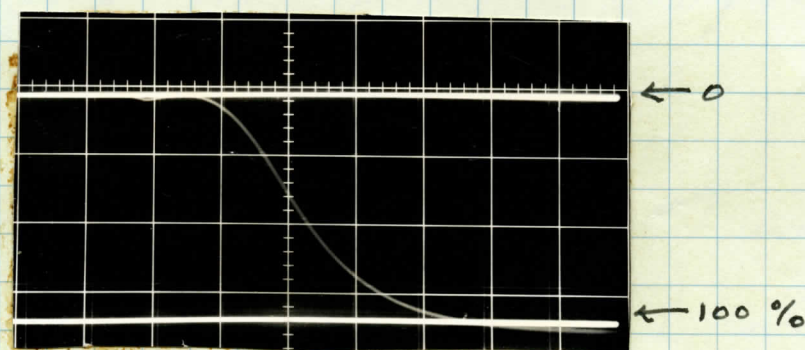
Current ideas are that the ear tissue is more or less fixed and that by increasing extravascular pressure to ~~40~~ ≥ 200 mm. Hg. the ear is rendered bloodless. It is doubtful that P_1 remains fixed & P_2 certainly doesn't. It is theoretically practical to obtain P_3 from Hgb. determinations & to a lesser degree by Hct. A better scheme would be to place a sample of blood in the earpiece as in a cuvette & determine its density at 805 m μ & compute path length from this. Once the path length is established it should be possible to determine the calculation concentration of dye. Hopefully the temp. w^d densitometer will not require calibration but known aliquots of dye could be used.



$$R_i = \frac{10^2 V}{5 \times 10^{-6} A} = 20 \times 10^6 \Omega$$

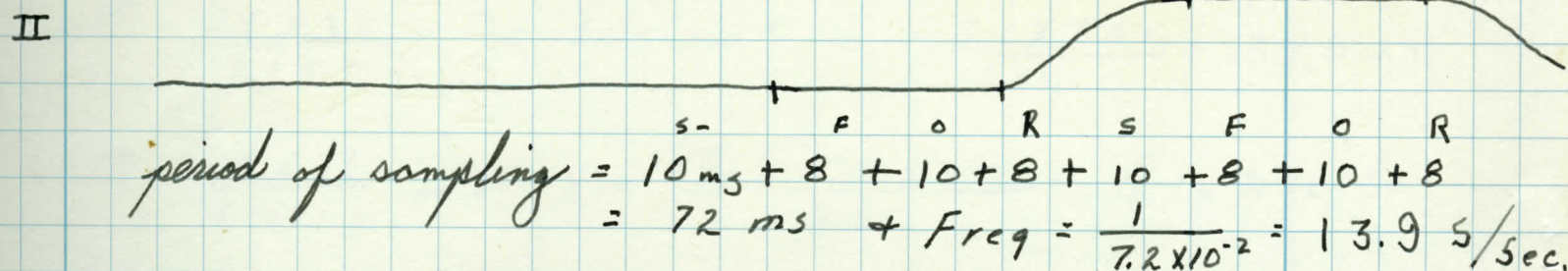
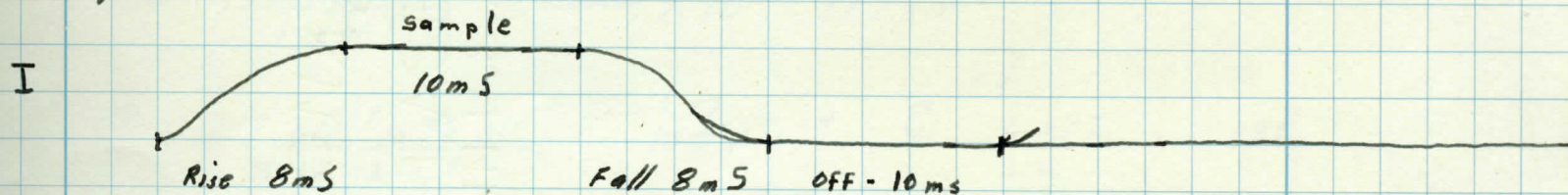
$$TC = R_i C_s = 15 \times 10^{-12} \times 20 \times 10^6 = 300 \times 10^{-6} = .3 \text{ mS}$$

microswitch has contact bounce.
It is impossible to judge accurately but
rise time appears to be on the order
of 8 mS (0-100%).



.1V + 2 mS / cm.

With rise & fall times of 8 mS and sample time
of 10 mS ± 10 mS off time then each channels



2nd June Evans Blue Curves.#1 - 10 λ in 3 ml H₂O

1 cm. path

#2 - 0 ① $\bar{c}$ H₂O blanks② 50 λ of #1 in H₂O 3 ml.

Abs. 0-1 T. 0-100%

③ 2x " " " " " "

④ 3x " " " " " "

⑤ 5x " " " " " "

⑥ 7x " " " " " "

⑦ 9x " " " " " "

⑧ 11 " " " " " "

⑨ 13 " " " " " "

⑩ " " " " " "

? Mixed {

(100 λ) added100 λ added

↓ ↓

↓ ↓

↓ ↓

?

10 λ (1×10^{-6}) of undiluted Evans Blue were added to 3 ml. of H₂O. This gave a conc. of:

$$\frac{10^{-5} \text{ mgm}}{3 \times 10^{-3} + 10^{-5} \text{ L}} \approx .333 \times 10^{-2} \text{ mgm/L.}$$

Call 1 ml. of EVANS blue 1 mgm. Curve #1 was run & this $\bar{c}$ an absorb. O.D. ≈ 1.41 $\bar{c}$ 1 cm. path length.

Aliquots of this were then added to a 2° ml. of H₂O & the following vols. & concs.

$$\textcircled{2} \text{ Conc} = \frac{\text{Mass (mgm)}}{\text{Vol (L)}} = \frac{5 \times 10^{-5} \times .333 \times 10^{-2}}{(3 + .05) \times 10^{-3}} = \frac{1.665 \times 10^{-7}}{3.05 \times 10^{-3}} = 5.48 \times 10^{-4}$$

$$\textcircled{3} \frac{10^{-4} \times .333 \times 10^{-2}}{3.1 \times 10^{-3}} = \frac{.107}{3.1} \times 10^{-3} = 1.07 \times 10^{-4}$$

$$\textcircled{4} \frac{1.5 \times 10^{-4} \times .33 \times 10^{-2}}{3.15 \times 10^{-3}} = \frac{1.57}{3.15} \times 10^{-4} \quad \textcircled{5} \frac{2 \times .33}{3.2} = 1.97$$

$$\textcircled{6} \frac{2.5 \times .33}{3.25} = 2.55 \times 10^{-4} \quad \textcircled{7} \frac{3.5 \times .333}{3.35} = 3.48 \times 10^{-4}$$

$$\textcircled{8} \frac{4.5 \times .33}{3.45} = 4.35 \times 10^{-4} \quad \textcircled{9} \frac{5.5 \times .333}{3.55} = 5.16 \times 10^{-4}$$

$$\textcircled{10} \frac{6.5 \times .333}{3.65} = 5.94 \times 10^{-4} \quad \textcircled{11} \frac{7.5 \times .33}{3.75} = 6.17$$

Evans Blue Absorption

Trans. Absorbance" ($\lambda = 600$)

$$\% = \frac{I}{I_0} \times 100$$

$$\text{Abs.} = \frac{2.303}{\text{Conc.}} \log \frac{I_0}{I}$$

$$\text{Dens.} = + \log \frac{I_0}{I}$$

$$\log \frac{100}{94.5} = \log 1.055 = .0212$$

$$\frac{100}{89.5} = 1.12 \quad .0492$$

$$1.17 \quad .0602$$

$$1.23 \quad .0899$$

$$1.43 \quad .1553$$

$$1.52 \quad .1818$$

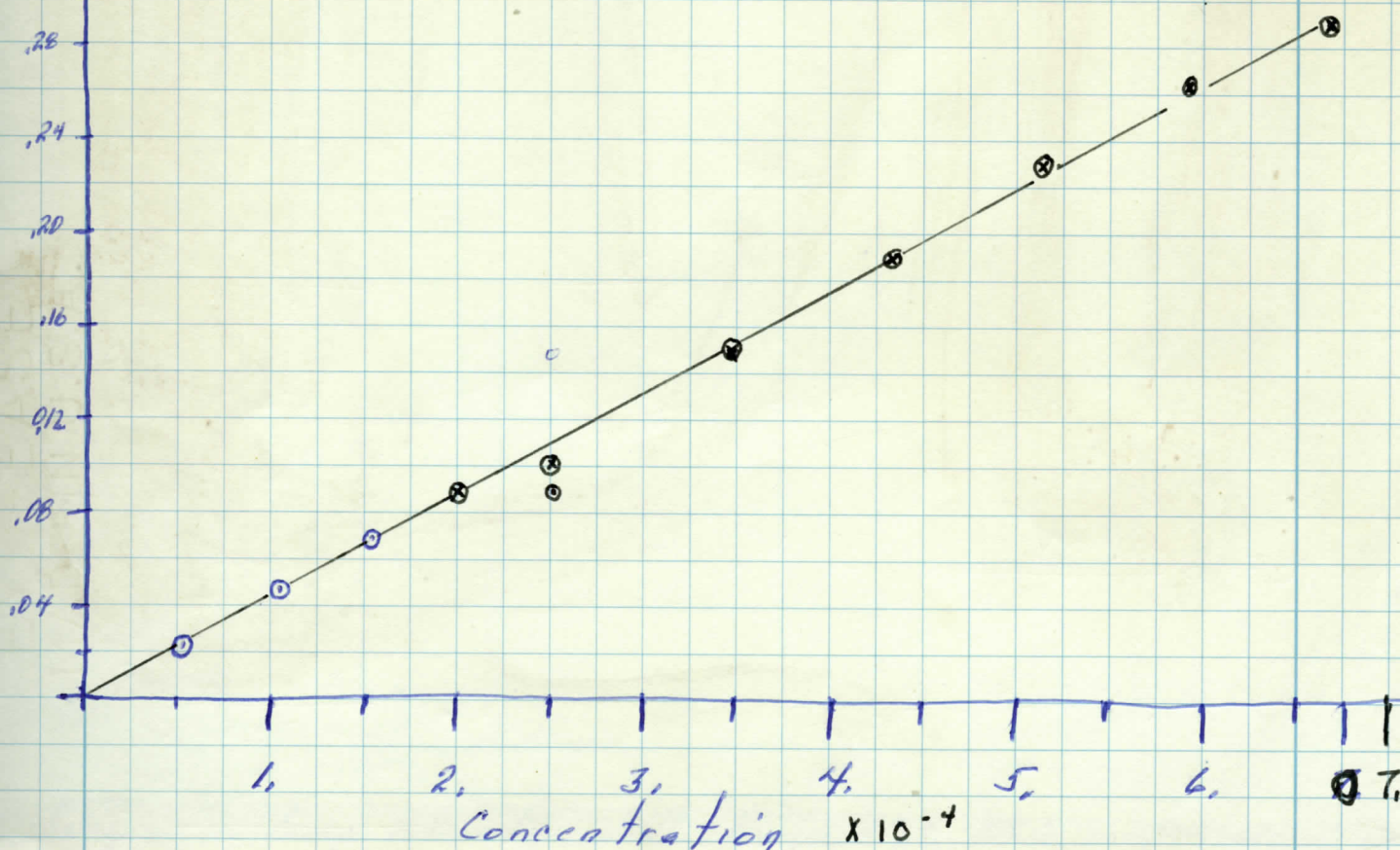
$$1.73 \quad .2380$$

$$1.83 \quad .2625$$

$$1.93 \quad .2856$$

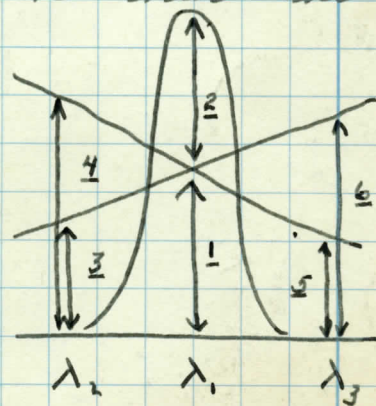
Dens.
(Absorb.).32
.28
.24
.20
.16
.12
.08
.04

Concentration Vs Density.



Resume of experience $\bar{c}$ Waters densitometer

This instrument is a 3λ arrangement in which one filter is set at $\sim 805 m\mu$ to pick ~~a~~ sense changes in intensity caused by injected cardiogreen which ~~absorbs maximally~~ has peak absorbance at that point. Variations in ^{total} Hgb ~~and~~ concentration will also be sensed. The variations in Hgb are separately sensed at two other wavelengths which are not isobestic but presumably chosen such that the differences in Hgb + HgbO absorption are ~~presum~~ equal and opposite.*



This correction is subtracted from the $805 m\mu$ signal leaving the dye signal.

It should be pointed

out that this "compensation"

cannot be complete $\bar{c}$ the beautifully smooth curves published by Waters + Wood. The flow of dye through the ear is pulsatile and with adequate response of the recorder these pulsations of dye will remain after removal of the Hgb contribution.

Another theoretical impossibility of complete

* High changes in lamp intensity, which changes $\bar{c}$ pt., this compensation will change.

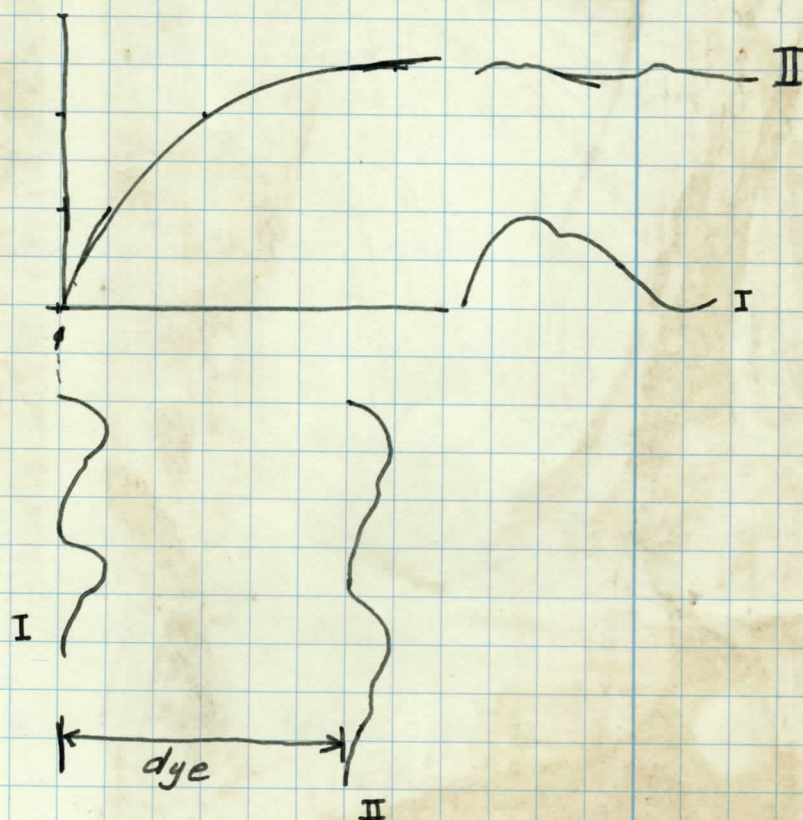
$$\frac{1}{\lambda_1} \approx K(\lambda_2 \underline{3} + \underline{4} + \lambda_3 \underline{5} + \underline{6})$$

$$\text{Conc dye} = F \lambda_1 \underline{1} + \underline{2} - K(\lambda_2 \underline{3} + \underline{4} + \lambda_3 \underline{5} + \underline{6})$$

compensation arises in the use of a logarithmic detector which is reputedly used here. Prior to injection of the dye the Hgb. signals from the Hgb are balanced.

Ignoring the pulsatile nature of the dye:

The dye may shift the operating point such that the slope of the transfer curve is reduced & the Hgb. pulse is diminished in resulting



~~undercomp~~ overcompensation of the curve. This may be only of theoretical importance since the detector is probably operating on only a restricted portion of the curve (i.e. is essentially linear).

The Waters instrument is set up by first zeroing ~~the~~ a fixed value of resistance substituted for the light variable conductance of the cell. The cell is substituted and light intensity adjusted to maintain the same value of cell resistance

i.e. the cell is operated on the same portion of its curve which is essential in a log device. It should be noted that although a given wavelength may be accurately compensated in this fashion, the two point compensation may be ~~very~~ unbalanced.

* A C.B.C. V.V. recorder $\bar{c}$ type 7-315 galvanometers (flat to 60 cps) $\bar{c}$ amplification was used for the recorder. A differential + scale changing ckt. was also built (See notebook #1) for $\bullet$ conditioning the signal to be recorded on tape. Calibration + linearity of the galvos are also in #1 + #2. Output curves could be ~~consider~~ usually obtained if the ~~carpus~~ instrument were balanced just prior to injection. The predicted pulses and of greater amplitude because of improved freq. response, were present on the dye curve. A very real problem

* { Initially a direct writing Moely 608-c recorder was used and on 19th Apr two runs were attempted $\bar{c}$ unusable curves, probably from attempting to balance erroneously and/or too long prior to injection. On 20th of Apr. 6 runs were attempted $\bar{c}$ the following results: It was found necessary to adjust immediately prior to injection, otherwise the instruments drifts (possibly bar changes). With repeated, 5, inj. of 10 mgm of Cardiogreen the instrument could not be zeroed. The subjects all sustained burns on the ear which was traced to the presence of 5 V. D.C. on the carpiece through an error in the factory wiring. (Photos will be included.) On 22nd Apr. the device limited on peaks of dye curves in one subj. and again ~~can~~ the

* { lamp brilliance could not be raised to compensate for
 & inj. of dye. At this point it was decided to
 go to the galvo recorder & look at all both outputs
 & their difference.

is the transient nature of records from the UV
 recorder. Some records were lost because of this. The
 device continued to limit sometimes $\bar{5}$ apparent reason
 but ~~was~~ ^{more} after ~~the~~ $\bar{5}$ exercise. Suspect increase of path
 length after exercise causes this which in turn raises
 the question of adequate heat flushing.

The records were obtained from one subject using venous
 injection (ante-cubital) but $\bar{3}$ other means of determining C.O.
 A number of other records were obtained from ~~exercised~~
 bed rest subjects using the ~~but~~ integral differential
 output of the recorder and $\bar{c}$ the integral of the curve
 from obtained from an analog integrator. Limiting
 continued to occur in $\approx 30\%$ of the runs and adequate
 brilliance of the light source remained a problem especially
 after ^{multiple} injections ~~or~~ and in one case $\bar{c}$ a negro subj.

The results $\bar{c}$ the instrument were sufficiently
 unpredictable and in the abs plus the absence
 of a quantitative calibration method (which
 would have to be changed) to make an

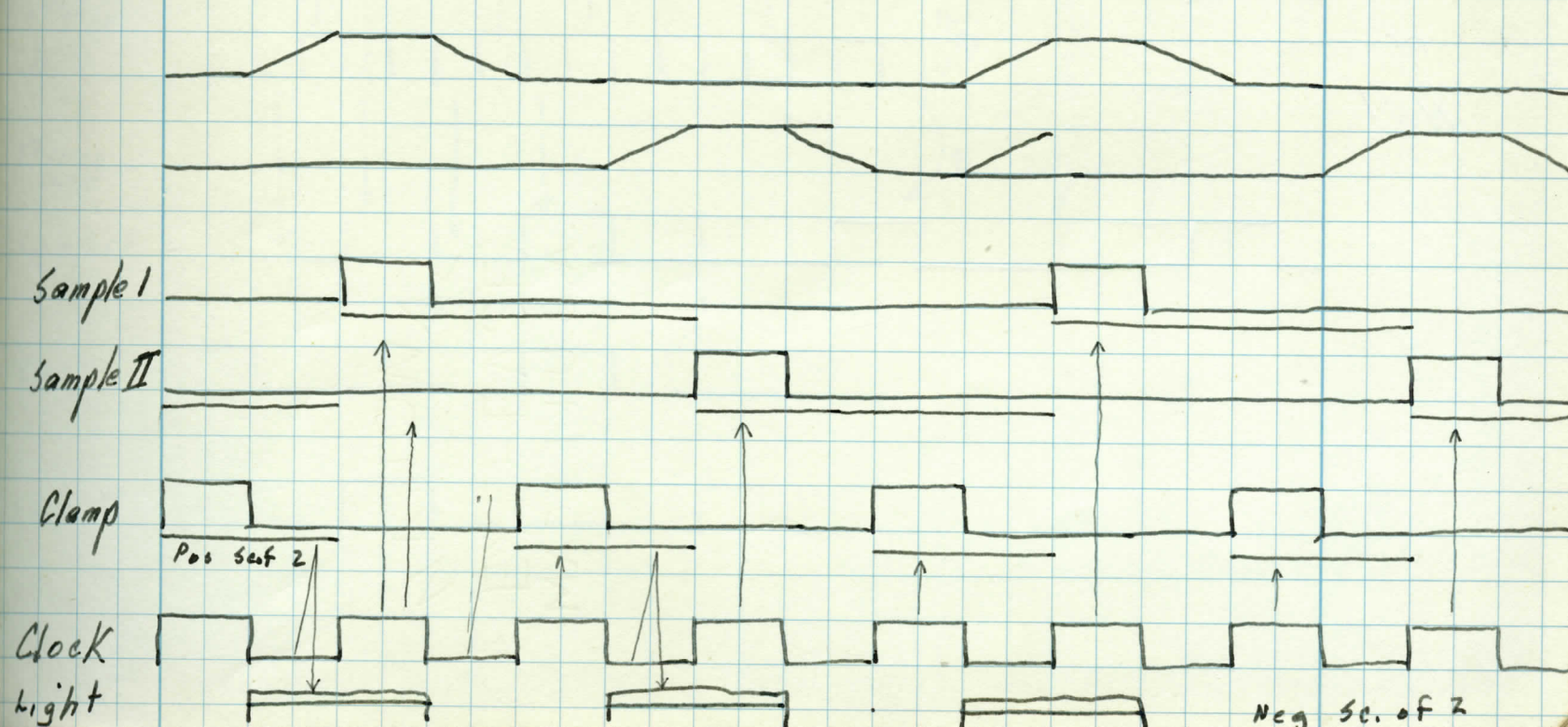
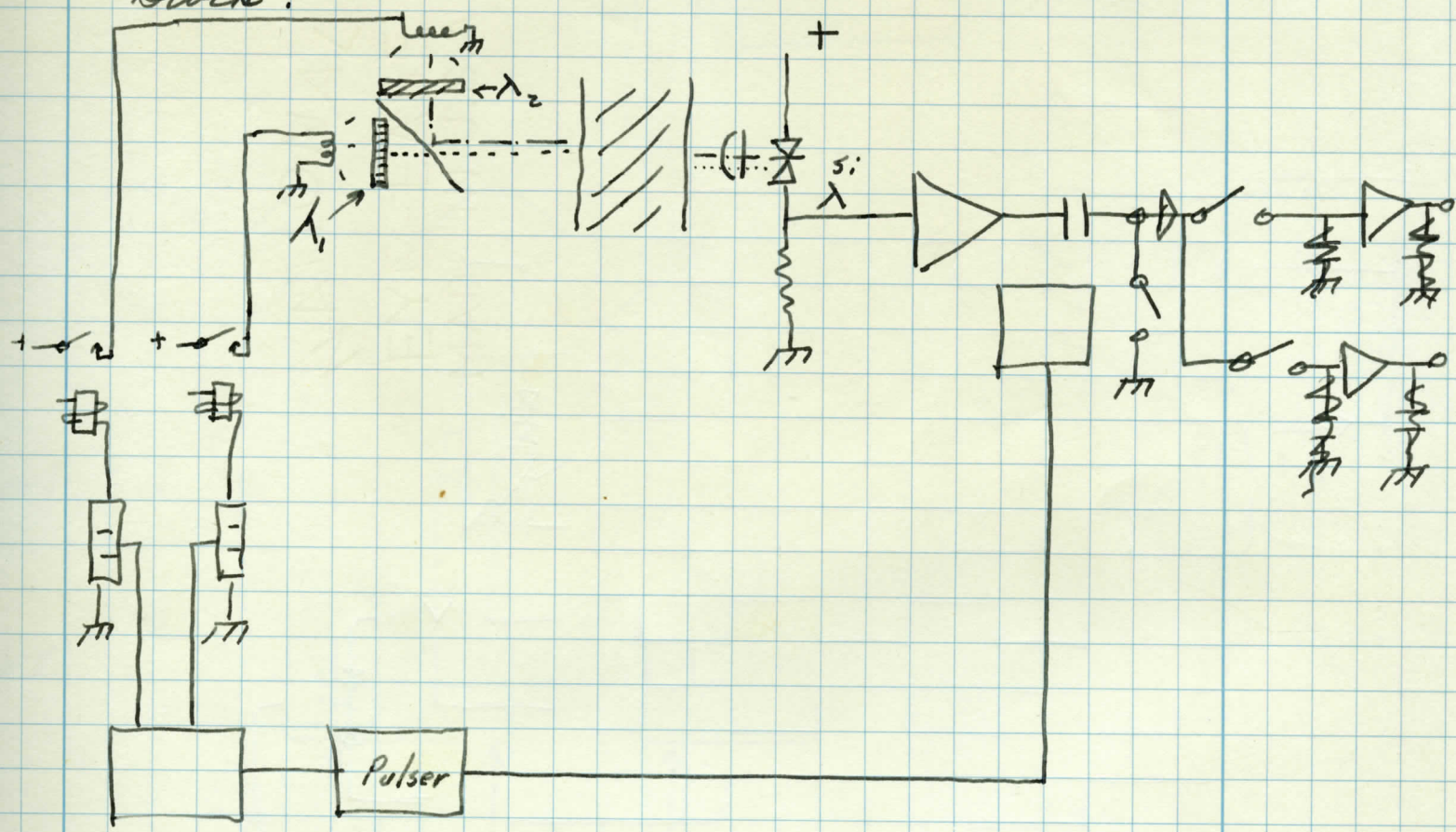
investigation & modification of this instrument mandatory. Rather than this it was decided to concentrate on the design and construction of a densitometer using Evans blue especially since Dr. Schwan of the T.B. hosp. is anxious to participate in the development of such a unit and can provide subjects & simultaneous arterial densitometry -

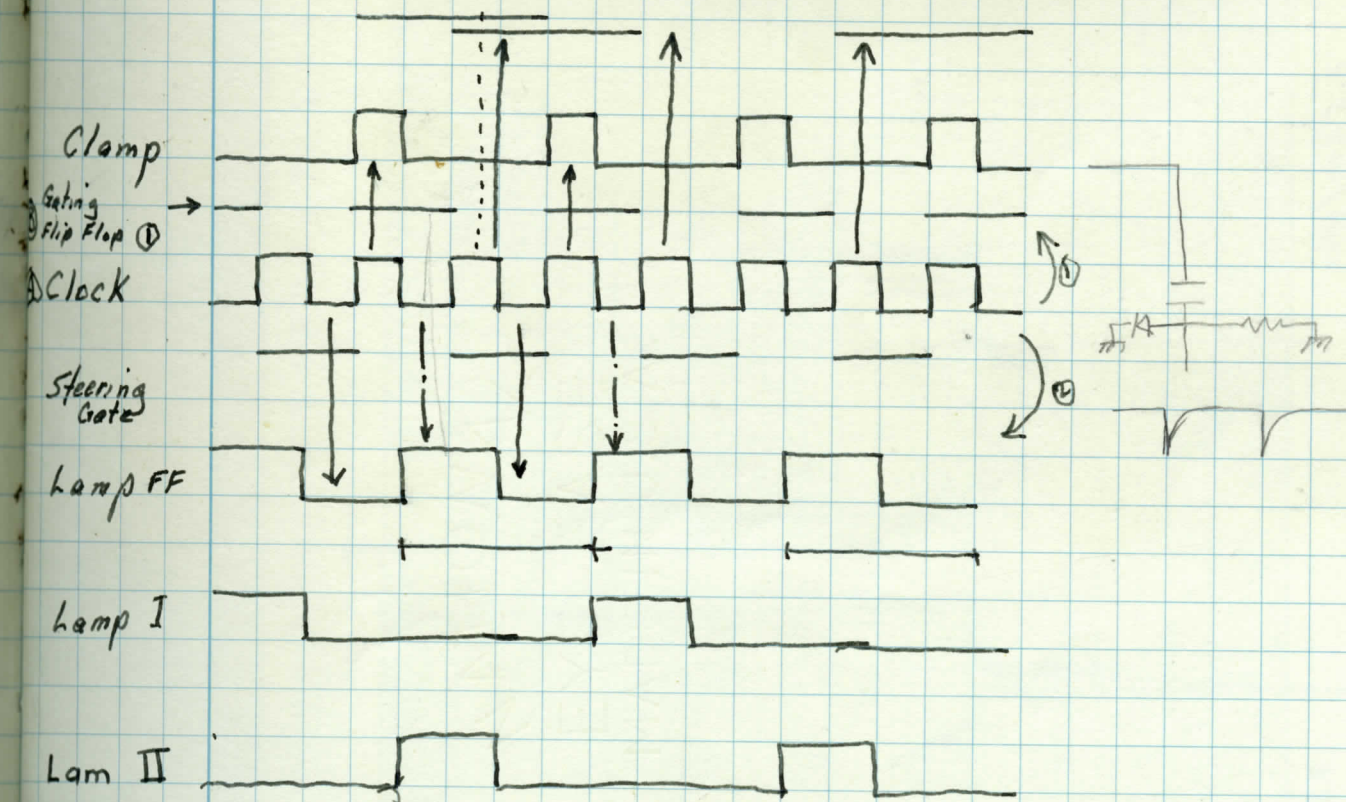
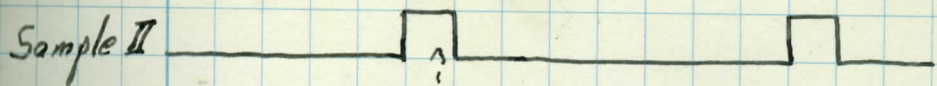
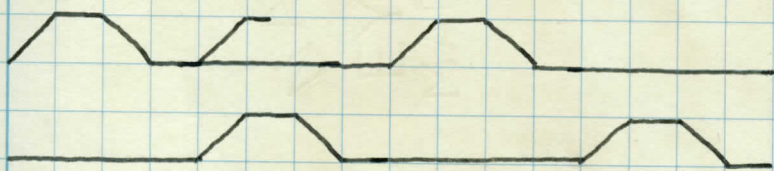
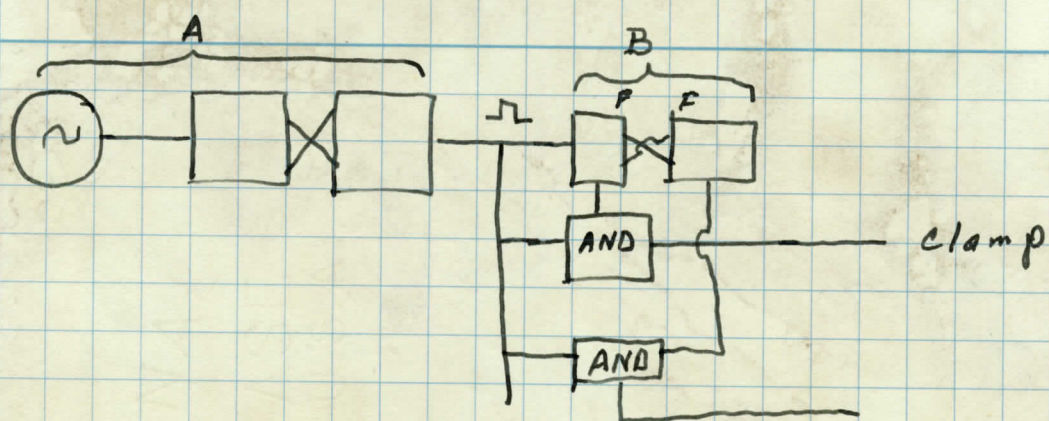
Op. Amps. -
 Trans - μ Power
 Bulbs
 Relays

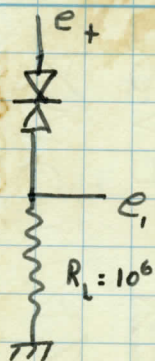
Proposed Densitometer:

Pulsed lights & monochromators & combined in partially silvered mirrors & single detector. λ is at $\lambda_1, 6350 + \lambda_2, 10000 \text{ \AA}$.

Block:







$$E_1 = 5.4 V$$

$$E_1 = 1.2 \times 10^{-3} V$$

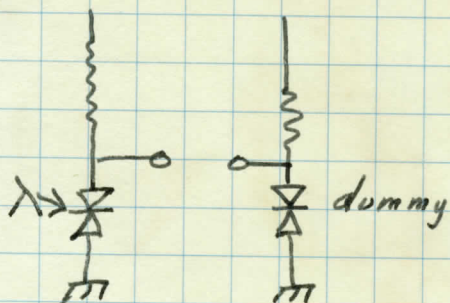
$$.2$$

Dark

" T-Body

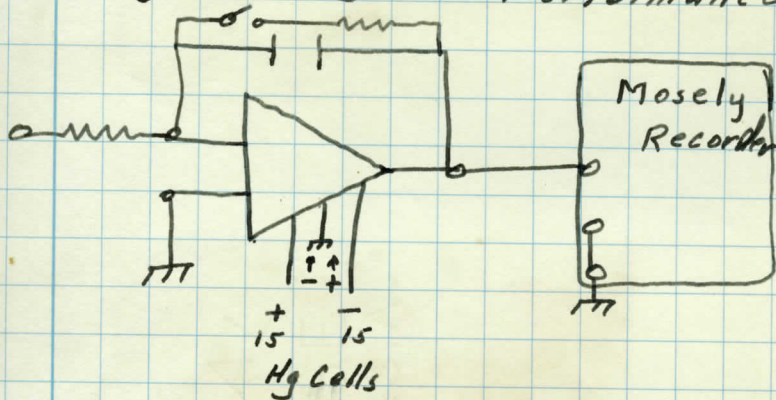
" T-~72'

Temp Compens -



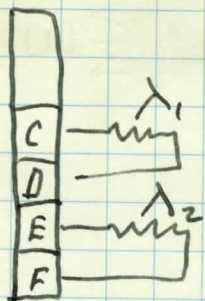
8 June 1965

Performance cks. of Philbrick P-65A

ckt. drifted $\bar{e}$ $C = 8 \mu$
+ $R = 1 M$ $R = .1 M$

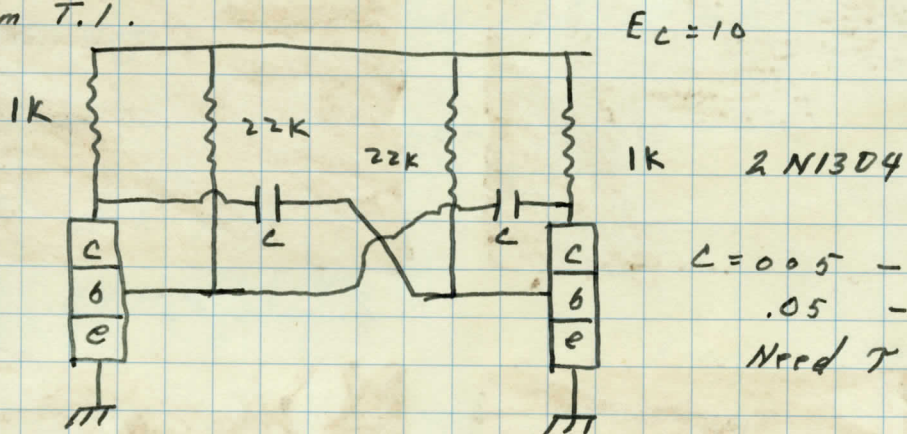
See Opp Pg.

Wiring of X-301 Densitometer Earpiece



Clock -

From T.I.

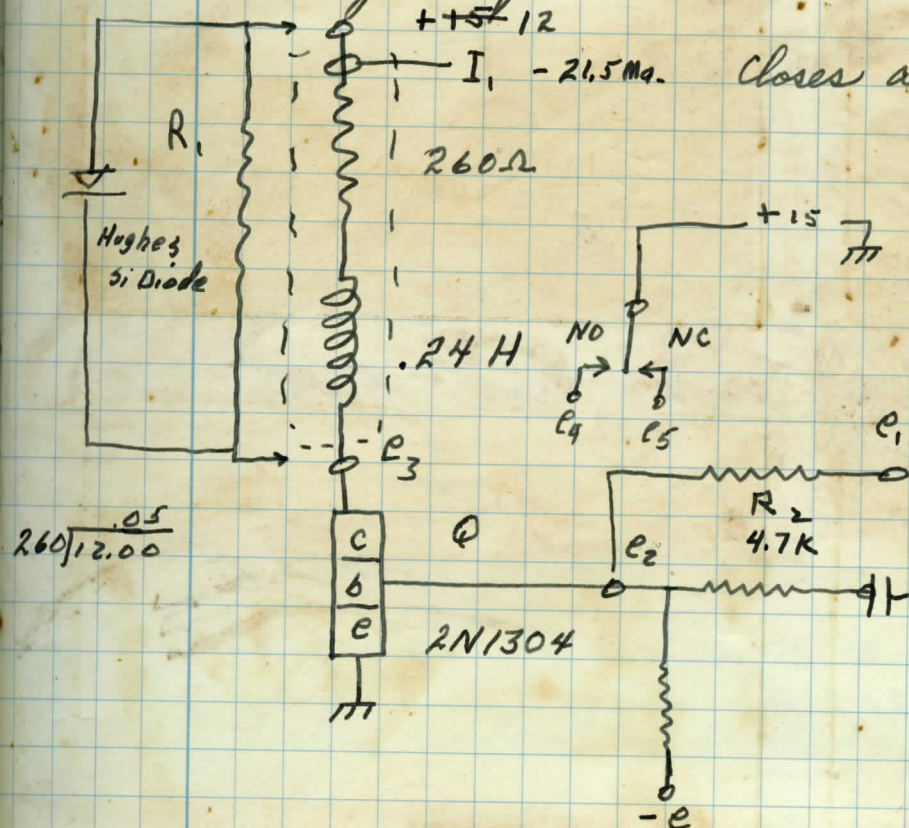


$$C = 0.05 - T \approx 2.7 \times 10^{-6} \times 50 = 1.35 \times 10^{-4}$$

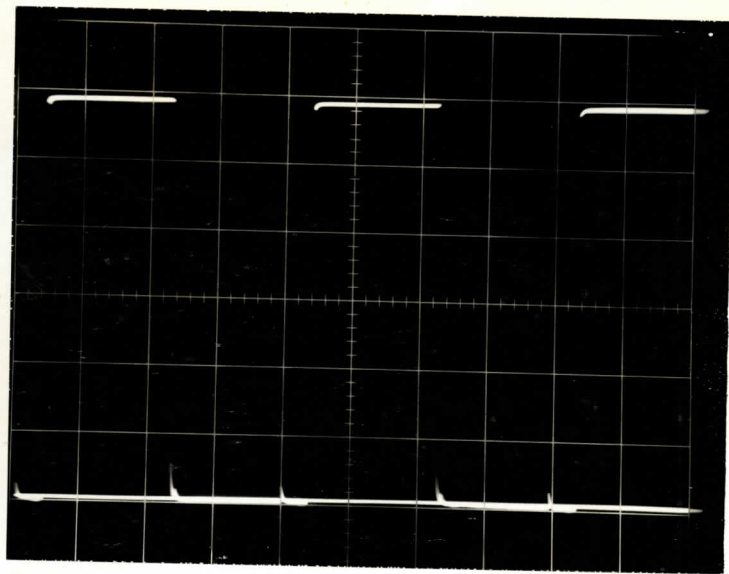
$$.05 - 1.5 \times 10^{-3}$$

Need $T \sim 5$

Magnecraft 12V 250 Ω Hg wetted Relay -

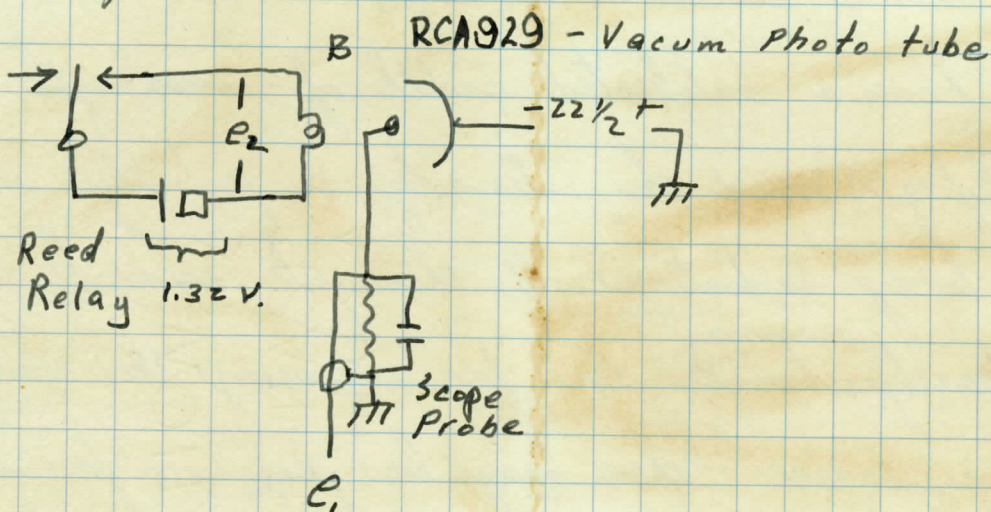


From EXACT - 251 Funct. Gen



7. E_4

Rise & fall times of switched bulbs:



The Sylvania lamp is superior to the Pindite & has higher output & & rise & fall times -

Sylvania Special Products Div.

Salem Mass - 617 754 4500

	T_{rise}	T_{fall}	
Syl -	12	7 1/2	m/sec
Pin -	56	14	"

Airman Mann called saying that delivery of the Hearcott motor would require 3-4 mos. Called Mr. Guerin of Dallas A.P. - 214 Fleetwood 2-1764 who has two in stock & can ship in 2 wks. if insp. OK. Called Mrs. Carroll 83-23175 who confirmed above & will issue order on confirmation of test.

Transferred to:

Sylvania, Ipswich Mass

617-EL 64311

Mr. Meile promised to send samples of improved bulb -

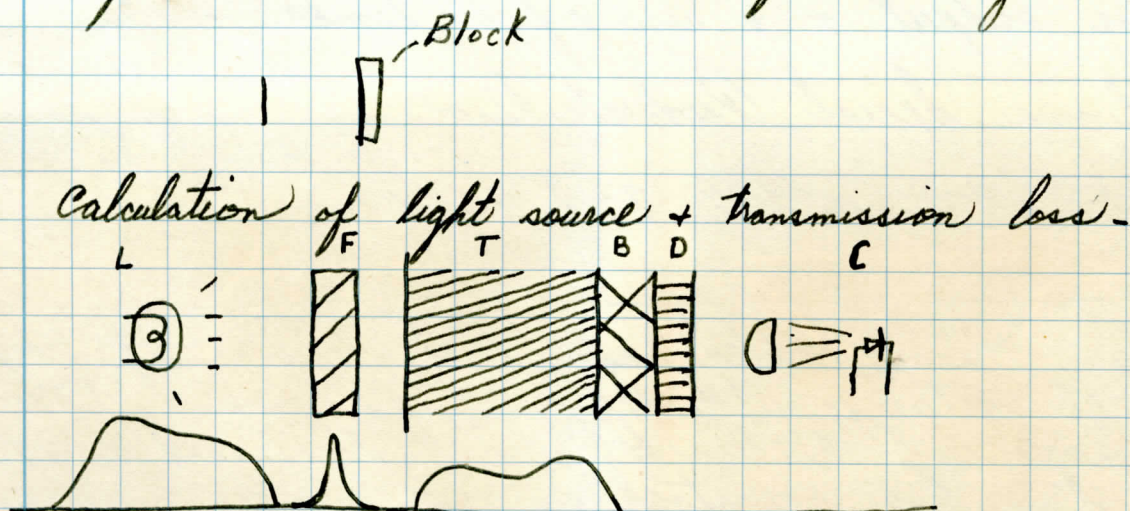
17 Jun. new Syl. bulb arrived - 1 V + .1 A A.

From Curves & bulb: $\frac{1.1}{.1A} = 11 \Omega$

1.34
1.01
2.4 V drop
R = 2.4 Ω

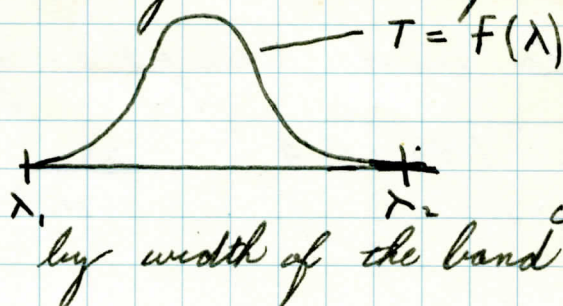
$$\frac{.24}{16 \times 10^{-3}} = 15 \Omega$$

Also needed are known light sources. The Beckman units have a calibrated width of wavelength spectrum [as $f(\text{freq.})$] and the intensity is probably that of black body radiation. A thermopile could be used as an intensity ^{measuring} device. As for measuring the emission from a source: there may be provision for this on the DK unit. Otherwise it might be possible to compare the source to that of the integral Beckman source.



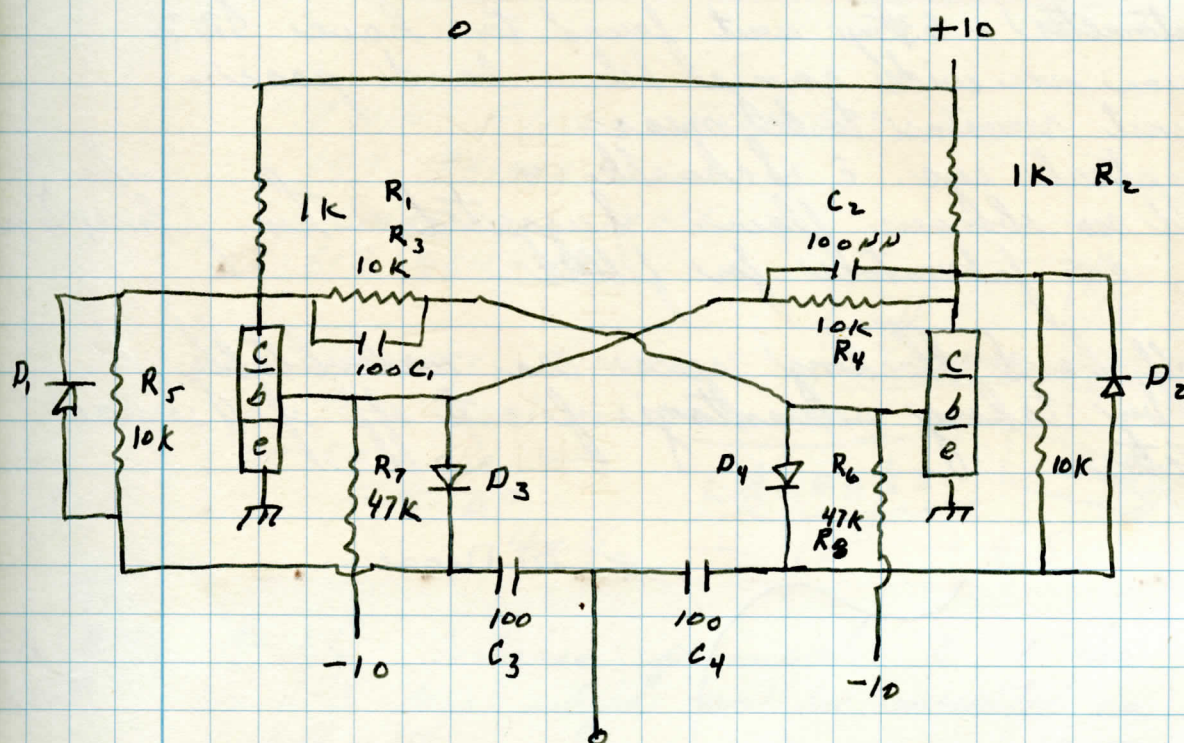
L - Lamp spectrum can be calculated from black body law. Intensity will be a function of area of filament and may be measured by comparison $\bar{c}$ standard source.

Filter "loss" can be calculated from knowing peak transmission and integrating from extremes of wavelength knowing the curve shape. Illumination curve can probably be assumed to be flat over restricted region of λ as well as the detector response.



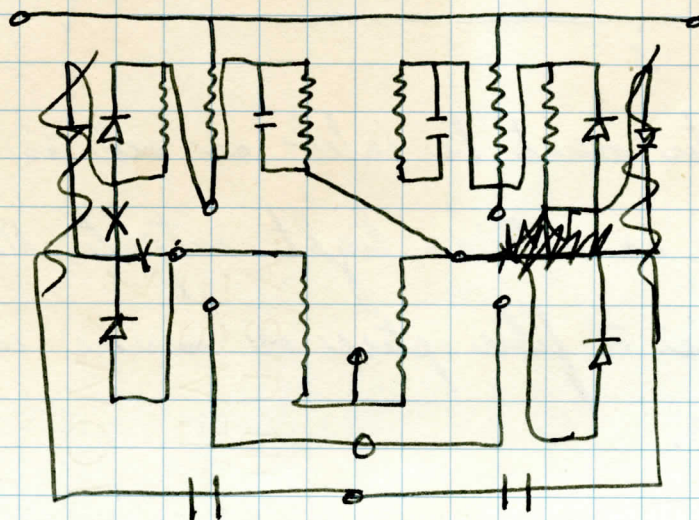
For purposes here the energy contained may be approximated by width of the band $\times$ amplitude -

Flip-Flops - From p-377 T1 S.C.HB



ckt. worked well after $\uparrow C_3, 4$.

For expediency will do a chrt bd. for multiple units.

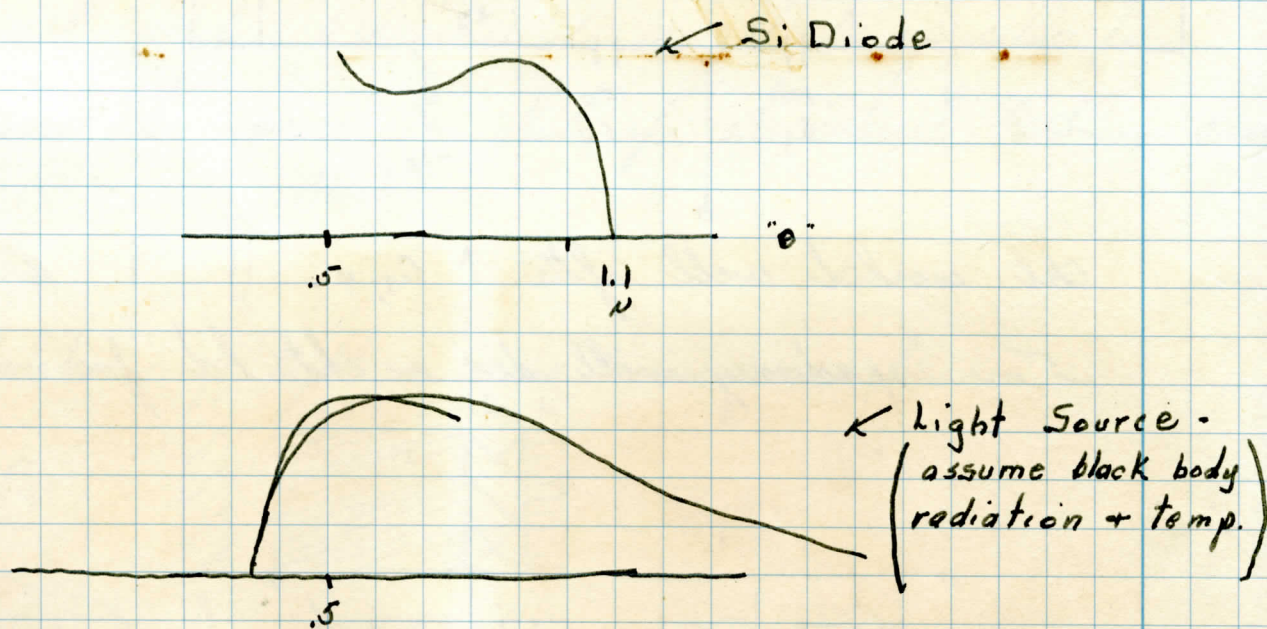


16 June 1965

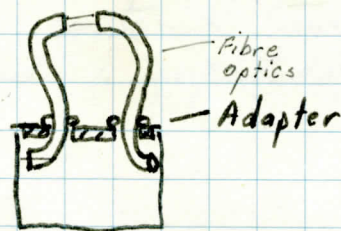
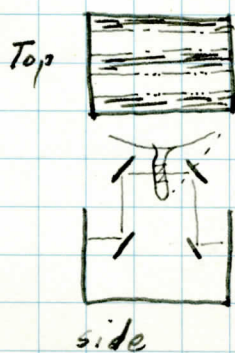
Baird Atomic filters were meas. $\bar{c}$ Carey spectrophotometer - 635m μ unit found to have 92% transmission over wide range below band pass - 800m μ unit remains to be meas.

Discussed optical sys. $\bar{c}$ Schauble & who could find no obvious flaw - Suggested thin films, I no as fabricators for filters -

The off band blocking specs. can undoubtedly be relaxed by taking advantage of cutt off of source and detector.



Sens. of detector must be calib. as well as path. Path should be meas. as well as light output. Density of ear might be meas. $\bar{c}$ fibre optics or mirrors using the Beckman DK-2.



See back of P. 55

18 June 1965

Called Mr. Fred. Tompkins of Film Prods. Inc.

THIN FILMS PRODUCTS, INC.

169 BRIDGE ST.

CAMBRIDGE, MASS.

617-864-4910

FREDERICK TOMPKINS

Wm Goolishian

1" → 1 cm dia
.25 Å

Edmunds

40% → $10^5 - \pm 5$

# 1" -	#
± 20	50
	120

10° cone

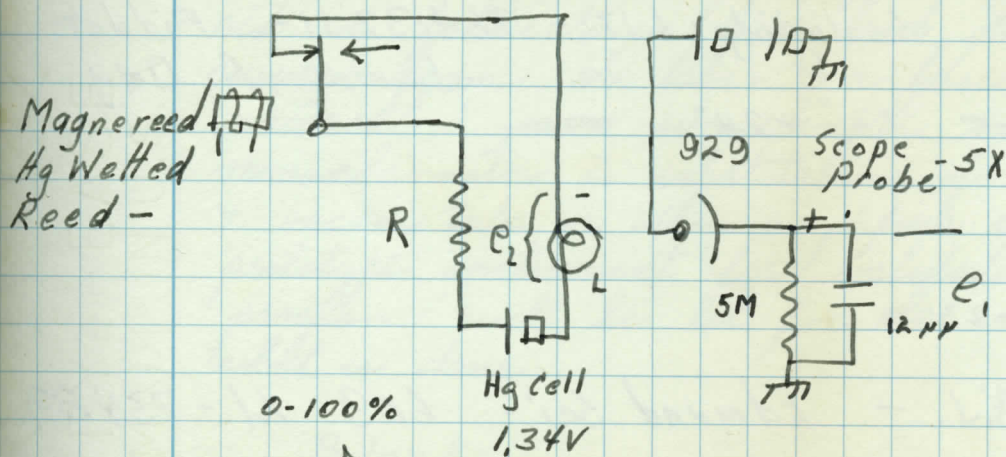
3 wks. or less
delivery on 1 cm.
round filters.

± 10	625
1.00"	800

5 July Goolishian promised 2 1" dia $\pm 10 \times 10^{-3}$ " filters
in 2-3 days which can be mounted in a metal ring
3 difficulty - 8100 - 2-3 wks. ± 10 var 50 $\pm 10^\circ$ A 50%

18 June '65

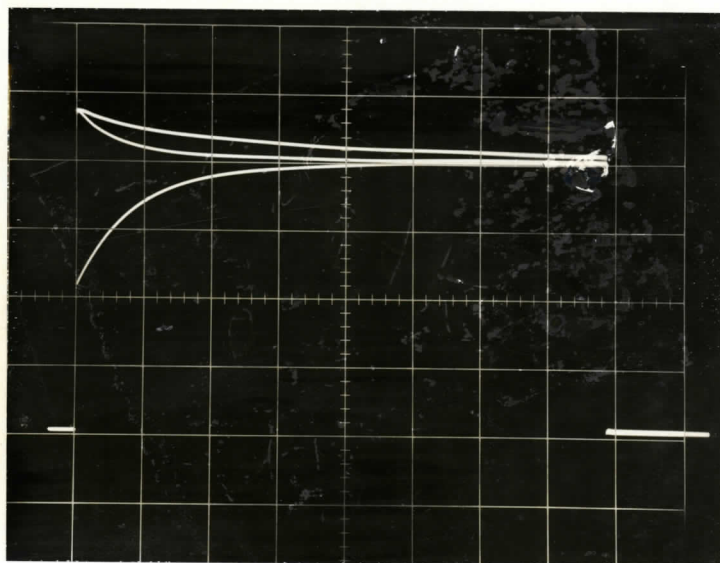
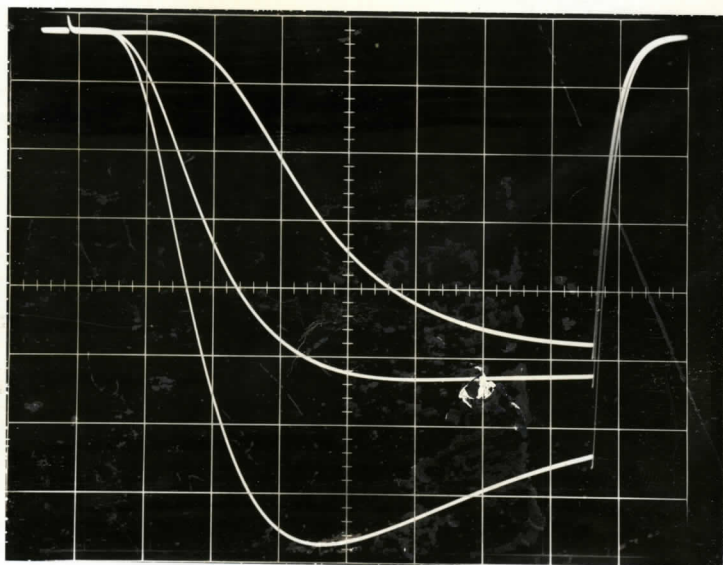
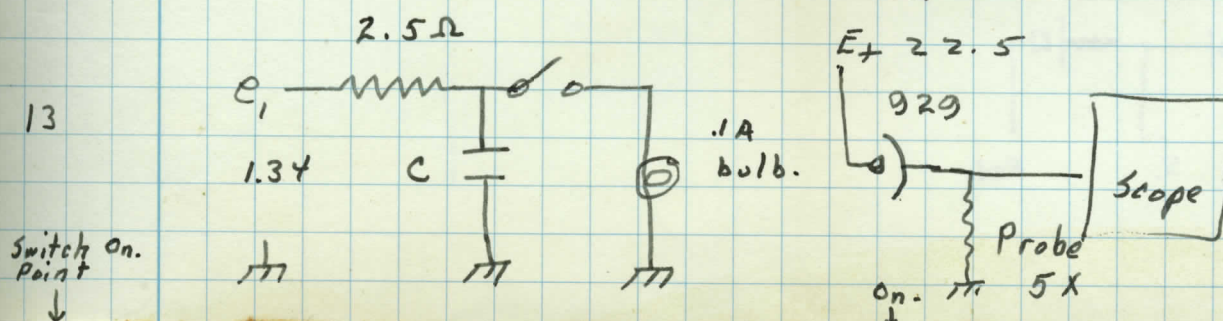
Response time of Sgl. min bulbs.



Low Pwr.
Small bulb
" "
Hi "

Tr	Tf	E2	E1
m sec	m sec	Volts	
17.5	4	1.15	.5
17.5	4	1.3	
40.	6	1.0	
25.	6	1.3	

It seems theoretically possible to increase speed of bulb & capacitor discharge during early portion of cycle.

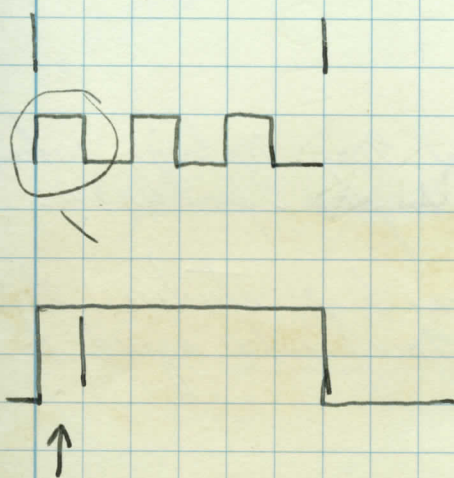
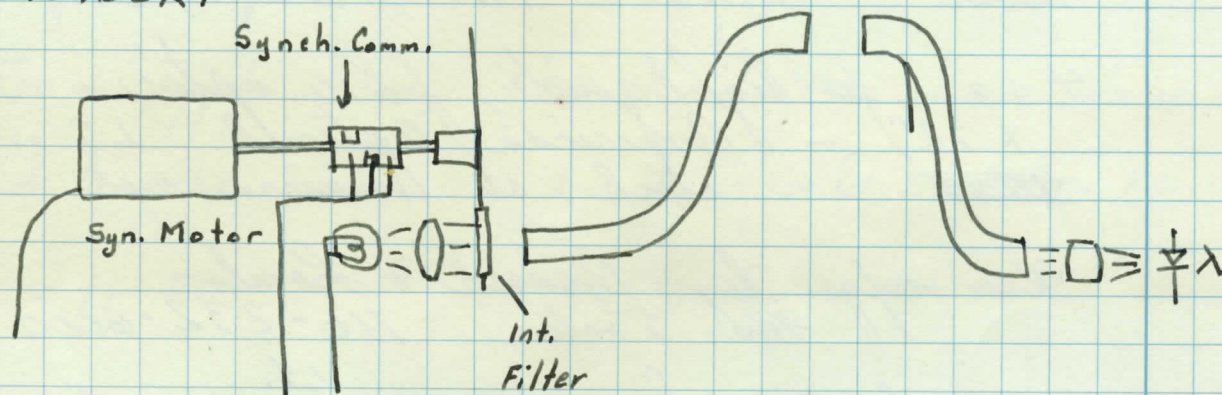


5V + 5. mS/cm PEC Out. $C = 0.1 + 2 \times 10^3 \mu\text{fd}$ Volt. Across Lamp.

21 June '65 -

There are continuing difficulties in supply, no aid in fabrication (no aid period) and in obtaining curves from the lab. In face of this will do a 'universal' ~~monochromator~~ wavelength monochromator (rotating monochromator & substitution of filters) & light pipes + vacuum tube or other amplifiers as required i.e. a prototype instrument for validation. A large development program will be let for the actual instrument no matter what is done:

Block:



2.5 ms
Ry Op. Time or 5 ms tot. +
5 ms = 10×10^{-3}

$$\frac{1}{10^{-2}} = 10^2 \text{ cps.}$$

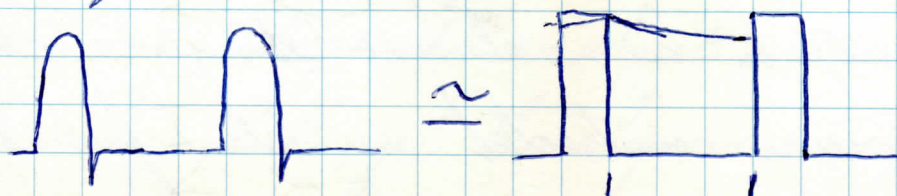
6 equal periods,
3 sample + 3 blank,

$$\frac{1}{60 \times 10^{-3}} = \frac{1}{.6 \times 10^{-1}} = 1.33 \times 10$$

$$213 \text{ R.P.S. or } 60 \times 13 = 780 \text{ RPM}$$

1800 RPM is nearest size + speed.
May be able to ↑ speed of Ry or will
gear motor.

Operating ckt. - for use on cardiac outputs from
 flow meter - of
 Offner recorder has single ended output of 100Ω and
 max. volt. of ± 10 volts. This will feed a preamp
 input of $\geq 2 \times 10^6 \Omega$.

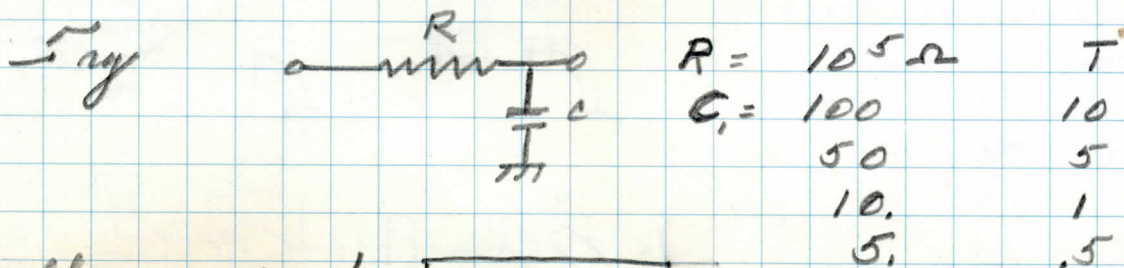


For a ripple of say 5% at 1 C.P.S., assume device is
 charged to max. value. $E = E_0 e^{-t/RC}$ $E = E_0 \ln \frac{RC}{T}$
 $\bar{E} = T = 1$

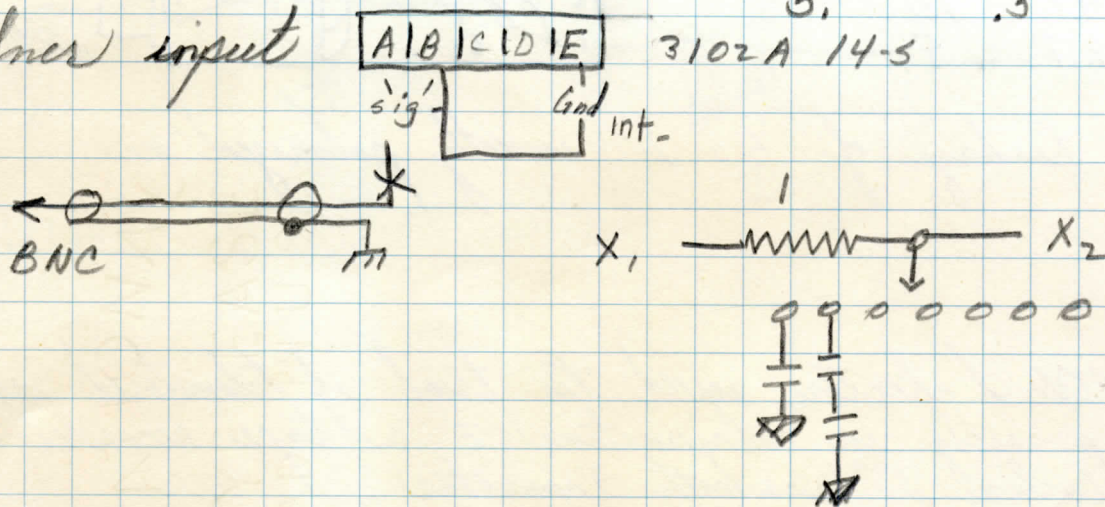
$$\frac{E}{E_0} = \ln RC \quad \& \quad RC = \text{anti log } \frac{E}{E_0} = \frac{.95}{1} = .95$$

$$\text{Anti log } .95 = 8.91 \approx 10^4 \quad \bar{C} \quad R = 10^4 \quad C = \frac{10^{-1}}{10^4} = 10^{-5} \text{ f}$$

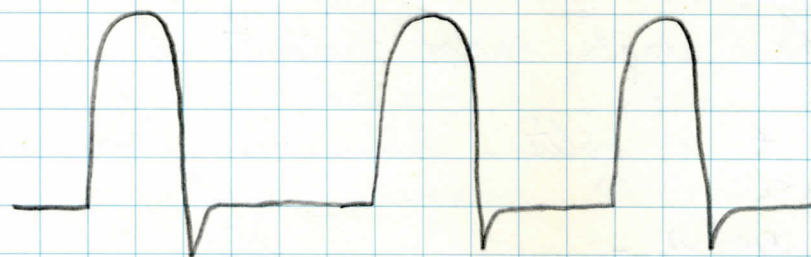
$$= 100.0 \mu\text{fd}$$



Offner input

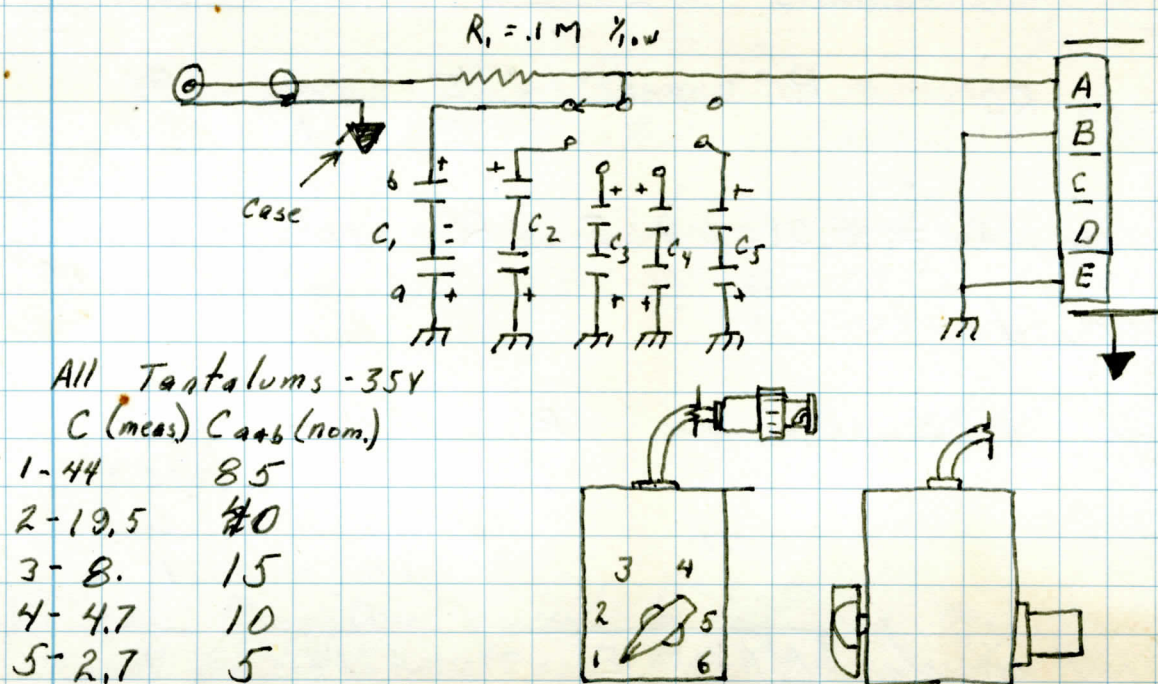


Cardiac output on a stroke basis



cardiac output is volume / time usually L / M
 a prototype was constructed as below for trial by
 Dr. Dong -

MS-3106 E145 5P



Leakage of 45 μ correctly polarized on

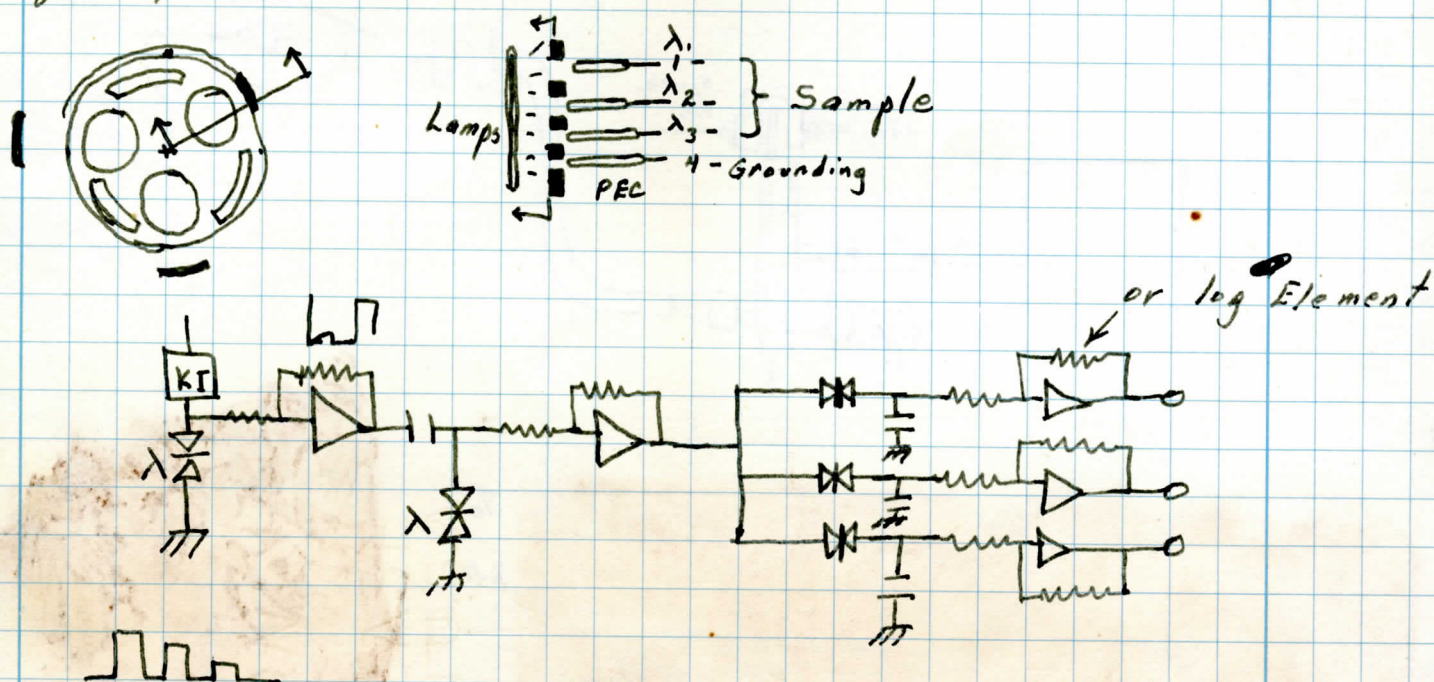
30 June 64 Dr. Schecter agreed to trial of telemetered monitoring
 possibly in conjunction $\bar{c}$ a tape recorder and
 Corbin & Farnsworth apparatus.

Mr. Callum, James of Beckman Inst. feels there is
 a possibility of using light guides $\bar{c}$ DK-2 - as
 emission detector the PbS cell is flat from 7 to 2. μ .
 Bulb is black body source at 2870°K -

30 June 65 -

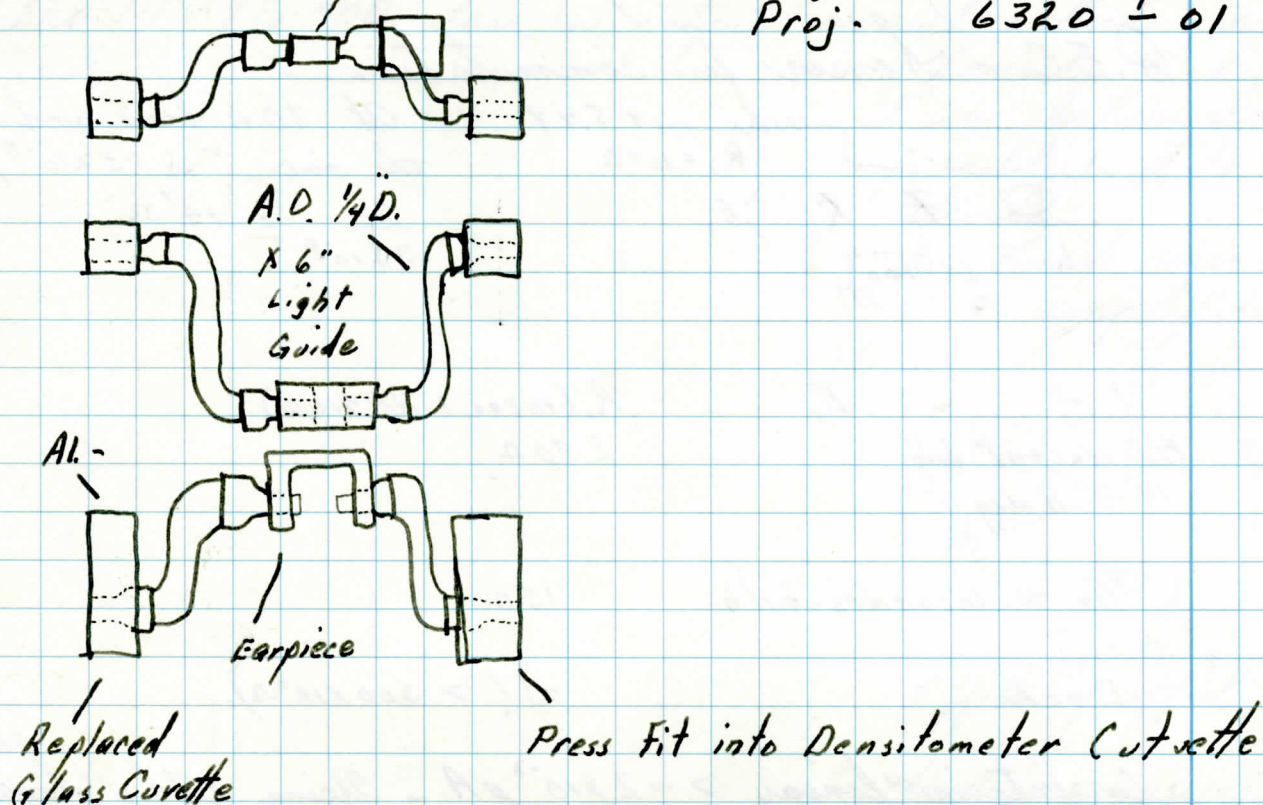
8 mission curve was run on DK-2 $\bar{e}$ P65 cell
2-12" lengths of light guide A-D $\frac{1}{4}$ " Dia
were lashed up on DK and curve was run
by partially closing shutter - very crudely the
car was interposed & at .8 μ a reading was
present - Will get the shop to modify a cuvette holder.

1 July '65 - Shop is modifying or rather making adapters to the holder
after extraordinary efforts. Order for FR-306 is in -
The average ckt. on the opposite page has ~ correct
time constants but the caps. look introducing a small
error. It would also be desirable to have a variable
gain pot incorporated in the ckt.



Beckman adapter -

Phys. Data Acquisition Sys.
Proj. 6320 - 01



Hamamatsu

R-136

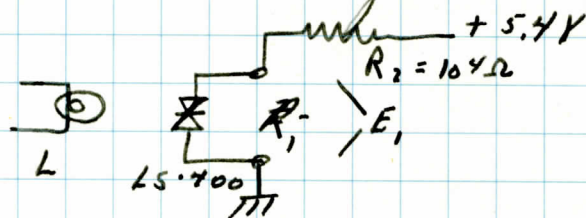
Xenon-

Transmission of the active path is shown opposite. A Using a child's ear it was possible to obtain curves in the Pb cell + W source (2870) which are on the following page. There was no detectable transmission at 0.10% transmission but by partially occluding the balance path relative readings were obtained. There was no constant diff. between bloodless + normal ears and simple pressure could not be correctly applied. The spectrophotometer was operating near its maximum limits as regards sensitivity since the light is reduced to ~1% of normal however the slit mechanism remained operational. A collimating lens would aid here for the light guide disperses the beam. This is made worse by the small area of the Pb cell. A series of calibrated neutral density filters are being prepared in photo to permit calibrated operation. The PEE a 1P28 has much greater sensitivity from a 10x gain switch + larger cathode. The slit operated at minimal opening in this detector + a W source from .4 to .7 μ . Using this arrangement (curve B) the ear showed a 1-.5% transmission over the range of .4 (min. range) to .7 μ .

Mr. Taylor of RCA did not have an interchangeable photo. tube that extended appreciably into the IR.

Tests of electronics for densitometer:

P.E.C. - Sensor for commutation -



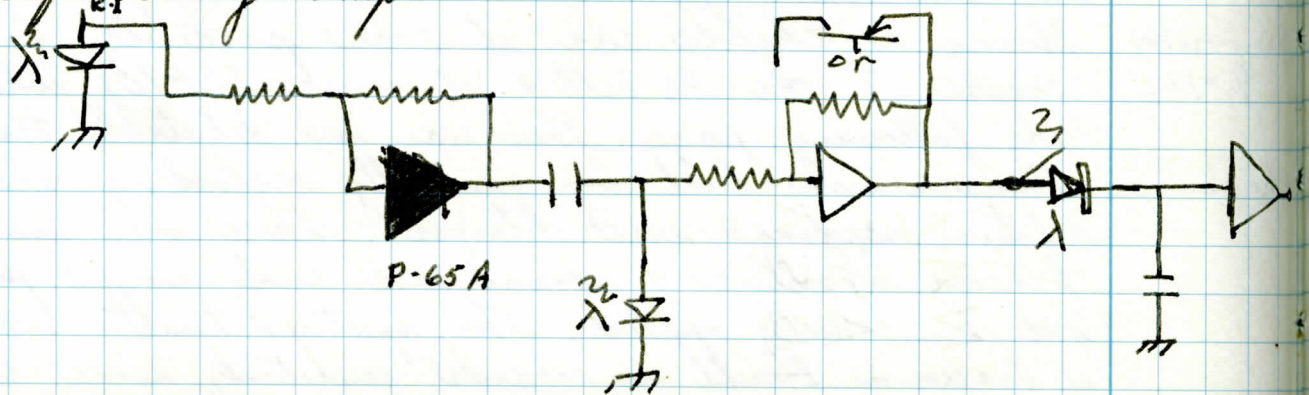
At 30V. bias and 27°C
the max. I is $3 \times 10^{-8} A$ + $R_1 =$
 $\frac{30}{3 \times 10^{-8}} = 10^7 \Omega$

L - Fluorescent bulb
~ 3 A way
E1
R1 (meas. $\bar{e}$ HP 410C)
250 Ω

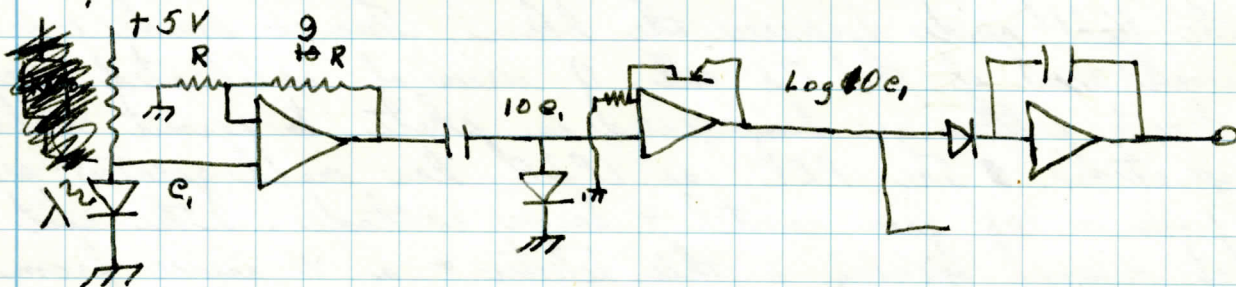
1/10 W. Incandes. bulb 150

Dark $\infty (> 500 \times 10^6 \Omega)$

Current is ~ linear $> \sim 2 \times 10^{-2} \mu A$ - Using either ^{log} resistances or K V source volt will $\propto$ light flux.
Scheme for testing amps.



Monochromator - 1800 RRM = 30 RPS $\times 3 N = 90$ ^{CP} ~~RPS~~



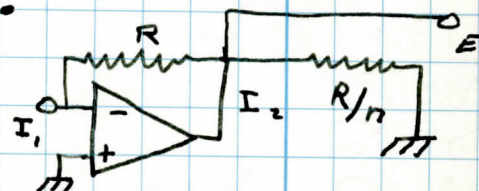
The Offner for power $\pm 15 V$.

+15 V —
+ —
-15 V —

7 July '65

The T-1 LS-400 has an output current which varies ~ linearly $\bar{c}$ light. Two schemes are possible 1. I to E device
2. Load resistor & amplifier -

1. :

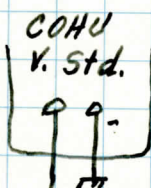
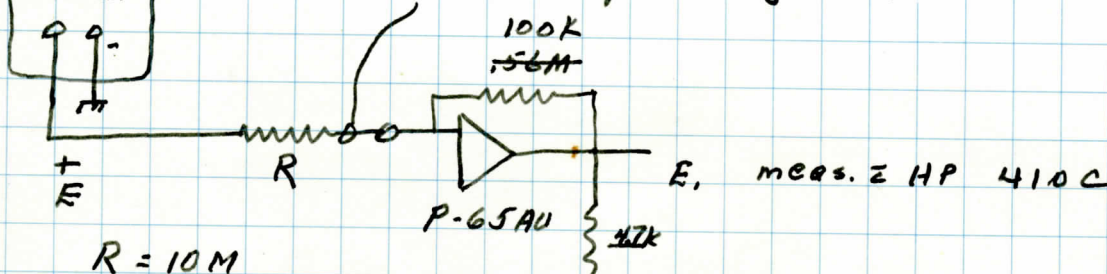


$$E = R I_1 \quad | \quad n \gg 1$$

$$I_2 = n I_1$$

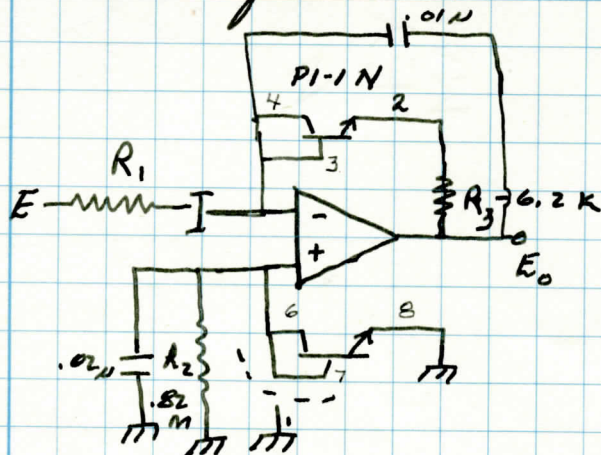
Effect of offset currents?

Operating current of detector should be on the order of $1-10 \mu A$. In outputs of say 1 volt $I_{2 \max} = 2 \times 10^{-3} \text{ ma.}$ $+ R/n = \frac{1}{2} \times 10^3 \Omega$ say $1 K \Omega$
 $\bar{c}$ $R = 100 K$ - Offset currents of $0.2 \mu A$ are possible $\bar{c}$ P-65A and $.1 \times 10^{-9} A$ $\bar{c}$ P-2. With $\pm 15 V$. from Offset T_1 - $R \neq R = .56 M$ & $R/n = 4.7 K$ $\bar{c}$ $I_1 = 0$ $E = 0$ (when trimmed) - After 10 min. drifted to $\sim 1.5 \times 10^{-3} V$.

I Meas separately $\bar{c}$ 410 C

E Volts	E_1 Volts	I A	E V.	E_1 V.	I $A \times 10^{-6}$		
0	-1×10^{-3}	$\times 10^{-6}$					
D.C. on - 0V.	-10.2	.02	40	.372	.363	400	3.75
1.00	19.3	.16	50	.463	.454	500	35.8
2.00	28.4	.25	60	.55	.565		45.0
3.00	37.6	.34	70	.64	.62		
4.00	46.7	.43	80	.735	.71		
5.00	55.0	.52	90	.825	.80		
10.00	105.	.97	100	.92	.89		
20.	190	1.82	200	1.8	1.76		
30.	.28	2.73	300	2.73	2.67		

9 July 65 Test of Philbrick Log. Elements



Ckt. was unstable until caps. & R_2 were added -
 $R_1 = 10 M$ & conn. as on P-13 from COHU std.

E_0	I	E
Volts	$A \times 10^{-6}$	
.21	.65	0 (input shorted)
.385	.07	0 - Supply on
.405	.16	1.0
.453	.97	10.
.56	9.2	100.

Pneumocardiography

Origin: changes in volume of heart and vessels within the thoracic cage and modified by reaction of surrounding structures to these changes:

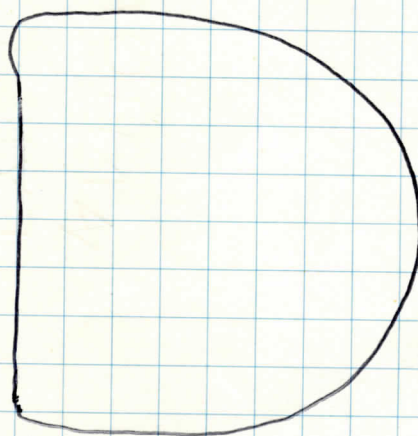
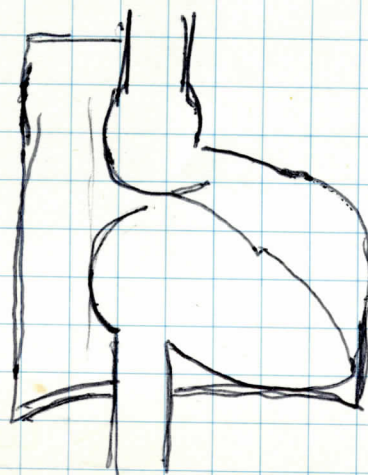


The ϕ primary or initial ^{volume} changes are in (1) the heart & large vessels and (2) any movement directly transmitted to associated structures. (1) is complex for blood enters and leaves the ~~major~~ thoracic cavity through the major vessels in varying magnitudes all throughout the cardiac cycle. These have been assumed to be the major contributions of volume change

- 1) filling and ejection of R atrium
- 2) " " " " R ventricle
- 3) " " " " L atrium
- 4) " " " " L ventricle

- 5) flow from S.V.C.
 - 6) " " I.V.C.
 - 7) " through carotids & subclavians
 - 8) " " aorta
 - 9) " " pulmonic vessels
- (2) 1) movement transmitted to the diaphragm
 2) movement " " " " @ chest wall.

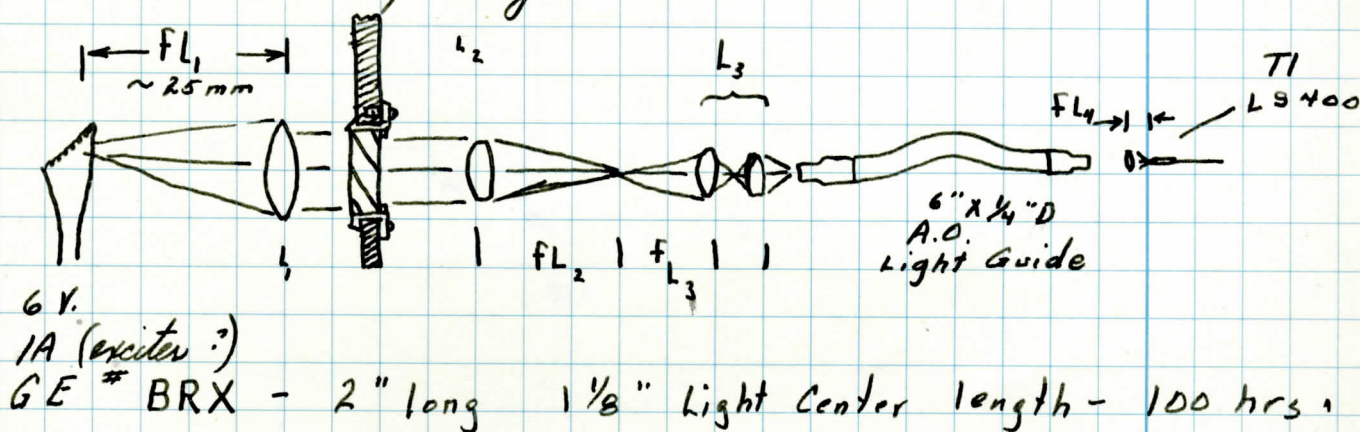
In order ^{an} to attempt to simplify explain some of these effects on the pneumocardiogram (PCG) the following model is postulated:



Oglin-

Take- Filters, LS 400 & IN 2175
Lamp
Hg b Curves -

Prototype densitometer: General scheme of P. 69
is followed & an 1800 RPM (30 CPS) turn λ discs. Discs
are 1" dia. & 1" spacing.



Sylvania
11.1A Min
Fott Bulb

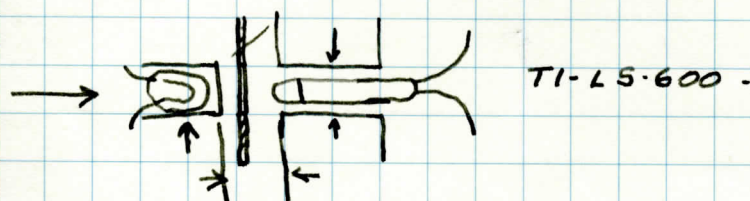
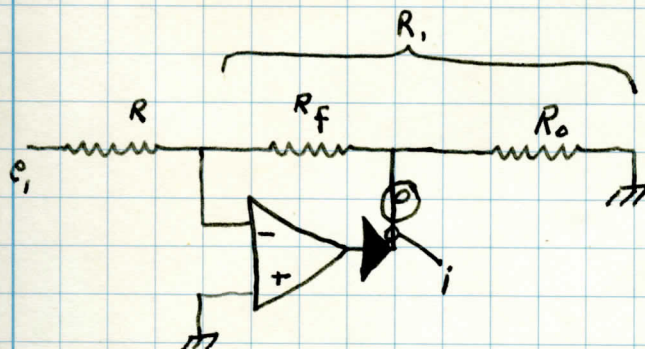


Photo-conductive Cell.

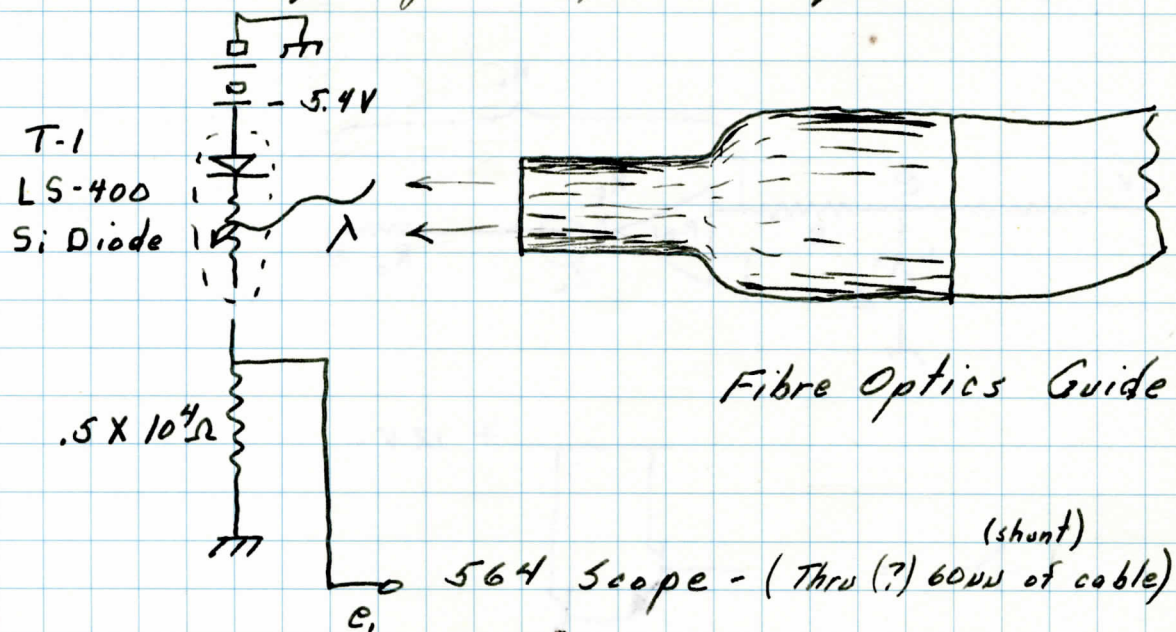
Stabilized current source for BRX bulb. 6 V. 1A.
Basic scheme described in GAP/R application brief D7 5/17/63



$$i = \frac{E_i}{R} \frac{R_1}{R_0}$$

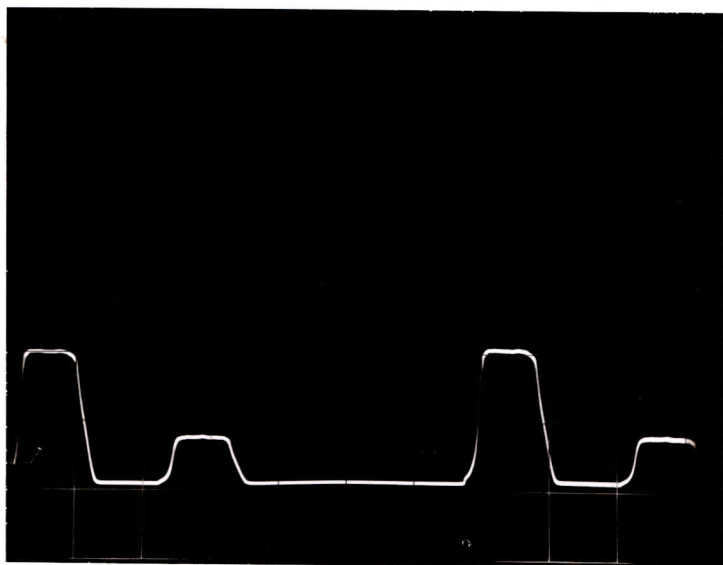
Since a booster amplifier of sufficient power is not
available, a simple emitter follower booster will be
used tried.

Measurement of light output waveforms:



Output was low from Fibre optics -

E_i (V)	Location	λ (nm)
0.09	Thru Fibre Optics	635
0.25	" " "	635 805
0.5	" Field lens	635
71.5	" " "	805
0.1	" Filter	635
0.3	" " "	805

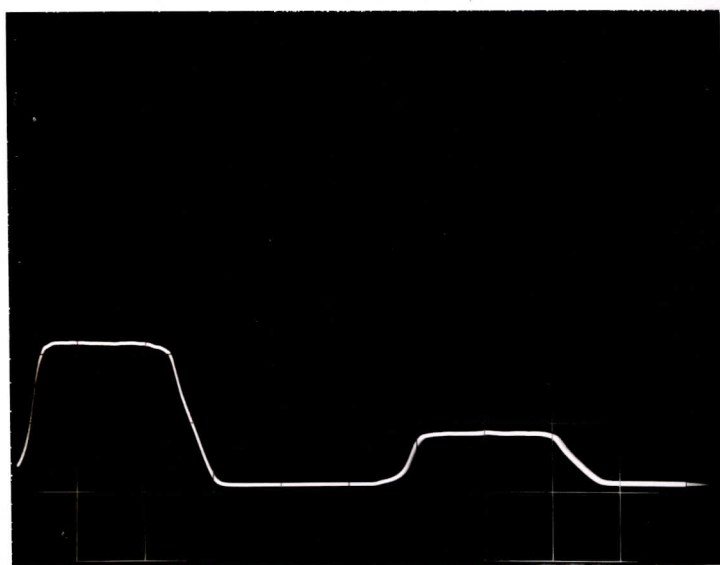


↑
805

↑
635

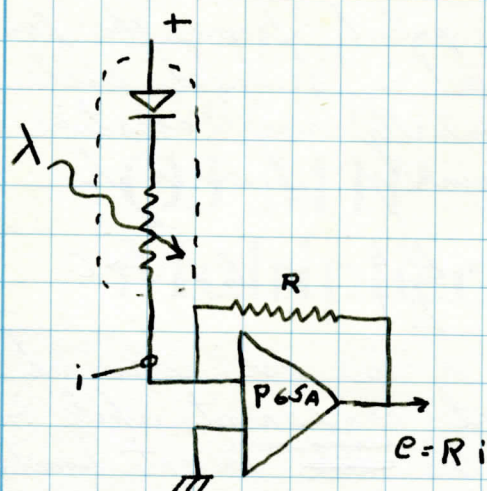
5ms x .05 V/cm.

Output of detector

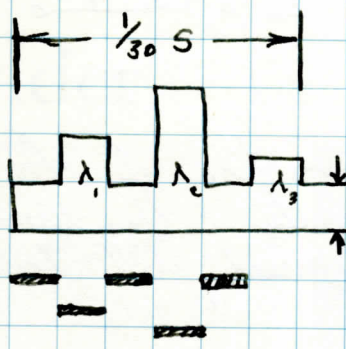
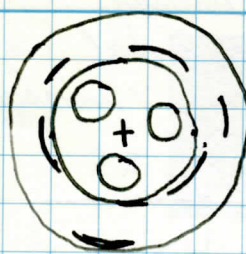


2ms x .05 V/cm

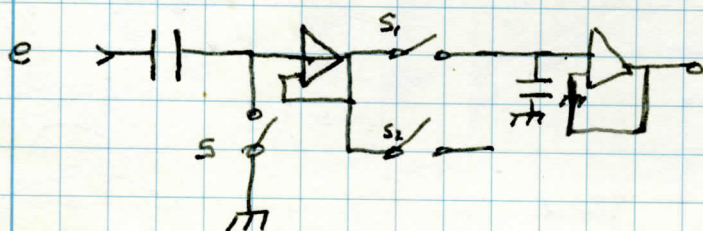
Densitometer: Signals



$\bar{E} R = 10^5 \quad E = 10^{-4} \mu A$
Say max. of 5V.



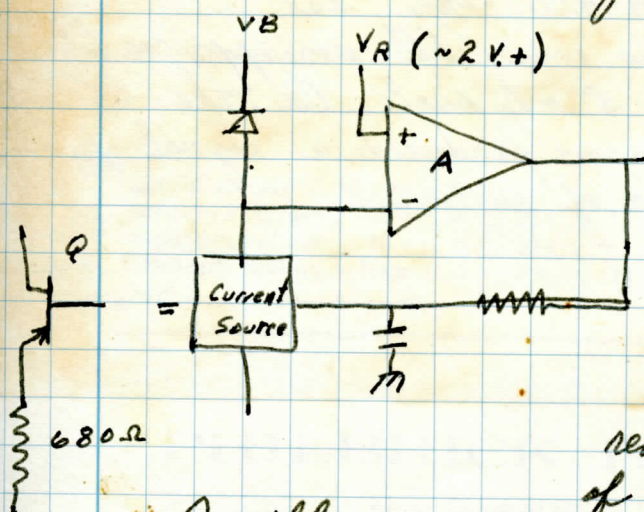
$$\frac{33.3 \text{ m/s}}{6} = 5.5 \text{ msec}$$



According to a paper and experiment by a T.I. engineer
(The Si. Photo-diode in a voice comm. receiver):
The planar diode is probably superior to a "mesa" type
has reduced $1/f_c$ noise and?

1. The diode should be reverse biased
2. A.C. loading should be minimal.
3. Static diode current should be low

An experimental ~~only~~ ckt. $\bar{E}$ good performance was:

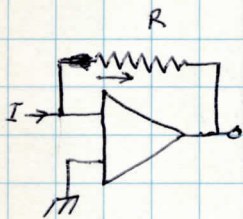


The emitter collector of P will have very high impedance while the input Z of A is prob. $> 1 M.$ so $Z_{in} > 1 M.$

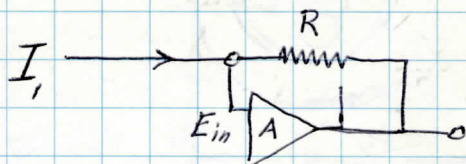
The arrangement planned is similar and should yield equivalent performance except for reduced gain. The input impedance of a P-65 is open to consideration. Possibly a P-02 would be proper here.

(over)

Detector circuitry:



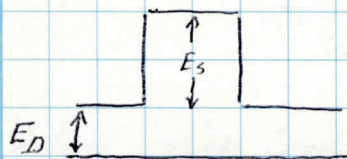
A conventional current to voltage operational arrangement results in an equivalent ground point from the feedback.



The input is arranged such that E_{in} has essentially no variation since the gain of A is high.

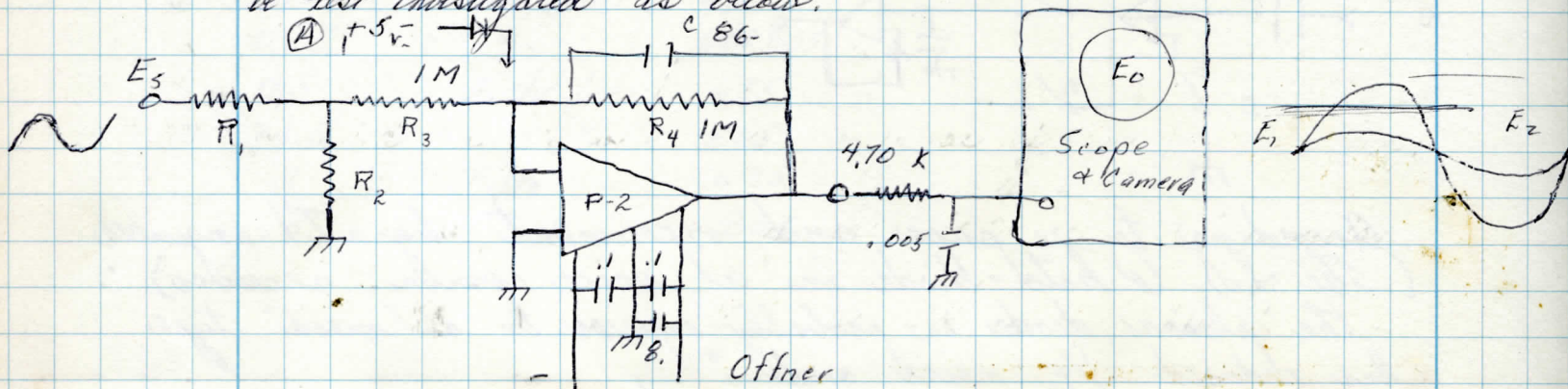
$$R = \frac{\Delta E}{\Delta I} \quad \text{+} \quad \Delta E \rightarrow 0 \quad R \rightarrow 0$$

The description of the ~~current~~ diodes use was at much higher currents & a small signal component while in this case the current will be low & the ~~max.~~^{max.} current limited to



$E_D + E_S$: E_D will consist of dark current + any stray light - it should be possible to completely exclude the latter. E_D has a quoted mean of $1-2 \times 10^{-9} A$ at body temp. Signal current is unknown.

To obtain some idea of the noise ~~an~~ under various modes of operation and signal level the LS-400 will be test investigated as below.


$$R_{3,4} = 1 \text{ M} \quad C = 100 \mu\text{F}$$

Freq. Response -

Freq. RMSV out

5' KC .50

10 " .45

20 " 38

40 " , 24

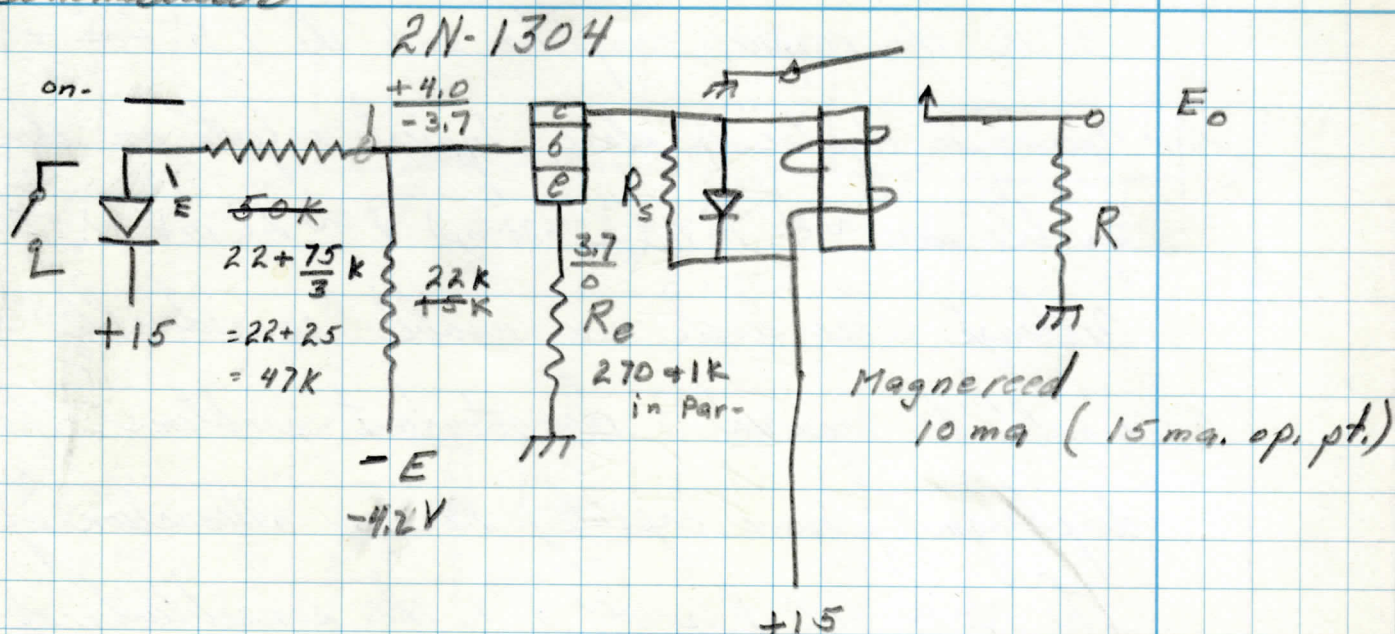
the light beam thru the pinna of an ear-

With this arrangement & at 5 mV/cm there is no appreciable L.F. noise - 5 mV

corresponds to: $E = IR$ & $I = \frac{5 \times 10^{-3}}{10^6} = 10^{-9}$

With the LS-400 conn. as ^{10°} above A there was still no appreciable noise on the 5 mV scale. On the 50 mV/cm scale the sensor produced a signal from thru the pinna of an ear.

Commutator



$$\beta = 50$$

$$I_B = \frac{15 \times 10^{-3}}{5.0 \times 10} = 3 \times 10^{-4} = .3mA$$

$$\text{For } R_e = 2 \times 10^2$$

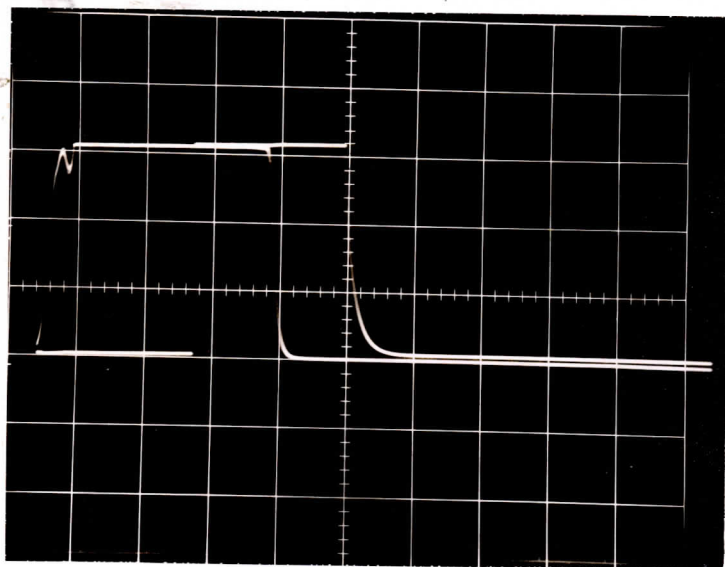
$$I_{R_e} = 15 \times 2 \times 10^2 \times 10^{-3}$$

$$= 30 \times 10^{-1}$$

$$= 3.0V$$

When connected to the rotating disc, it was necessary to lower R_e to 47Ω ($I_c = 37mA$) to close the relay - On the 50 mV/cm. scale no discernible signal could be seen at E_o .

Waveforms below are the output of the PEC - E & E_o & the Ry mid-contact conn. to $+15V$.



1mS, & 5V./cm

$$T_{close} \approx 2 \times 10^{-3} \text{ sec.}$$

$$T_{open} \approx 10^{-3} \text{ sec.}$$

With the earpiece completed and the LS-400⁶⁰⁰ +
microscopic objective in place, typical outputs on the
ear lobe were ~ 4 mV. (λ_3 620 mV) + ~ 20 mV. (λ_1 805 mV).

Although these levels are usable considerable amplification
would be required to the attendant problems. The rubber
diaphragm (pressure capsule) has an attenuation of $\sim 80\%$.
The LS-400 has $\sim 2 \times$ the sensitivity of the LS-600
under conditions here. Some fundamental assumptions were in
error in the design of the optics for the earpiece detector.

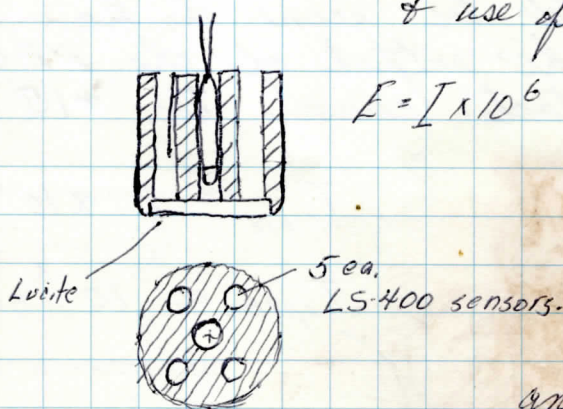
clear plastic
cap will be
obtained for
pressure capsule.

In light of supply difficulties a brute force solution will
be tried as below. By removal of the rubber dom ($\times 4$ gain)
& use of the 400×5 the resultant voltage:

$$E = I \times 10^6 \text{ should be: } 4 \times 10^{-3} \times 4 \times 2 \times 5 =$$

$$\lambda = 620$$

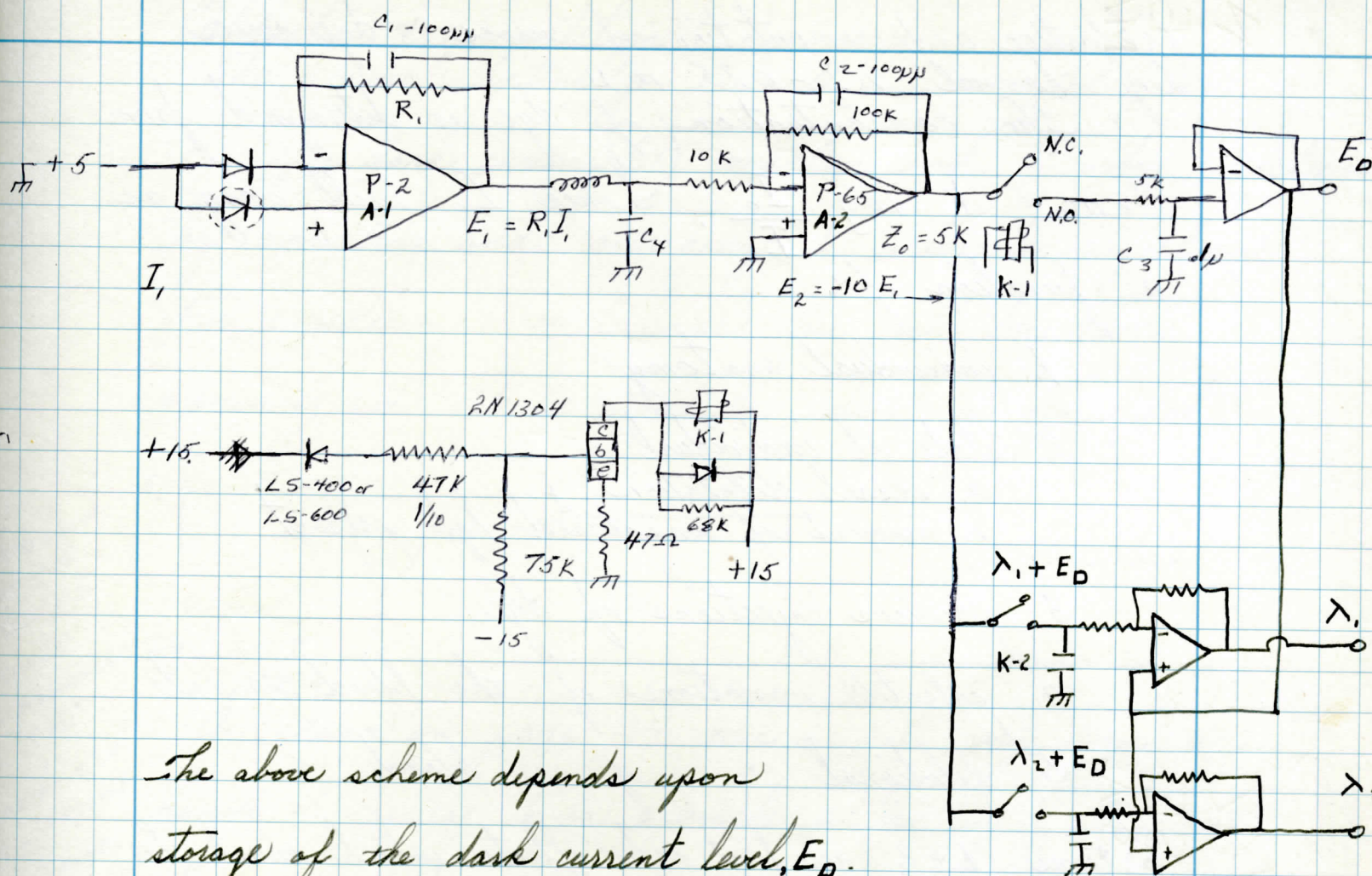
160 mV. By assume a minimum



P-65AU
SP-2A

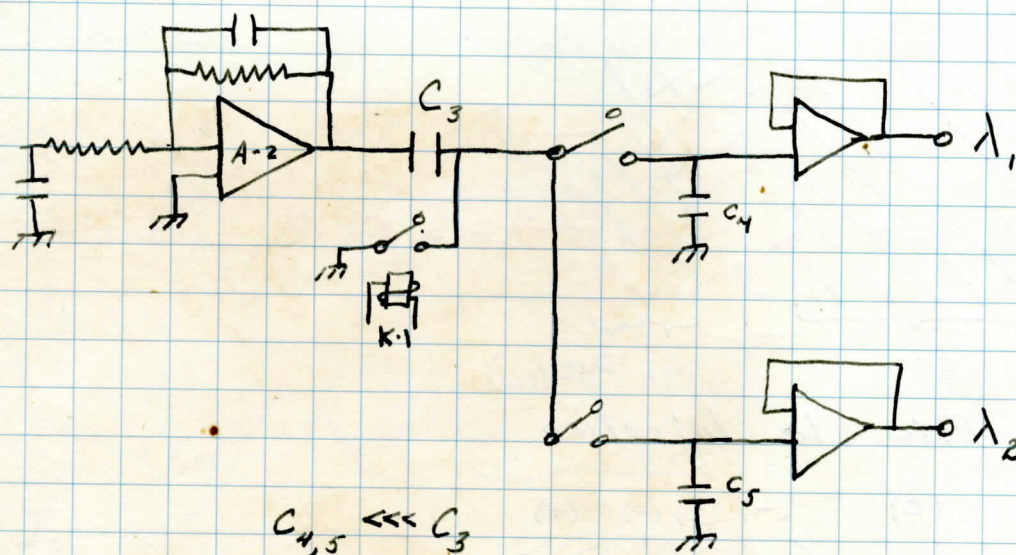
of 0.1 V. This will result in
an appreciable increase in dark
current. With the following operational amps:

	P-2	P-65AU
Input	100 μ V	< 50 μ V/Day $T_{min} = K$
	6 mV.	6 mV Temp - - 25°C to +85°C.



The above scheme depends upon storage of the dark current level, E_D .

An alternative scheme is shown below.



Calibration and computation of curves: dye curves

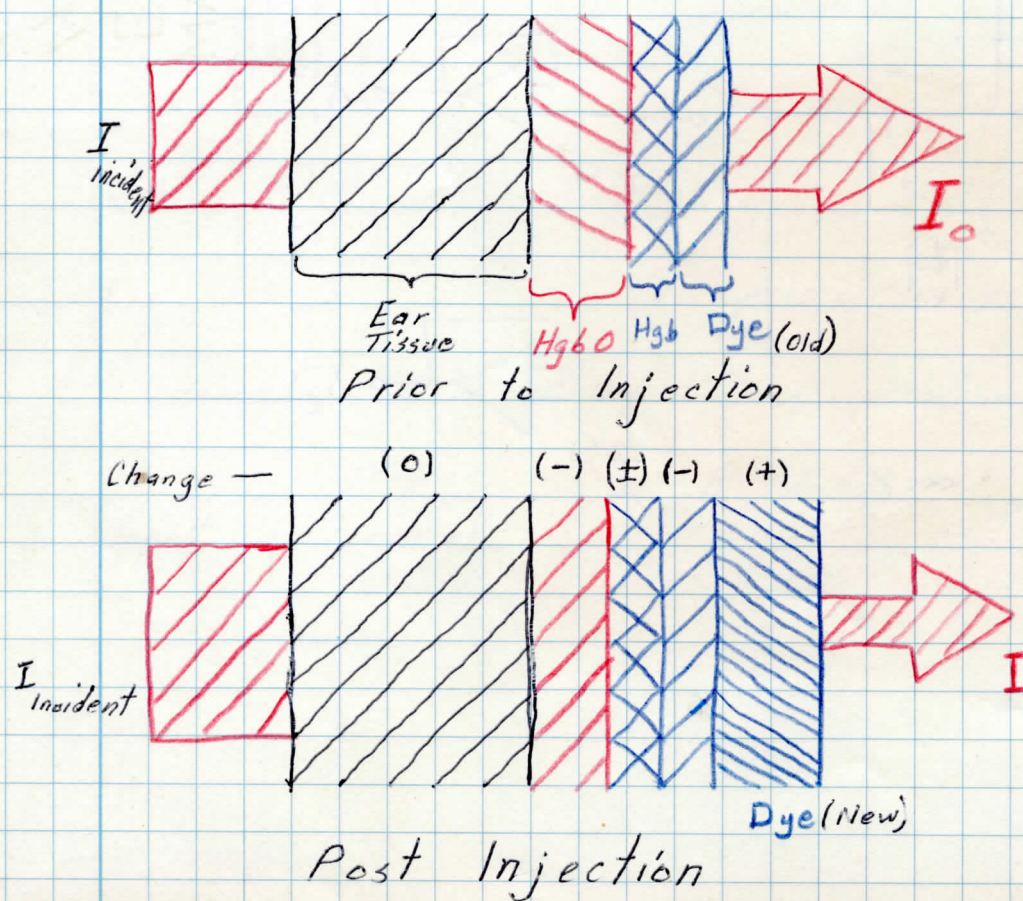
Dye channel $\lambda_3 - 625 \text{ m}\mu$

The concentration of dye is determined from

$\text{Conc} = K \log \frac{I_0}{I}$, Since I_0 will vary as a function of:

1. individual anatomy
2. state of individual
 - a. vessel dilatation
 - b. amount of unsaturated hgb present
3. previous injections of dye
4. pulsatile variations of the blood present
5. dilutional " of " blood "

Items 1. + 2. are first order effects which must be compensated for by measuring I_0 .



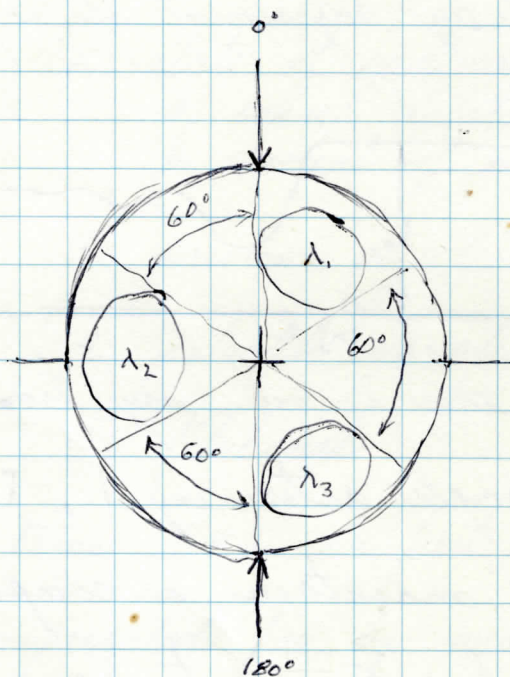
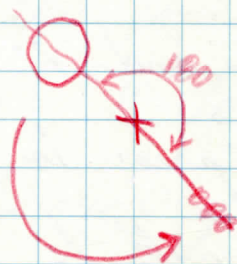
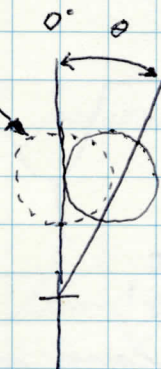
Commutator -

 ω :

$$\frac{1800 \text{ R/Min}}{60 \text{ sec/Min}} = 30 \text{ R/s}$$

$$360^\circ/\text{R} \times 30 \text{ R/s} = 10800^\circ/\text{s}$$

$$= 10.8^\circ/\text{m Sec}$$

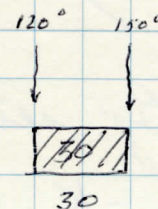
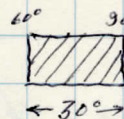
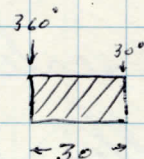
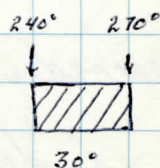
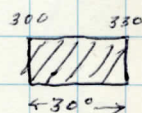
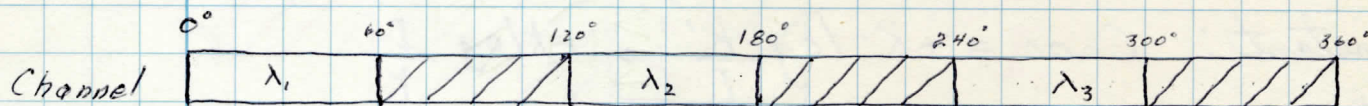
Dia. of
Optics tube

An additional
angle θ must be
added to the 180°
to accommodate the
early pickup by the
dia. of optics tube

$$\begin{array}{r} 15 \\ 24 \overline{) 360} \\ \underline{72} \\ 120 \end{array}$$

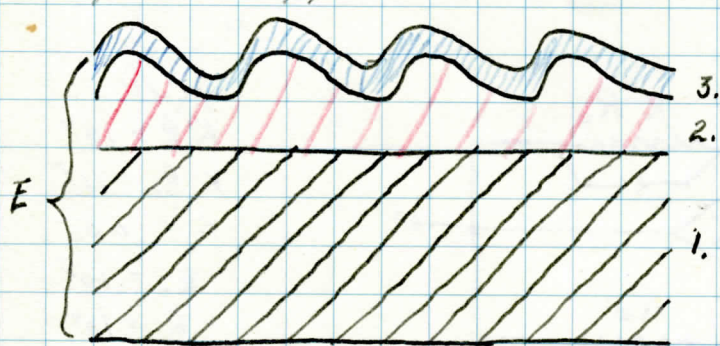
Dir. of
Rotation

→ ← 15°



Calibration and computation of dye curves

Effects of the varying concentrations of the blood path on the ear is complex and the so called "nonspecific effects" are even less well understood.



The output of the photo-cell (inverted) might be represented by $\bar{E}$ and $\lambda = 625$. $\bar{E}$ dye would consist of three components -

1. fixed tissue
2. variable path length of HbO
3. variable " " of Hb = variable concentration

After the first injection there will also be an additional pulsatile element, residual dye. All of these substances have a different coefficient of absorption and one of the "non-specific effects" is dilution of $Hgb + HgbO$ by the dye which is transparent at ~~the~~ λ_1 & λ_2 .

The substances present are:

2.1 Dye

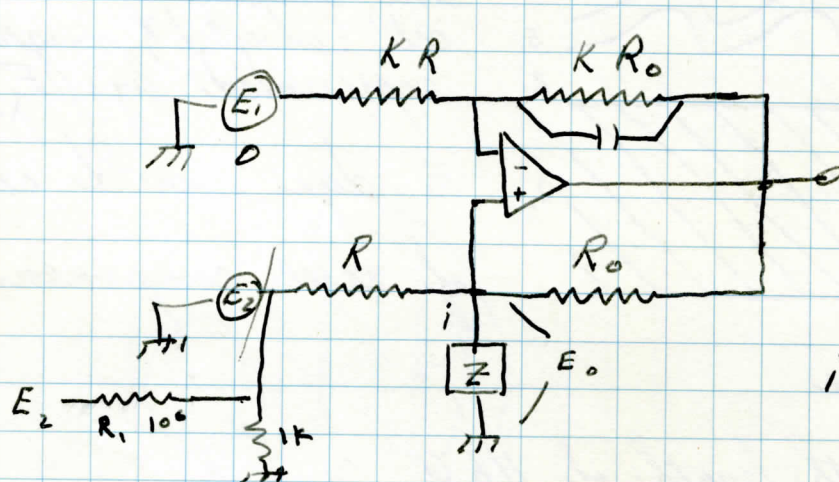
.2 Hb

.3 HbO

.4 Fixed tissue
Unless the

Eval. of log elements -

In the previous eval. there were difficulties in linearity which Philbrick (Mr. M.) attributed to improper current source. He suggested the source below:



(A)

$$KR = 10^4$$

$$KR_0 = 10^5$$

$$C = .005$$

$$R_0 = 10^5$$

$$R = 10^4$$

$$i = \frac{C}{R}$$

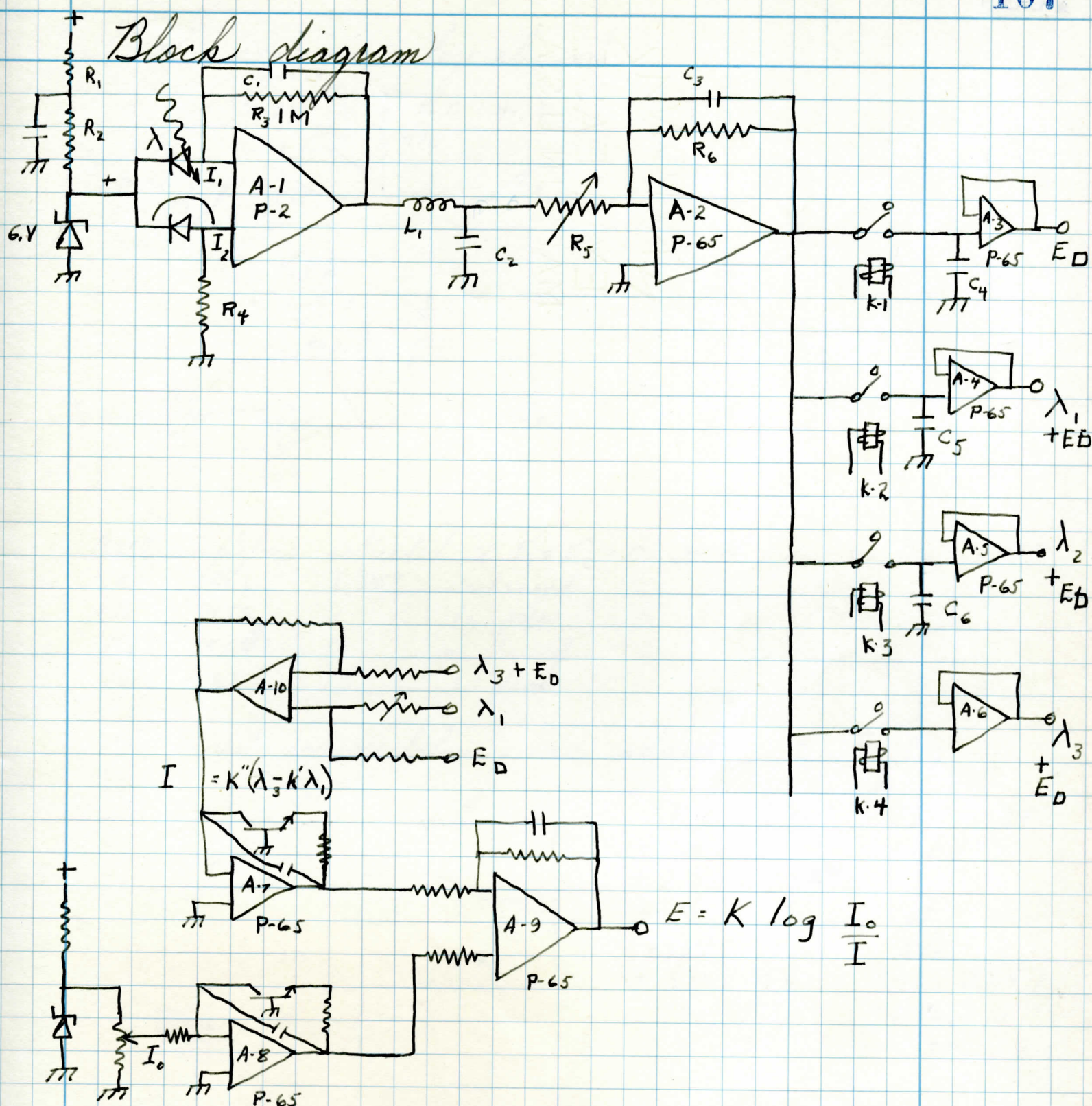
5X10⁻⁵

above values & $Z = 470 \Omega$

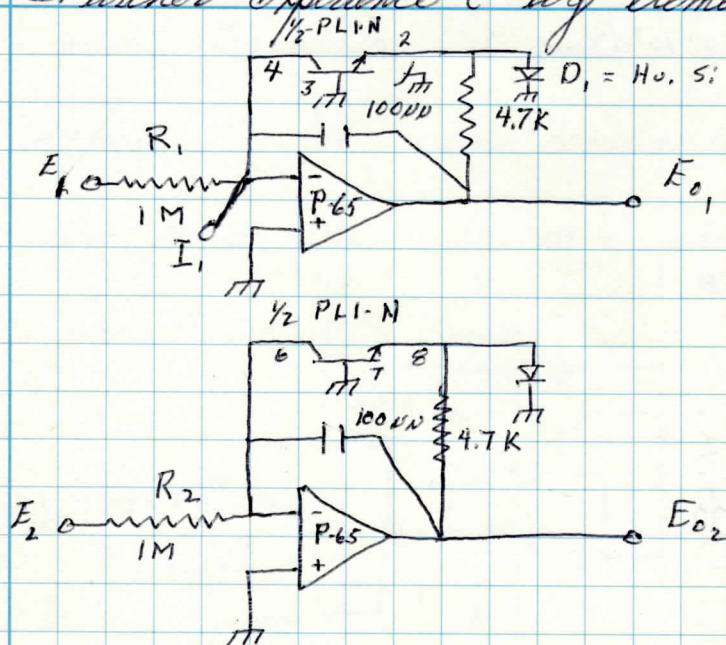
	E_2	E_0
R_1 10 ⁴	0	.000 - .001
	+ 100	+ .005
	+ 200	.010
	+ 300	.015
	+ 400	.020
R_1 10 ⁵	0	.001
	10	.005
	20	.009
	30	.013
	40	.017

E_1 apparently cannot be 0.
The above ckt. behaved quite
well with all $R_1 = 10^4 \Omega$ & $E_1 = +1.34V$.

Block diagram



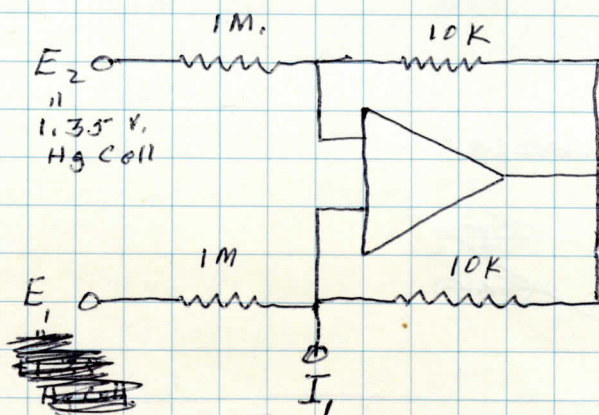
Further experience c log elements:



Both amplifiers saturated $\bar{E}_1 + E_2 = 0$. With $E_1 = +1$ $E_{o1} = -.458$

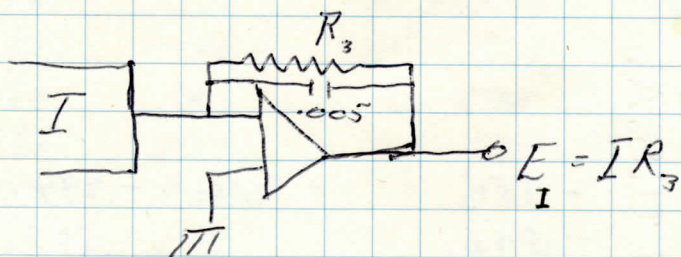
E_1	E_{o1}	$I, \times 10^{-6}$	unchanged by pres. or abs. of Si diode
+1.	.458	1	
10.	.562	10	
100.	1.07	10^2	

The current source below was added: $I_1 = \frac{E_1 - E_2}{R}$



E_1	$I \times 10^{-6}$	E_{o1}	ΔE_{o1}
+1.0	—	sat	
+2.0	.64		
+1.34	0	sat	
+1.64	.33	-.328	
+3.64	3.3	-.482	.054
+33.64	33.3	-.690	2.17
	333.	-2.21	.55

Look at current source:



For $I = .3 \times 10^{-3}$
 $\& E = 3 \times$
 $R = \frac{3}{.3 \times 10^{-3}} = 10^4$

$E_1 - E_2$	E_I	E_I (10k in series)
0.	+ .003	.003
1.01	-.008	.008
2.01	-.018	
3.01	.028	
4.01	.038	.038

$E_1 - E_2$	E_1	$E_2 \approx 10^4$ in series
5.01	-.048	
6.01	-.058	
7.01	-.068	
8.01	.078	
9.01	.088	.088
10.01	.098	
20.01	.198	
30.01	.298	
40.01	.398	
50.01	.498	.499
60.01	.599	
70.01	.699	
80.01	.800	
90.00	.900	
100.	1.00	-1.00
200.	2.00	-2.00
300.	3.00	-3.00
400.	4.01	-4.01

Checked PL1-N on trans. chr. + has

$$\beta = \frac{500}{2.5} = 200$$

$$E_C = 1V$$

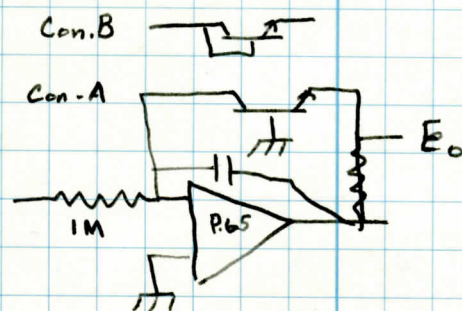
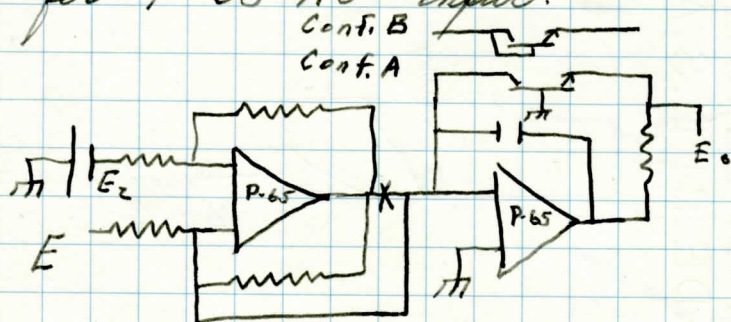
Replaced current source -

$E_1 - E_2$	E_0
0.	+1.737
1.	+1.598
2.	+1.600
V	+1.588

I		I	Diode	-1.81
.008	0.	+12.1		
	1.	-.447		
	10.	-.558		
	100.	-1.05		
	200.	-1.56		
	80	-.543		
.008	1.01	-.449	-.451	-.565
.078	8.01	-.543	-.545	-.505
.800	80.01	-.953	-.952	.565

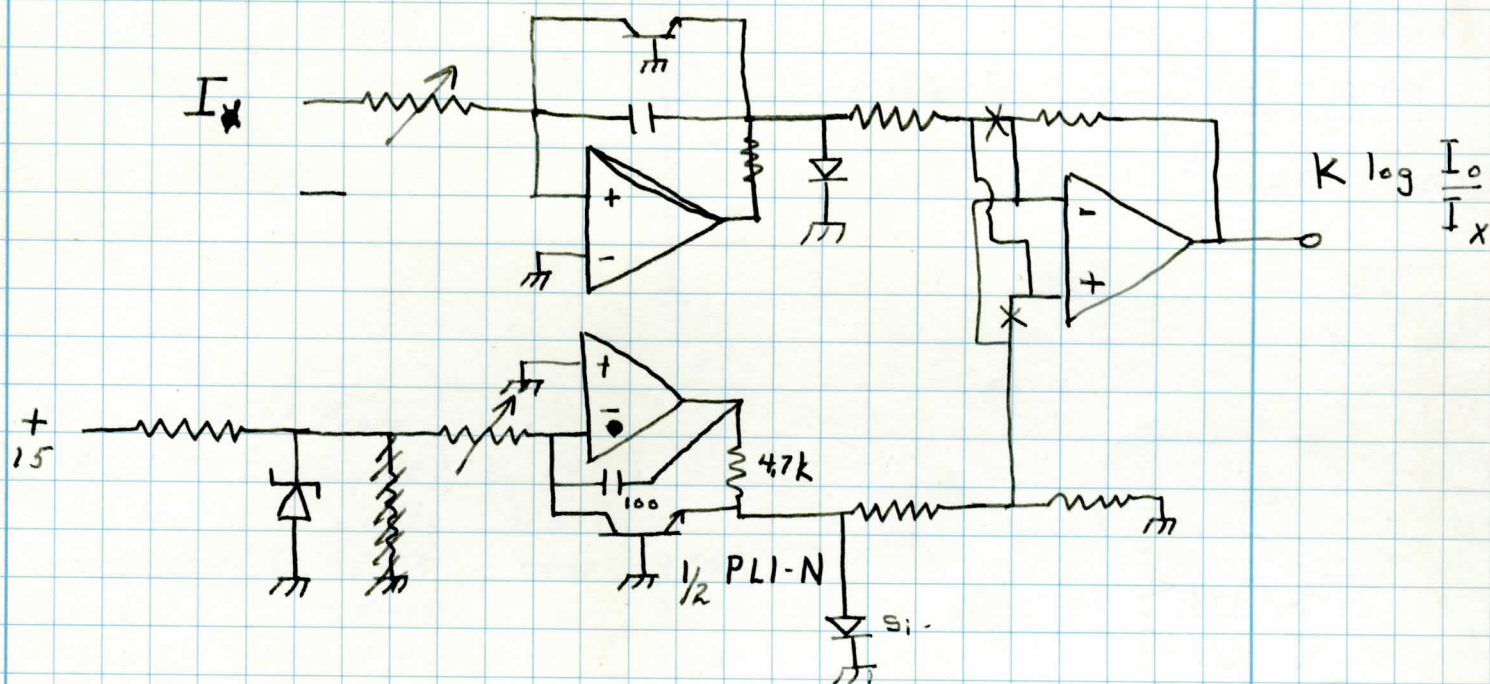
Called Mr. Brian David of Philbrick who pointed out that I was using the incorrect junction pt. i.e. amplifier out put. Also verifies that voltage to

current translator is not required so long as the input voltage is large as compared to the amplifier input. He feels that $\frac{1}{2}$ mV. is a reasonable variation for P-65 AU input.

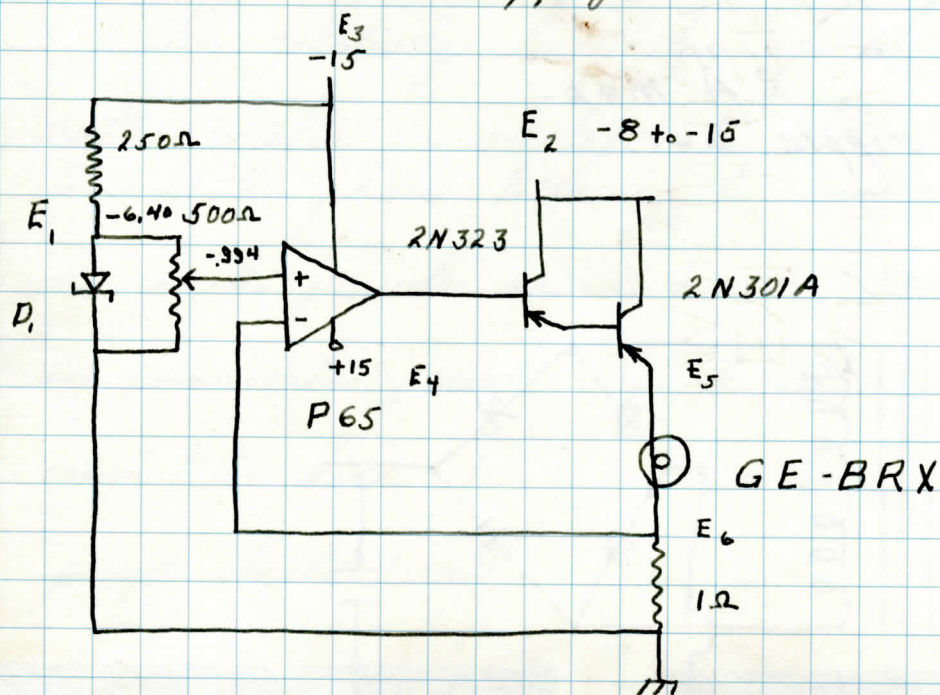


$E - E_2$ + V	$E_0(\text{Conf. B})$ V	$E_0(\text{Conf. A})$ V	E_1 V	$E_0(\text{Conf. A})$ V	$E_0(\text{Conf. B})$ V
1.01	+7.24		1.00	- .451	- .450
2.01	- .465	- .465	2.00	.469	
+ 3.01	- .477		3.00	.479	
4.01	.485		4.	.487	
7.01	.501	- .501	5.	.492-3	- .492
8.01	.504		10.	.510	.510
9.01	.507	- .507	20.1	.530	
10.	.510	- .510	50.1	.552	.552
20.	.528	- .528	100.1	.570	.570
30.	.539	- .539	150.1	.581	.580
40.	.546	- .546	200.1	.588	.588
50.	.552		300.1	.599	.598
60.	.557	- .557	400.1	.606	.606
70.	.561		.500	.434	
80.	.564	- .564	.100	.392	.391
100.	.570	- .570	.050	.374	.373
150.	.581	.581	.010	.332	.333-2
200.	.588	.588	.01-1	- 60 mV	
250.	.594	.594	.1-1.	- 59 mV	
300.	.599	.599	1.-10.	- 59 "	
400.	.607	.607	10.-100.	- 60 "	

Revised Ckt.



Test of power supply, const. current -



$$W_Z = E_2 = \frac{15.00}{8.63} = 6.37$$

$$\frac{E_2}{R} =$$

$$\frac{8.6}{2.5 \times 10^{-2}} = 3.45 \times 10^{-2} = .034$$

$$I_{500\Omega} = 12.8 \times 10^{-3}$$

$$\frac{22}{6} = 132 \text{ mV}$$

D1 1/4 W Zener

E_3 Volts	$E_1, f(E_3)$ Volts	$E_5, f(E_3)$ Volts	$E_6, f(E_3)$ Volts
-12.0	-9.78 -6.32	-7.43	-6 -9.78
-13.0	-6.34	-7.48	-9.81
-14.0	-6.35	-7.51	-9.84
-15.0	-6.37	-7.55	-9.85
-16.0	-6.38	-7.57	-9.87
-17.0	-6.39	-7.60	-9.88

E_2 Volts	$E_5, f(E_3)$ Volts	$E_6, f(E_3)$ Volts
-10.1	-7.60	.988
-11.	-7.60	.988
12	-7.60	.988
13	7.59	.988
14	-7.60	.988
15.	-7.60	.989

E_2 Ripple -
.5 V.P.P. at 15V
 E_5 Ripple + noise
< .1 mV P.P.

E_6 as $f(\text{temp})$
1300 Volts - .985 Room (chassis Cool) 22.5°C
1400 - .987 " (chassis warm)

$$E_+ = 0.15 + E_2 = -12$$

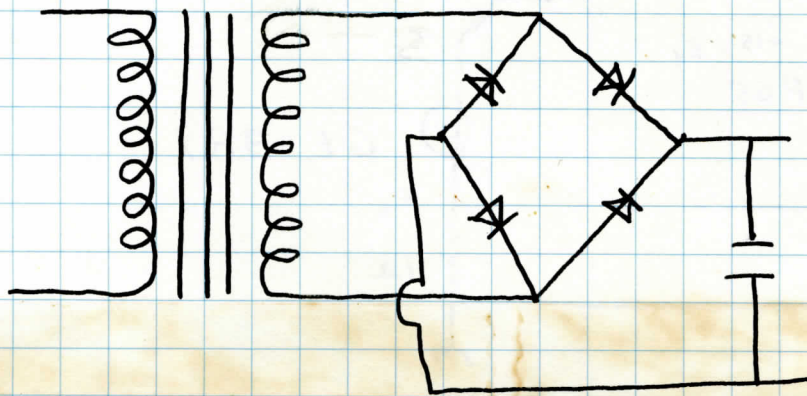
Low Voltage supply for Lamp.

12 V -

1 A -

2 A max.

.5 V.P.P. ripple max.



$$\frac{.5}{12} \times 10^2 \approx 4\%$$

From P-1176 R.D.H.B.

Assume 2 A Load $R_L = \frac{12}{2} = 6\Omega$

$$\omega C R_L \approx 10$$

$$C = \frac{\text{Farad}}{\omega R_L} \quad R_L = 6\Omega$$

$$2\pi f \approx 6.3 \times 1.2 \times 10^2 = 7.56 \times 10^2$$

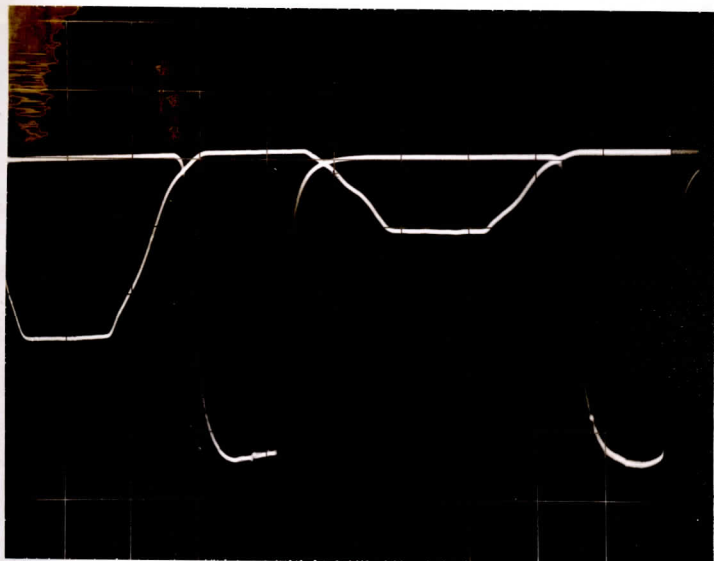
$$\omega R_L = 6 \times 7.6 \times 10^2$$

$$C = \frac{10}{7.56 \times 10^3} \approx 2.2 \times 10^{-3}$$

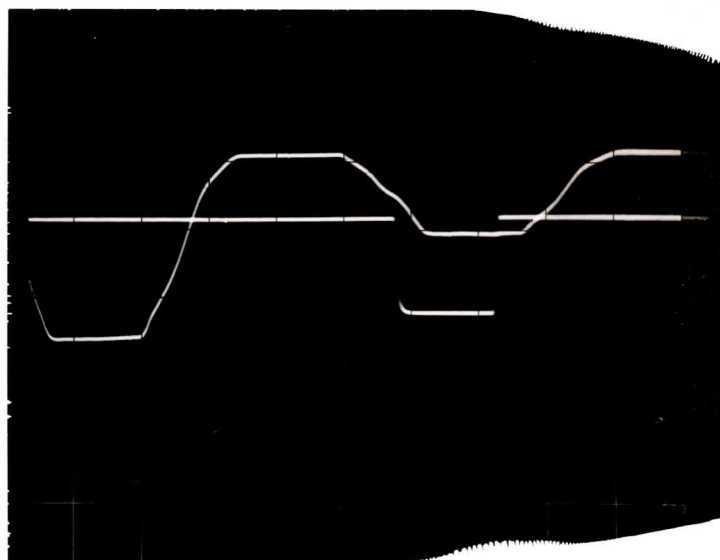
$$= 2.2 \times 10^3 \mu\text{fd}$$

Timing of commutator disc.

The relatively large dia. of the signal optical path results in overlap into the optical dark periods. From the photo below it would appear that the dark periods are 3.4 mS ($\sim 34^\circ$) while the ~~one~~ commutator periods are 3. mS. By advancing commutator disc 1. mS (-10.8°) a 2 mS sample period should result.



λ_1 D λ_3 D
Detector + Dark Commutator



λ_1 D λ_3 D
Detector + λ_3 Commutator

Densitometry:

$$I = I_0 10^{-\epsilon d c} = \frac{I_0}{10^{\epsilon d c}}$$

$$\epsilon \Big|_{\substack{d=1\text{cm} \\ c=1\text{mM/L}}} = \frac{-\log T}{d(\text{cm}) \cdot c(\text{mM/L})}$$

$d = \text{depth}$
 $c = \text{conc.}$

$$\epsilon = \frac{1}{d} \Big| \frac{I}{I_0} = \frac{1}{10}$$

$$T = \frac{I}{I_0}$$

$$D = \log \frac{I_0}{I} = -\log T$$

Hb

HbO

$$\epsilon_{\lambda=620\text{m}\mu} =$$

2.

$$\epsilon_{\lambda=805} = .21$$

$$.21 \times 10^{-6} \text{ mole}$$

1.
2.

$$\epsilon_{\lambda=1000} = .08$$

$$.25 \times 10^{-6}$$

1.
2.

$$\epsilon_{\lambda=1100} = .01$$

$$.1 \times 10^{-6}$$

1.
2.

$$\epsilon_{\lambda=1030} = .02$$

$$.21 \times 10^{-6}$$

1.
2.

Calibration & computation (cont'd. from 94)

The fixed tissue density is supposed to remain constant and may be accounted for (theoretically) by occlusion of blood & dye $\bar{c}$ pressure.

At two points $\lambda_1 = 805$ & $\lambda_2 = 1000$ the only pigments present are Hb & HbO and the path length is equal.

Typical light absorption:

$$\lambda_1 - \epsilon = .21 \times 10^{-6} \text{ mole. Conc.} = 150 \text{ gm/l MW} = 68 \times 10^3 \text{ gm/M}$$

$$I = \frac{I_0}{10^{\epsilon d c}} = \frac{I_0}{10^{.21 \times 2.2 \times 10^{-2} \times 10^{-6} \times 10^{-3}}} \quad (?) \quad = \frac{150}{68} \cdot 10^{-3} = 2.2 \times 10^{-3}$$

Path (d): assume .01 cm.

$$D(\text{ens}) = \log \frac{I_0}{I} = \epsilon = \frac{.21 \times 10^{-6} \text{ mole}}{2.2 \times 10^{-3} \text{ mole} \times 10^{-2} \text{ cm}} = .01 \times 10^{-1} = .01$$

In the above meas. I have not been able to account for factor of 10^{-6} . Using Drabkin's values:

9.8.65

The theoretical results obtained yesterday (P.122-3) indicate that the signal level will be very low. There are two objections to these values.

1. The path length was estimated - .08 cm. and may not be correct - ~~A.~~
2. The values used are based on pure Hgb which is different from erythrocytes. The RBC - Hb may behave as a N.D. filter.
 - A. Try to find measurements
 - D. Build short path cuvette + meas.

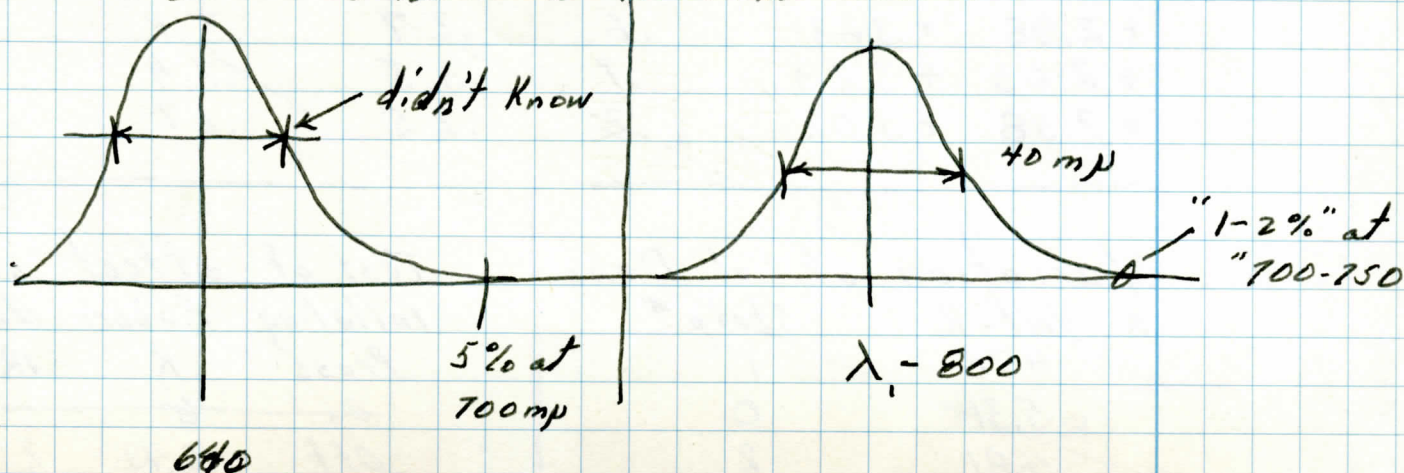
1. A. Try to get estimate
- B. Meas. $\bar{\epsilon}$ Waters.

Called Dr. Jack Reed, Dept. Physiology, Mayo Clinic #507-282-2511 for info on comparison of ϵ of hemolyzed + whole blood and of blood path length in the ear. He thought that Zijstra + Mook of Holland, assoc. unknown had published (also unknown) on this. Suggested book "Med. Reflection Photometry" published by Van Gorpam + Gorpam. He was not aware of direct or attempted measurements of ear ^{blood} path lengths but promised to send some references in this area.

P.F.C. seems to have

10 Aug 65

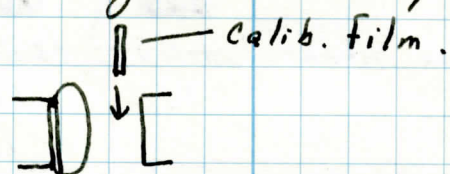
Also called Sedivy of Waters who stated that their oximetry earpiece had the following general characteristics. Promised to send curves.



Run ~~cut~~ thickness curves using this earpiece and the digital V.M.

11 Aug. '65 - Replaced I.R. emitter follower in XP-350 Waters per agreement $\bar{c}$ Sedivy not to void warranty. He claims output ~~is~~ all resistance change is "linear" $\bar{c}$ blood quantity but is vague on ^{output} voltage relationship. Output vs. density Lamp - 0.0

R -	I.R.	Dens.
		No Light
		0
+1.71	+0.078	1.38
+0.207	+0.103	"
+5.45	+6.09	
+0.034	+0.010	2.76
.033	+0.008	∞



← Location of Film (Film nr. Lamp P.E.C.) causes Variation (" " Lamp)

P.E.C. seems to have 'memory' it does not immediately return to prev. value

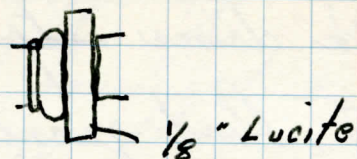
R	IR	Dens.	ΔR	ΔIR
+ 4.88	+ 5.60	.1	.57	.49
+ 4.43	+ 5.13	.2	.45	.47
+ 3.99	+ 4.69	.3	.44	.44
+ 3.64	+ 4.33	.4	.35	.36
+ 3.25	+ 3.94	.5	.39	.39
+ 2.98	+ 3.63	.6	.27	.31
+ 2.63	+ 3.29	.7	.35	.34
+ 2.38	+ 3.02	.8	.25	.27

Variation of ol Dens.

Volt. R	Strip #
4.78	1
5.31	0
4.81	2
5.29	0
4.81	3
4.78	4
5.29	0
4.82	5
5.28	0
4.81	6
5.28	0
4.80	7
5.29	0
4.80	8

Test of effect of
Inflating Rubber dam-
Press R IR

On	6	
Off	6.49	7.36
On		7.21
Off		7.16
On		7.20
Off	6.23	7.14
On	6.27	
Off	6.22	
On	6.25	
Off	6.20	



Pinna (R) ear ~~R~~ IR Press On = max pass. press. to capsule i.e. until Tech

R IR Press
4.83 Volts Off
1.10 1.62 Off
1.86 On
1.58 Off
1.97 On
1.55 Off
fitted more 1.60 Off Off
tightly 1.91 On
.712 Off
1.050 On

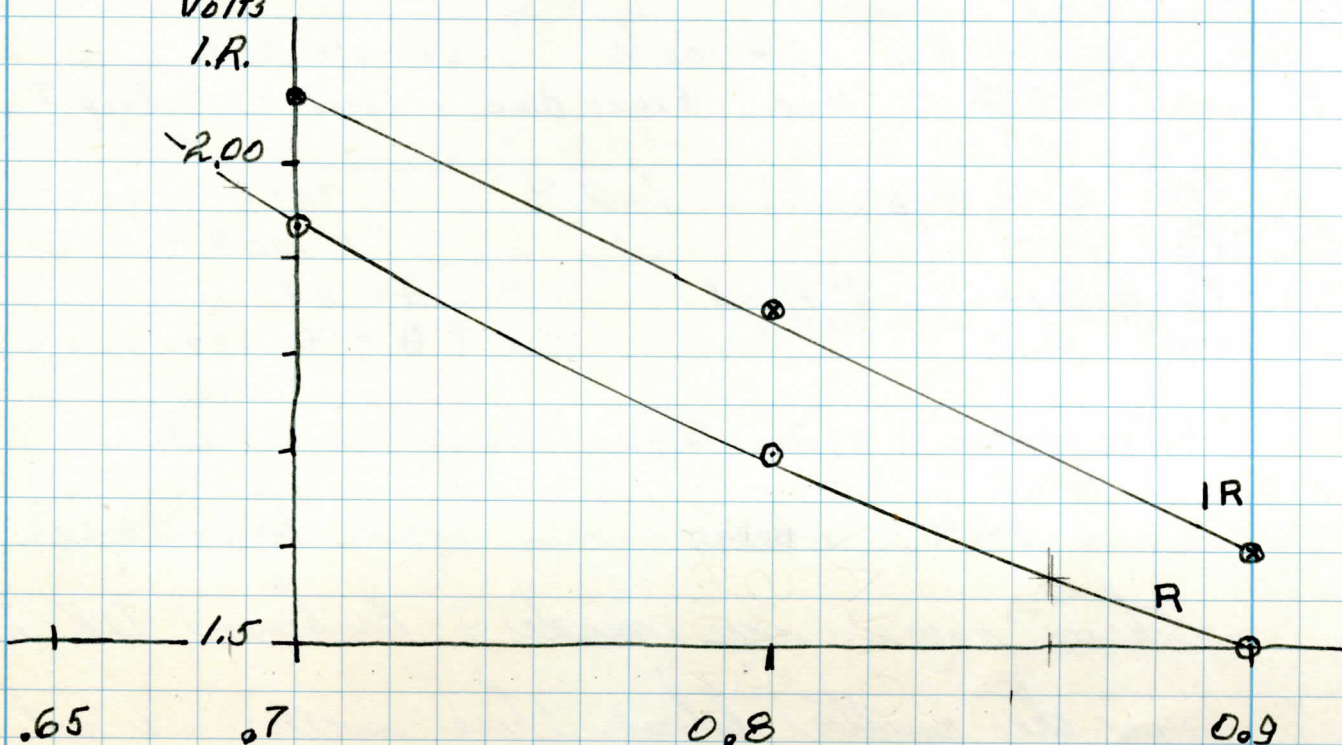
1.93 N.D. Filt. D = 1.70 .70
2.07 1.85
1.85 1.70 + #8 ol D
1.60 1.50 above + #7 ol D
2.07 1.94 .70 only

Meas. made $\bar{z}$ gap =
pinna (R) ear & c
capsule in place

$$E = \frac{D(\text{dens})}{\text{Path}(d)}$$

Volts
I.R.

$$D = E d$$



For I.R. press up-down difference of 1.97 to 1.57 $\Delta D = 0.171$

Assuming no desaturation & using value of E_{HbO} at 805 μ from Drabkin of 0.228 d would be.

$$|E, d = D \quad \& \quad d = \frac{D}{E} = \frac{0.171}{0.228} \approx 0.7 \text{ cm} = 7 \text{ mm.}$$

$d = 1 \text{ cm}$

Such a path length is impossible. ~~meaning complete desaturation~~

~~unlikely - expect the answer will lie in measurement of whole blood E.~~

Meas. of non-hemolyzed blood $\bar{c}$ short d.
Calib. of cuvette:

A- 1st Run 0 + 100% - sample slit
2nd " Undil. Evans Blue - Speed-50 Resp. T. 2

① - 2 - H₂O blanks $d = 10^{-3}$ " A- 0-1 } TC = 2 Sp = 20
② - " " " " T = 100% }
③ - Hemolyzed blood - A- 0-1
④ - " " " T - 0-100

1' - 0-100% H₂O blanks -
2 - 0-1 " "
3 - 0-100% T Blood

These meas. were made $\bar{c}$ Beckman DK-2
using the cuvettes below. These cuvettes are not
balanced as a function of wavelength, possibly because
of the thickness of lucite. Path length $d = 10^{-3}$ " or:

$$1" = 2.54 \text{ cm. } \&$$

$$1.0 \times 10^{-3} = 3.254 \times 10^{-3} \text{ cm}$$

$$= \frac{.0025}{75} \text{ cm}$$

$$= \frac{.025}{75} \text{ mm.}$$

1.0 x 10⁻³ was not in fact used.

Calculation of ϵ

From 2° Record

$$\epsilon \left| \begin{array}{l} 1 \text{ cm.} \\ \lambda = 575 \text{ m\mu} \end{array} \right. = \frac{\text{Dens}}{d \times C(\text{conc})}$$

MW Hgb - 16,700 (White) P-147

$$d = 2.54 \times 10^{-3} \text{ cm} \quad D = 0.525$$

$$C(\text{conc}) = 8.8 \text{ mM/mL}$$

(value not avail at this time)

$$= \frac{0.525}{2.54 \times 8.8 \times 10^{-3} \times 3}$$

$$= \frac{52.5 \times 10^{-2}}{3 \times 22.3 \times 10^{-3}} = \frac{7.6}{2.3} \times 10 = \boxed{2.3} \boxed{7.6} \quad (8.5)$$

This is approx. ^{10.5% <} value given by Drabkin ~~(8.5)~~
Recalculate using transmission -

$$\text{Dens} = -\log \frac{I}{I_0} = \log \frac{I_0}{I} = \log \frac{1}{.31} = \log 3.25$$

$$2^\circ \text{ run has value of } = \frac{0.513}{\approx 0.45} \quad \text{negl. diff. from above.}$$

> Most obvious source of error would be light path - zero may have been incorrectly set.
As expected from previous experience the values of ϵ from pure Hgb are not those of whole blood.

Light scattering by the corpuscles undoubtedly raises the ϵ . Looking at today's record it appears that a background which varies as $f\left(\frac{1}{\lambda}\right)$ is present & only the denser portions of the Hgb dye superimposed. Looking at this "background curve" it appears to have ~~three~~ two or possibly 3 slopes of the form $Y = \frac{-AX}{\lambda} + K$

1.0x10⁻³ was not in fact used.
It was 3x10⁻³ -

$$Y = \text{Density}$$

$$= -\log T$$

$$= \log \frac{I_0}{I}$$

From a region of ~ 650 to $1000 \text{ m}\mu$

the line has a slope of: $A_1 = -\frac{Y}{X} = -\frac{1.35 - 1.26}{1000 - 650} = -\frac{.09}{350 \text{ m}\mu}$

①

$$= -.257 D/\mu$$

$$* K = +.257 D/\mu \cdot X + Y$$

$$X = \lambda(\text{m}\mu)$$

$$Y = -.257 D/\mu \cdot X(\mu) + 1.517 D$$

$$= .257 D/\mu \times 1\mu + 1.26 D$$

$$= 1.517 D$$

②

Thus at 1μ where $E_{H_2O} \left| \begin{smallmatrix} 1 \text{ cm} \\ 1 \text{ mm} \end{smallmatrix} \right. = .25$ the equivalent E is: $E = \frac{1.26}{3 \times 2.54 \times 10^{-3} \times 8.8}$

$$= \frac{1.26}{76.2 \times 8.8 \times 10^{-3} \times .067} = \frac{1.26}{.041} = \boxed{1.84}$$

* the value depends on the area of the photo

② doubt that corrections were for C h i.e.

Turbidity effects:

Drabkin (Journal of Biological Chemistry, V-129 P-739 '39) was unable to compute ^{meas.} the effects of turbidity but empirically ~~derived~~ * the constants for various erythrocyte suspensions as follows - $E_{total} = E_{p.g.} + E_{scattered} = -\log T$

* the values $\bar{c}$ depend upon the optical arrangement of the photometer

$$* E_s = E_t - E_p \times F.(N) . \text{ He found that } F.(N) \cong 1 \text{ for } RBC > 3.6 \times 10^6 / \text{mm}^3 . \text{ I'm looking}$$

at λ_0 from 630 - 500 m μ E_s varied 1.836 - 1.793.

Hock (Biochimica et Biophysica Acta Vol 51 - P-429 '61)

Ⓢ doubt that corrections were made for $d \times \bar{c}$ here i.e. $E = f(\bar{c})$

states that the turbidity cannot presently be computed for erythrocytes - Mie's solution for spheres can be computed & is of the form $A = K / \lambda^2$.

Thus it appears that even though the E_s may be measured $\bar{c}$ blood, its value will depend upon the instrument used and will in any event probably be modified by the ear as compared to in vitro measurements.

Blood path length
 Out of curiosity a hypothetical blood path length for the core will be calculated using E_{Total} values measured and the values of the water's densitometer. $E_{805, Total} = \frac{D}{d}$ & $d = \frac{D_{Dens}}{E}$

$$E_{Tot} = \frac{1.375}{0.067} = \frac{1.38}{0.67} \times 10 \approx 20.$$

$$= \frac{0.171}{20}$$

$$= 0.0085 \text{ cm}$$

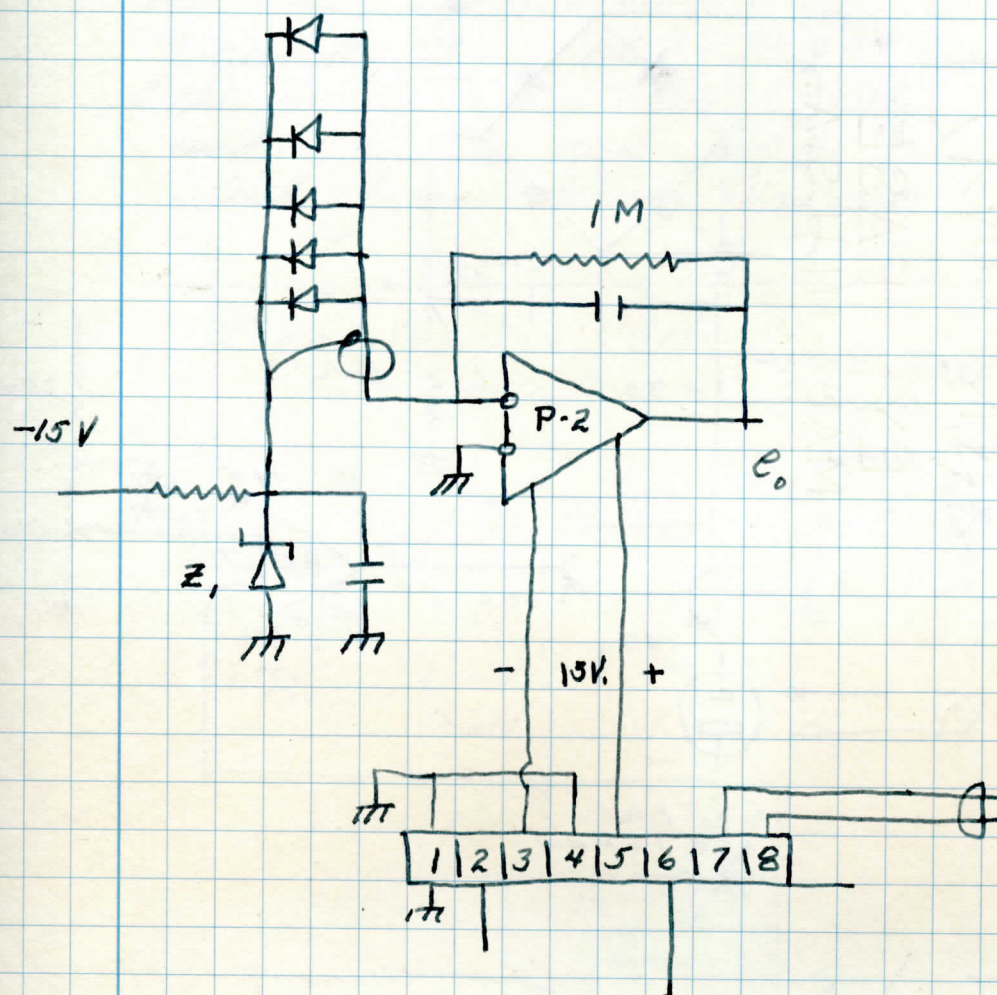
$$= 0.085 \text{ mm}$$

This value is not unreasonable —
 Also approximates value used in calculations of

Determination of E for whole blood

It now appears impractical to measure and accurately compare the turbidity effects from one densitometer to another but some effort will be made to determine its magnitude on the DK-2 spectrophotometer using $d = .003$ " cuvettes. Runs will be made on the following. 3 fresh samples each
① fully sat. (by O_2) and desat. (by N_2) blood,
hemolyzed and unhemolyzed ② plasma densities also determined.

Continued attempts to complete densitometer.



(Z₁ replaced by 5.4V battery)
With the above arrangement + the head shown
on P. 92 the following were obtained on pinna D ear.
Rubber dam was used.

Press - Volts (805)
Off - ~.5
On - ~.9

Volts (635)
.055
.09

Dark current was
not measurable on
15 mV scale.

DVM

Dark
Off

.000

On

.867

On

1.55

-

.750

.925

1.49 2.93

On

.475

.460

~~2.00~~ 1.40

Δ On-Off

.275

.465

1.53

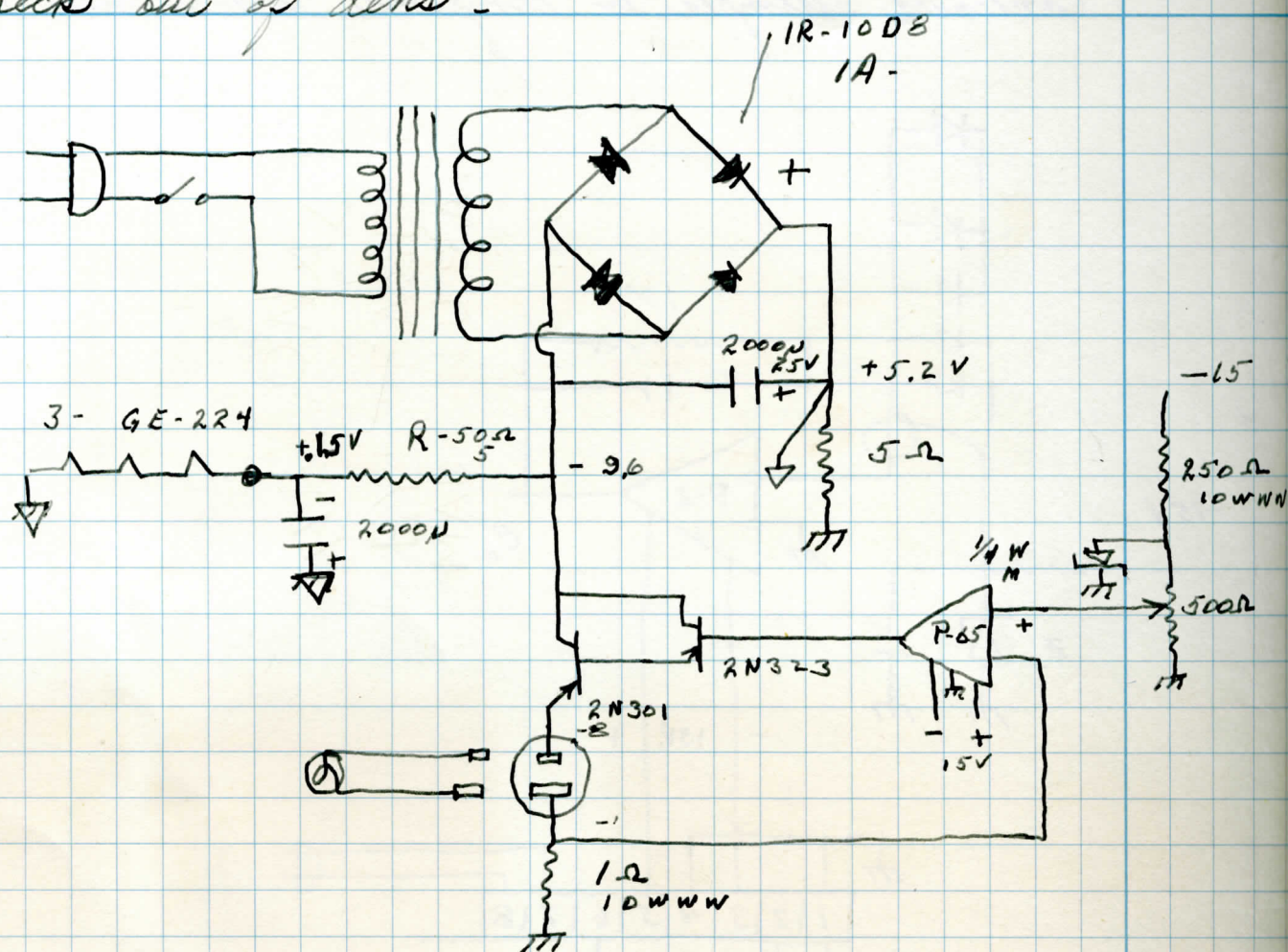
% " " Δ/off

57

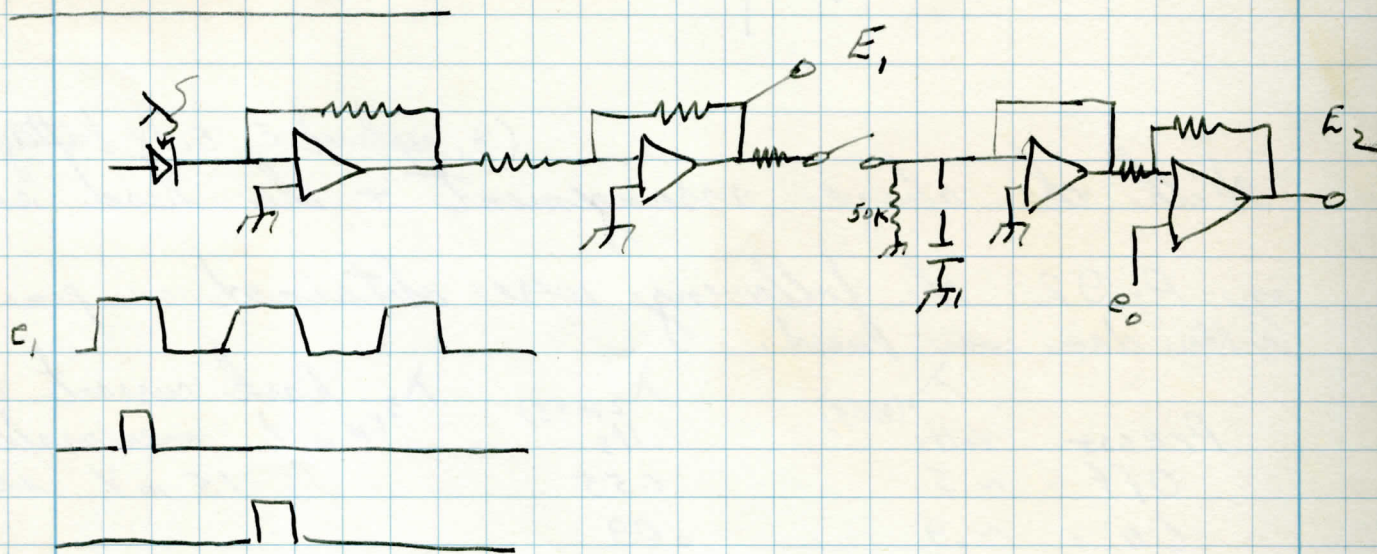
101

109

Check out of dens -



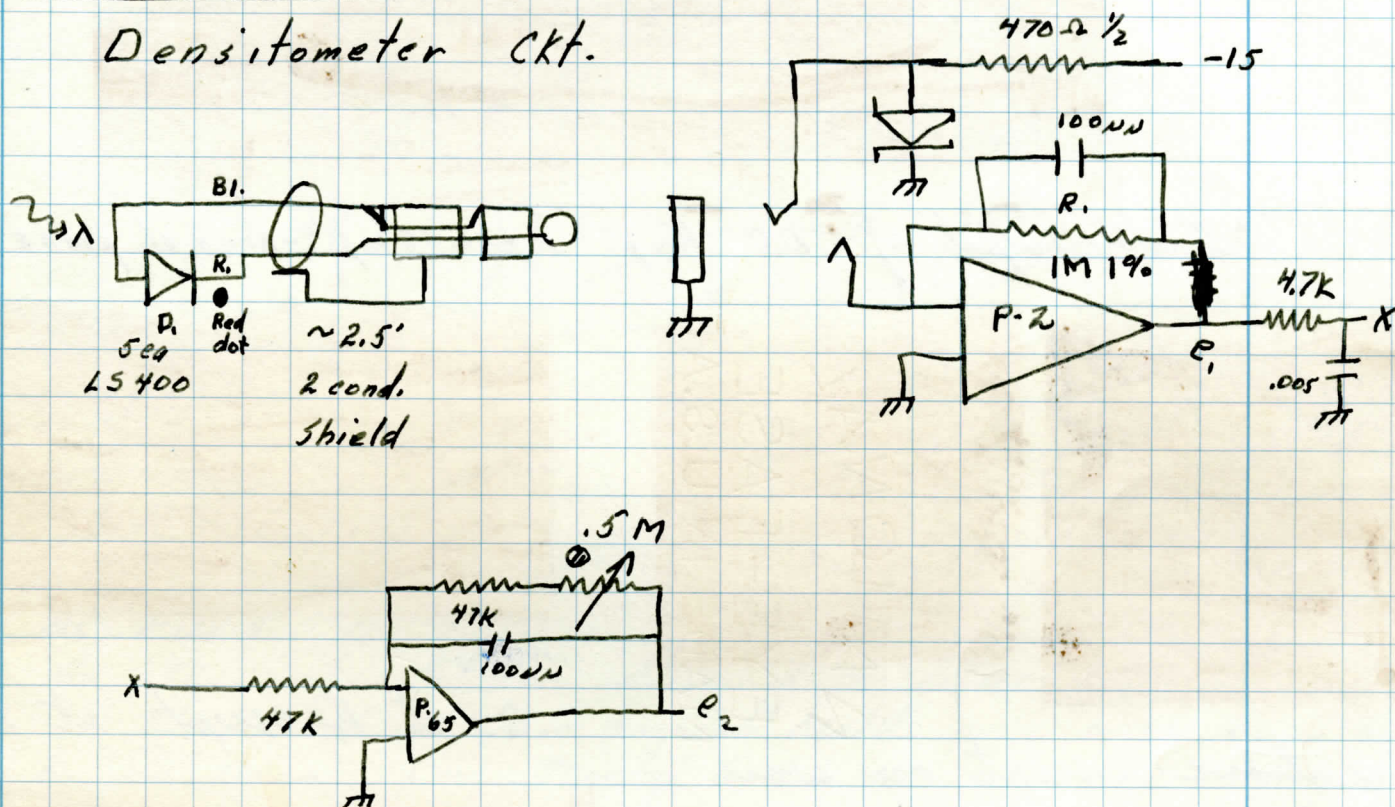
$$R = .2$$



15 Sep.

The Borg Amphenol 1001-45V motor was not in synchronism. Called Mr. Kordhezy at Jonesville Wis. 608-754-2211 who suggested that the problem was too great a moment of inertia, and that the next larger unit be used. This was ordered from Allied Radio.

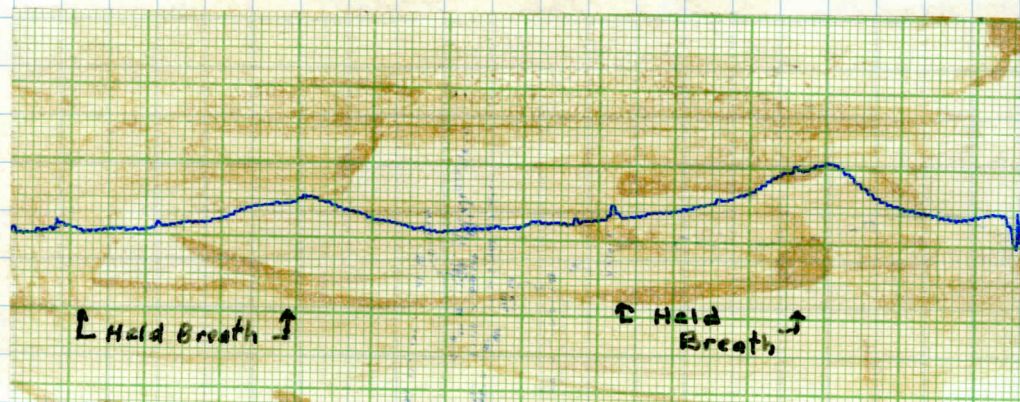
Densitometer Ckt.



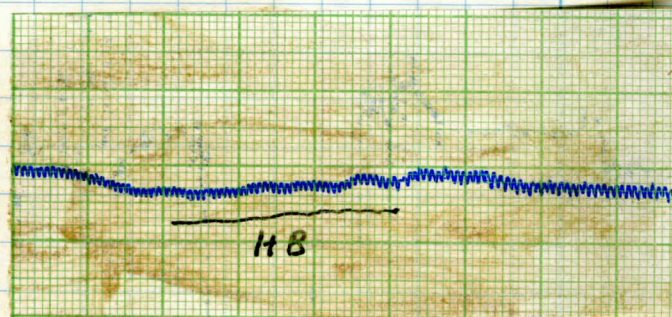
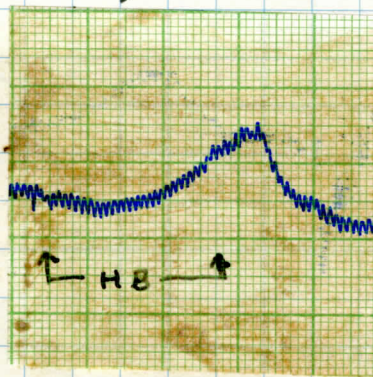
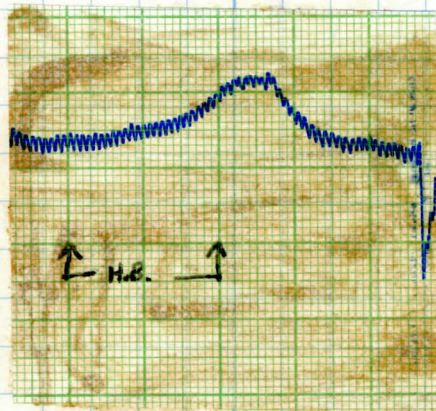
$\bar{C} R_1 = 1 + 0.1M$ in Parallel. & $\bar{C}$ rubber cap in place

	λ_1	λ_2	λ_3	
	805	630	1100	
$\bar{C}$ ND filter				
~.3" Gap	.994	1.59	.578	
0 "	1.67	2.68	.952	
ΔF	.00	.00	.005	gap
$e_1 = -20pV$ ^{Cells} Dark D.C.	3.59	11.1	2.88	Capsule infl. $\bar{C}$ ND
" Conn. + dark $\bar{C}$ Conn	1.56	4.05	1.63	
" " " "	1.57	.881	.923	Capsule not infl
" " " "	.048	.052	.037	" @ 200 mm Hg.
				$\bar{C}$ Cap. on ear

The curves below were run as a cursory exam of the ear and earpiece behavior.

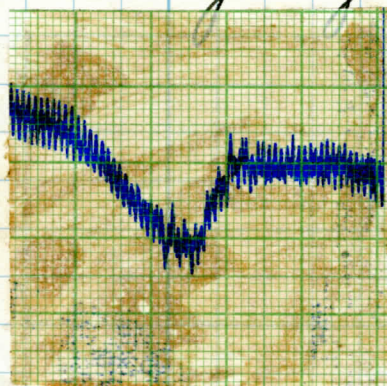


From output of D.C. Amp. $\lambda = 635 \text{ m}\mu$ - Normal pinna ? 5 cm min.

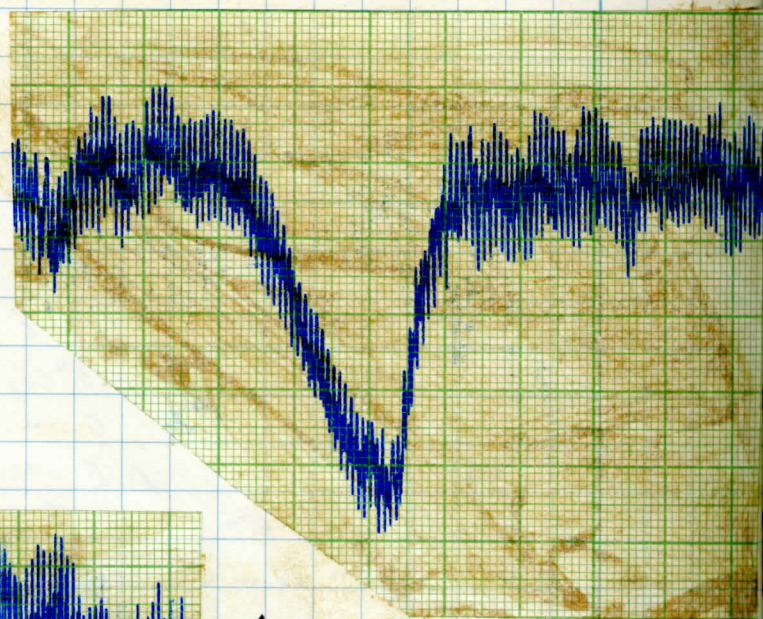


as above except ear was flushed by vigorous rubbing

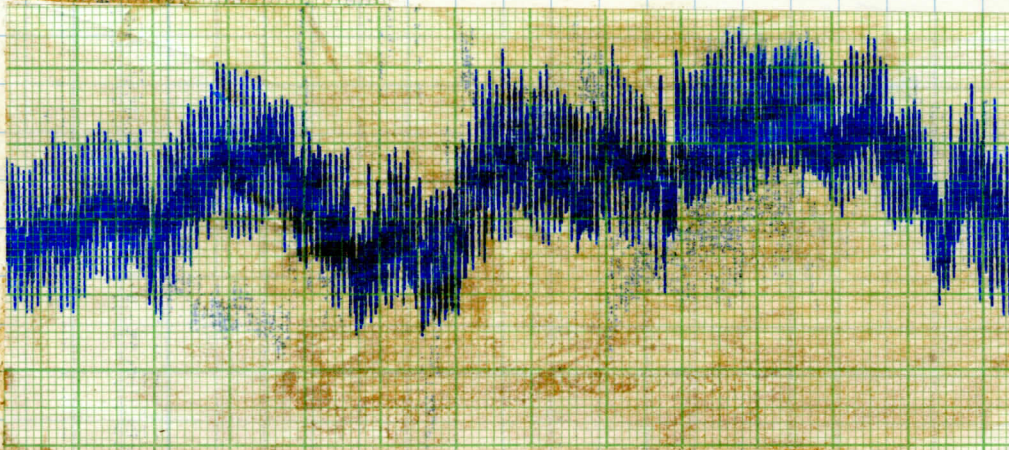
as at ② except at $1,100 \mu$

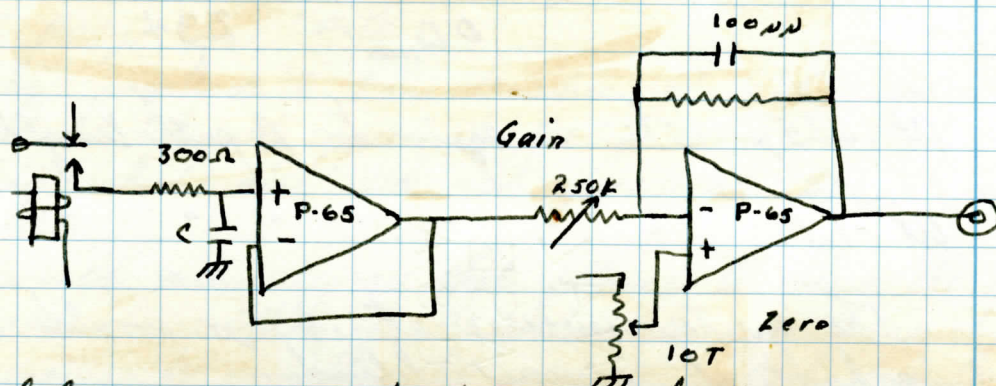
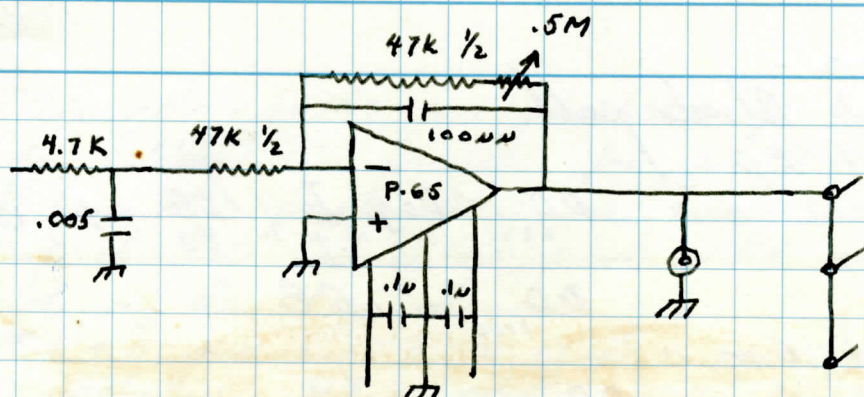


Shaw commutator
Held breath at
 $635 \text{ m}\mu$ R+L
↑ gain on ②



Same gain as above
at $1100 \text{ m}\mu$ -
Held breath - only
artefacts





The amplifier time constant was short. $\bar{e} C = .1 \mu$ and would drift rapidly to an equilibrium posn. well off zero. Called Mr. David who confirmed that the P-65 would have only 10 M imp. $\bar{e} 10^{-8} A$ current under these conditions & suggested the P-75A. A 5μ was used in all channel to extend the T.C. such that slow rotation of the device could be recorded. As 21 Y.O. A/B 155# in normal health was used as a subj. $\bar{e}$ (2) pinna. Two Mosley 608C recorders were used for recording 2 of 3 channels.

The first run was made on normal ear $\bar{e} 635 + 1,100 \text{ m}\mu$ recorded $\bar{e}$ the light completely blocked for 0 (∞ sens) and at max. $\bar{e}$ the capsule inflated to 200 mm. Hg. A N.D.(?) filter of O.D. = .01 was inserted for gain cal.

Run 2 O.D. Cal.		1 st Run		Press. Off Caps./Press. on Cap.	
48 to 29	635	635 m μ	89 mm/120 mm	"	"
62 to 70	1100	1,100 "	100/120 "	"	"
2 ^o Run Flushed Ear.					
2 ^o Run		Ear Rubbed			
	635 m μ	49/120 mm	P.D./P.D.		
	1100 "	61/120 "	" "		

Calculations -

Dens. of Blood path:

Normal Ear

$$\lambda = 635$$

$$OD_{635} = \log \frac{I_0}{I} \approx \frac{120}{89} = \log 1.35 = .078 \approx .13$$

$$OD_{1100} = .08$$

Flushed Ear

$$OD_{635} = 3.9$$

$$OD_{1100} = 2.94$$

$$E_{635}^{tot} = \frac{OD}{L.C.} = 3.9$$

$$E_{1100}^{tot} = \frac{2.94}{L.C.}$$

$$\log \frac{I_0}{I} = O.D. =$$

$$E [C] d$$

At .635 μ This is equiv. to A path length of $\frac{3.9}{.13} = 30 \times !$ At 1.1 " " " " " " " $\frac{2.94}{.08} = 35 \times !$

$$\frac{O.D._1}{O.D._2} = \frac{E_1 [C] d_1}{E_2 [C] d_2}$$

$$d_2 = \frac{d_1 O.D._1}{O.D._2}$$

$$\frac{2.4}{13.2}$$

The greater increase at .635 μ would be predicted by washout of venous blood.The first run $\equiv$ flushing displayed no appreciable displacement after 18 secs. of voluntary holding of breath after exhalation. No change detected in the 1.1 μ channel.Although it is not applicable for a variety of reasons, E values from Kramer will be substituted for estimates of path length.

$$E_{635}^{Hb} \approx 4 \times 10^{-6} \frac{cm^2}{M}$$

$$E_{635}^{HbO} \approx 1.8 \times 10^{-6}$$

$$E_{1100}^{Hb} \approx 1.6 \times 10^{-6} "$$

$$E_{1100}^{HbO} \approx 1.8 " "$$

$$O.D. = [C] e d$$

The path obviously does not consist of desaturated blood but taking as an estimate $E = 2 \times 10^{-6} cm^2/M$
 $[C] = 8.98 mM/\mu$

$$d = \frac{O.D.}{[C] E} = \frac{2.94}{8.98 \cdot 2 \cdot 10^{-6} cm^2/M \cdot \frac{mM}{cm^3} \cdot 10^3 \cdot 10^3} = 164 \times 10^3$$

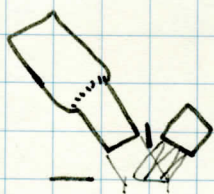
$$\approx 164 mm$$

The second run $\bar{c}$ ear flushed by rubbing consisted of subj. holding his breath for ≈ 30 sec. 3 times. Each time the desaturation was nicely demonstrated on the $635\text{ m}\mu$ channel but at no point could the change be detected on the 1.1μ channel.

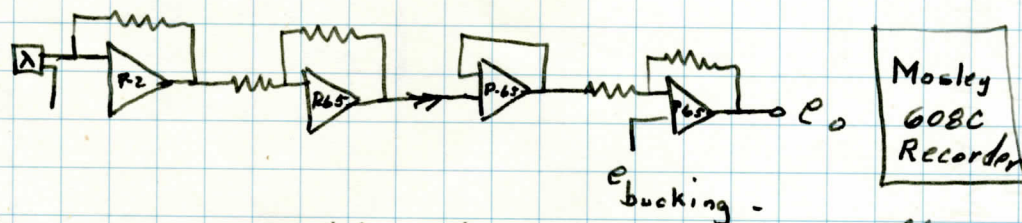
#5 + #6 were run $\bar{c}$ $\approx$ equal & increased gain on all channels. Large deflections were recorded $\bar{c}$ $\sim 30^\circ$ breath holding on $.635\mu$ $\bar{c}$ 1.1μ sl. decrease in density on 1.1μ on #5 + small $\uparrow$ in density at $.805\mu$ on #6.

The subj. smoked $\bar{c}$ $\uparrow$ in densities at $.635\mu$ correlated $\bar{c}$ inhalation which did not appear at $.805\mu$ and one additional breath holding which also did not appear at $.805\mu$ in spite of large change at $.635\mu$.

It would now appear that filtering to obtain the max. sig. noise ratio $\bar{c}$ recording of all 3 channels simultaneously is all that remains to complete the series $\bar{c}$ several more subjects. $12\%O_2 + 100\%$ might be used for academic interest. Other possibilities are exploration of digits or other area of the body, and/or reflection oximetry.



A cursory look was made taken at the behavior of the digital pulse. The densitometer was connected as below.



The gain was $\uparrow$ until pulse was readily visible including the dirotic notch although the record was undoubtedly damped. Several phenomena were noted $\bar{c}$ voluntary breath holding after max. expir.

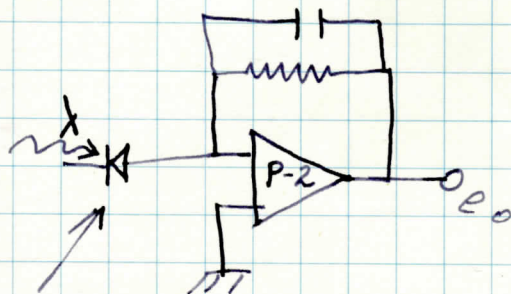
Run 1 $\lambda = \text{EE } 635$

(over)

26 Oct. - '65

Confirm results of oximetry at 805 + 1100 mμ.

1. Examine behavior of earpiece-



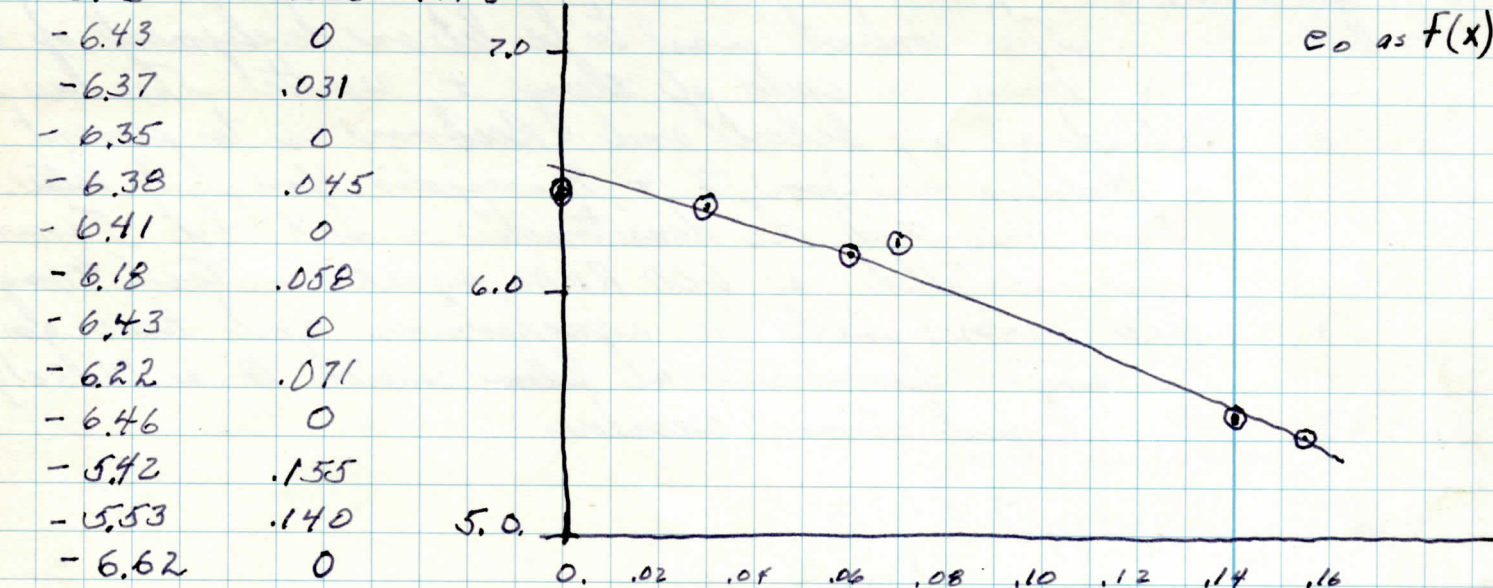
Average thickness of pinna of 6 ears compressed to micrometer by ratcheting to stop was .11"

4 ea L-5600

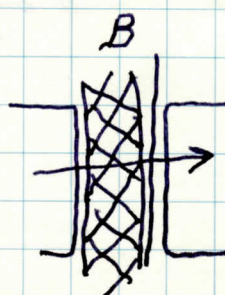
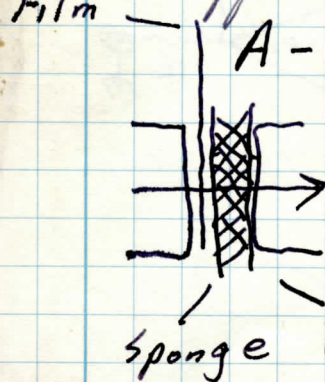
E_o Volts.	Condition
+ .012	Dark
+ .008	3 input
	Dark I



Sensors Adj. to fibre optics - + light reduced by mesh -
 $\times$.016 Volts



Effect of densities inserted between sensor + optics.



E_o	A	B	A
Dens Film			
$\lambda = 620$	0	1.65	1.72
	.1	1.12	1.85
		.53	.57
$\lambda = 805$	0		.684
	.1		.598
$\lambda = 1100$	0		1.10
	.1		.980
			.926

27 Jan.

Connected as shown some records were run using the original earpiece (single capsule, 25600 sensors etc.) and my right ear. The ① record was run in unrubbed ear and holding breath for ~ 30 sec. $\bar{5}$ calib. The usual response was obtained in the 805 λ showing an $\uparrow$ density until in pulse & total density until the first breath; $\bar{5}$ then a plateau & decrease. ~~Wm~~ The 635 λ density increases not at all for the first 20⁺ sec & then rises rather rapidly and continues to rise for ~ 10 sec. after resumption of resp. and then to decrease slowly. This is probably due to the relatively large quan- of venous blood in the path.

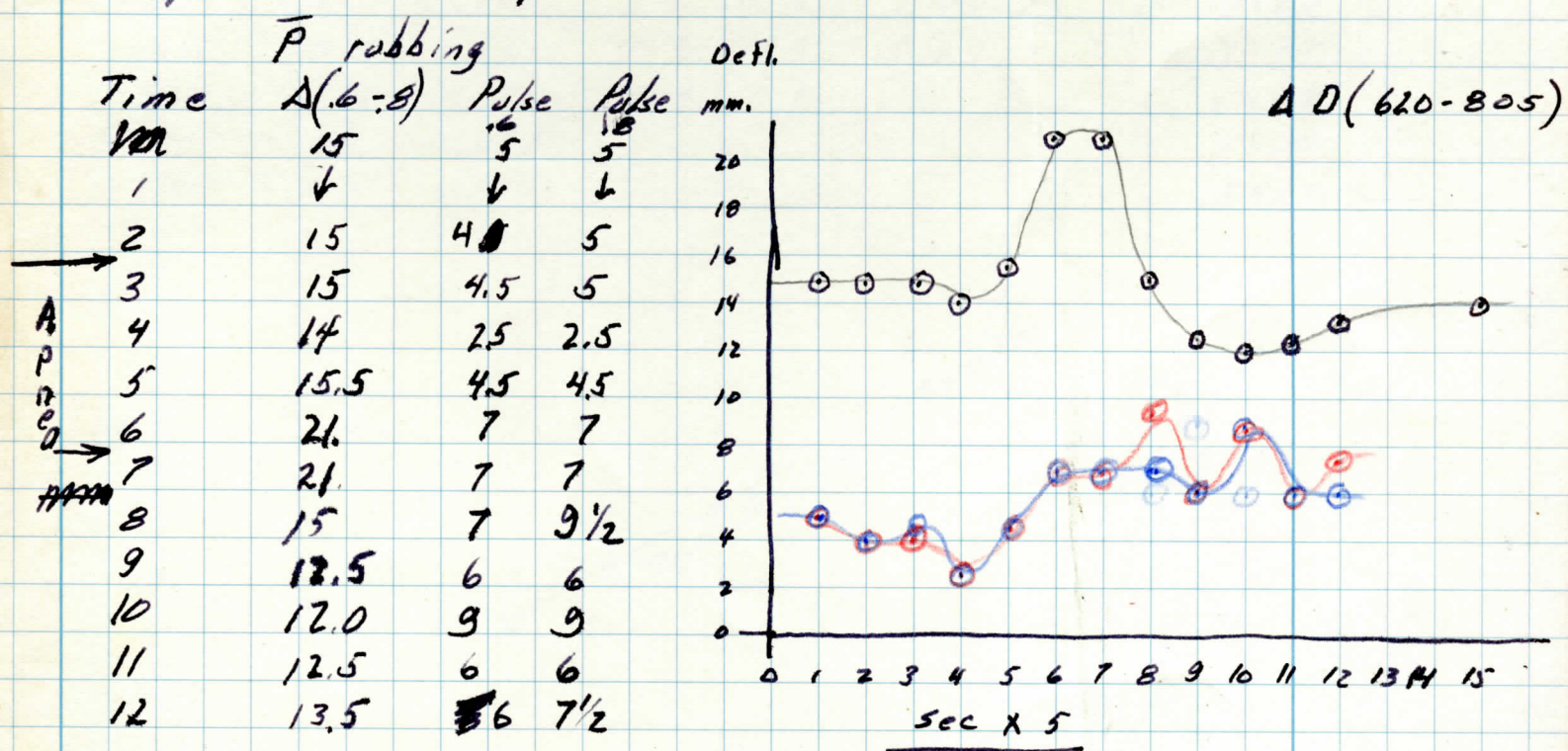
The same breath holding maneuver was next done in one pen recording 1.1 μ & the other .805.

As usual there was no appreciable response - see next pg. Two add. runs were made at .8 & .6 in the same results.

28 Jan

The same electronics were used as on 27 and the earpiece was connected to a headband. Run ① was simple breath holding & film partially exposed as a density calib. by simple insertion in the light path, $\bar{p}$ monochromator. Pulses were only $1/33$ of a .1 D change at 805.

② After rubbing ear the pulse ht. $\uparrow$ to $2/22$ of a .1 D change. Tab. below are differences in dias. pulse & pulse ampl. taken q 5 sec.

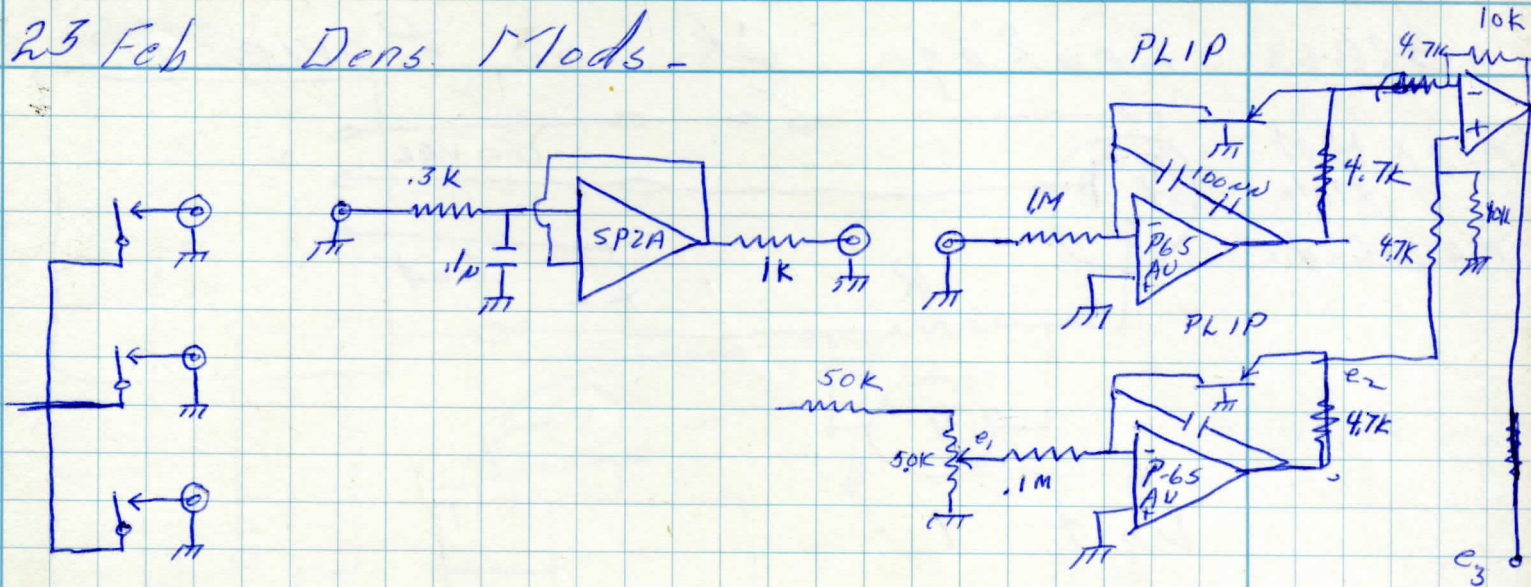


15

14

The above record is consistent & a large amount of venous blood present which is washed out $\bar{p}$ apnea and then slowly returns to normal. This is exp. true taken breathing 100% O_2 & the above to 3 mm.

23 Feb Dens. Mods -

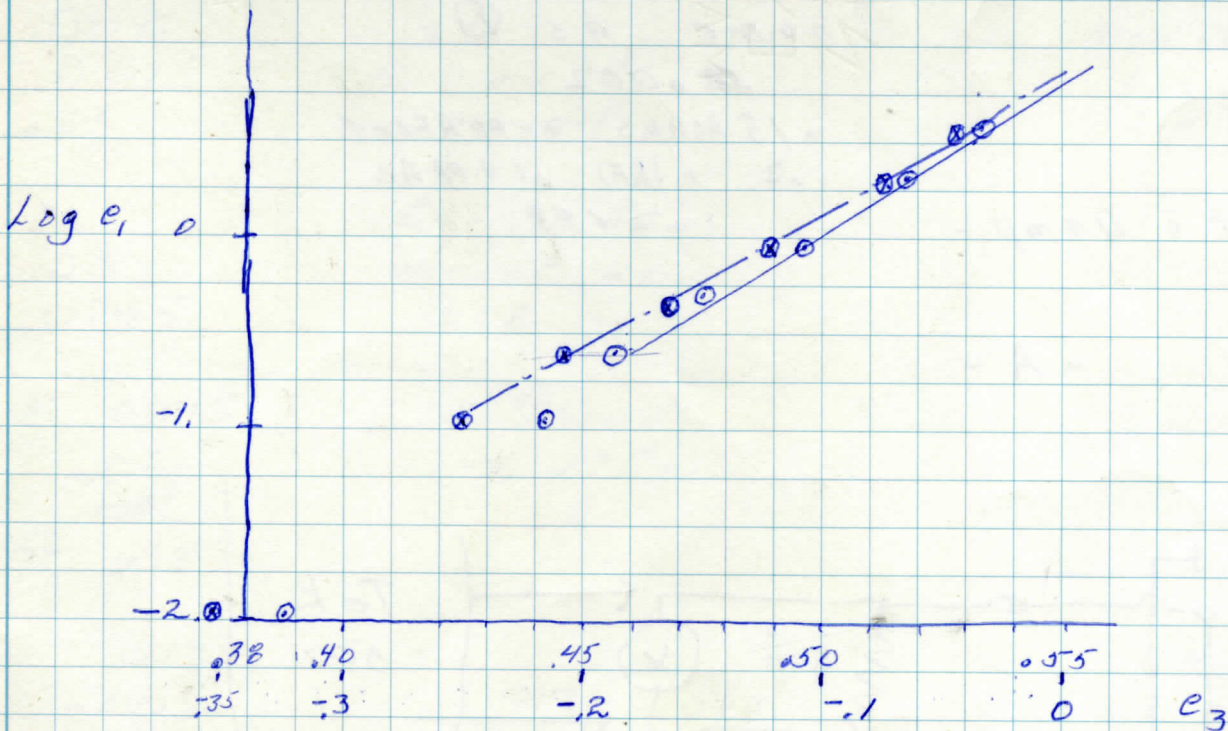


st-

H.P.-D.V.M.

10⁻⁷

	e_1	e_2	e_3		e_2	e_3		$\log e_1$
1	-.112	+.442	-.246					- .9508
2	-.011	+.388	-.356	1-2	.054	.110		-1.9508
3	-.224	+.457	-.207	3-1	.015	+.49.039		- .6126
4	-.448	+.475	-.163	4-3	.018	.044		- .3487
5	-.896	+.496	-.121	5-4	1			- .0477
6	-.200	+.518	-.077					.3010
7	-.355	+.533	-.046					.5502



From records today it appears that