

23

Feb. 66



COMPUTATION NOTE BOOK

43-648

Course EEG

Name W^m Thornton, M.D.

5131 Lancelot Dr. OL-54763

2 Feb. 66

Problem: Automatic Analysis of sleep EEG records -

Proposed method - Apply D.K. criteria by analog methodology.

Stage 0 - 60 sec. Epochs -

≥ 30 sec. of $8-12 \pm \frac{1}{2}$ C.P.S. $> 20 \mu V$.

subject must have $20 \mu V$ of occipital & electrodes > 3 cm. apart

scored by one second intervals - entire second if counted if $\geq 50\%$ of second has activity

Stage I - < 30 sec. $8-12$ C.P.S. $\geq 20 \mu V$.
no more than 1 K complex or spindle
 $13-16$ C.P.S. for spindles

Stage II ≥ 2 spindles + K complex & ≤ 12 sec.
of $1-3$ C.P.S. $20 \mu V$.

Stage III ≥ 13 sec. & ≤ 30 sec. of $1-3$ C.P.S. $> 20 \mu V$
N.B. Only frontal & central traces.

Stage IV ≥ 30 sec. of $1-3$ C.P.S. $> 20 \mu V$.
N.B. Only frontal or central leads.

Looking at this criteria a series of problems are obvious:

1. filters to differentiate activity
2. amplitude discriminator to classify filtered sigs.
3. time dependent detector to classify 1 sec. epochs
4. times summation for 1 sec. epochs
5. time discriminator
6. some method of identifying λ complexes + spindles (most apparently complex problem)

1. Filters -

8 - 12 Cps - possibly $\pm$ some variation in limits to accommodate individual variation. roll off slopes should be steep - >20 db. octave or more

13-16 Cps - steep slope - for spindles

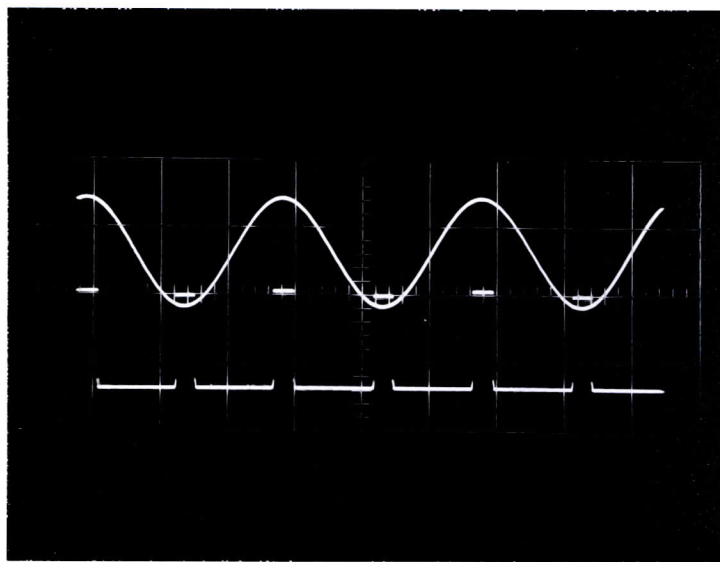
1-3 Cps - Δ activity

Active elements using op. amps. would be desirable - (called David at Philbrick + he promised literature)

4th SKR + UTC could offer nothing

Mr. McClean

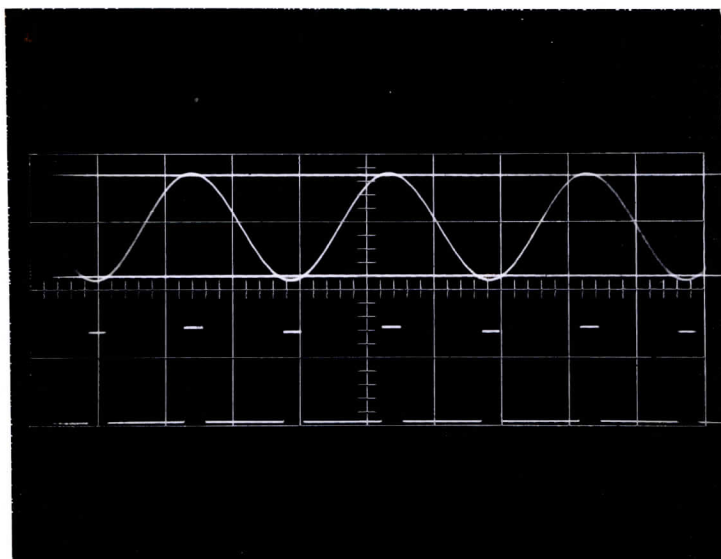
Spectrum Instruments Tuckahoe N.Y. 914 SP 98111
promised 7-10 day delivery of a band pass unit
2 to 20K C - ordered R + Stewer's unit -



5 V/cm

~ 3.5 CPS

10 V/cm



+E →

-E →

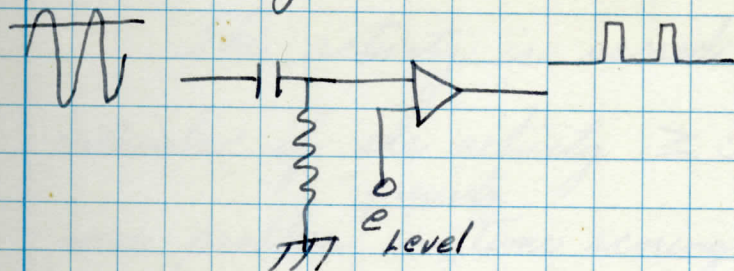
5 V/cm

~

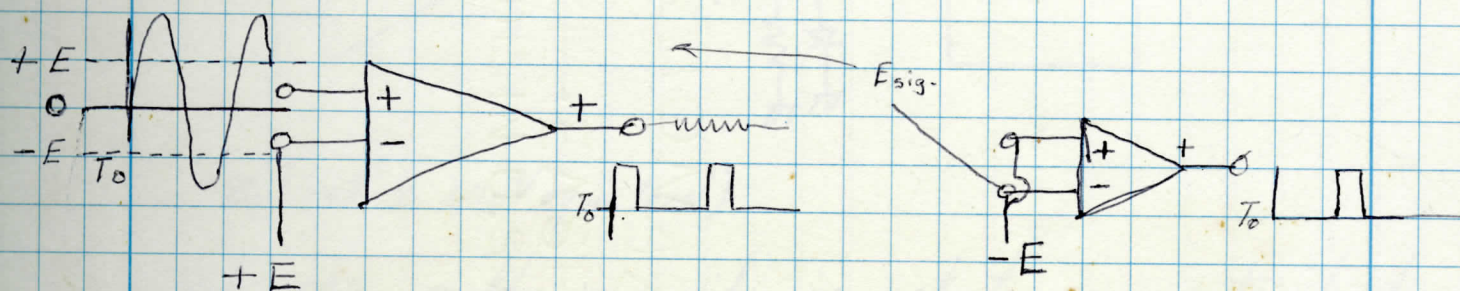
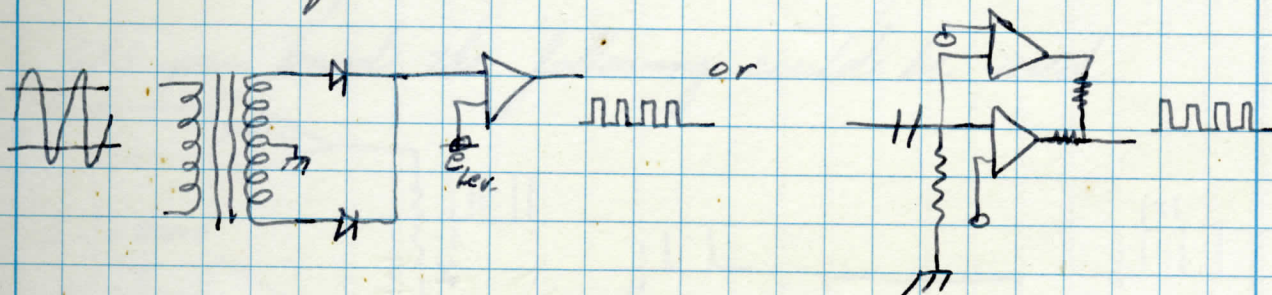
10 V/cm

5 V/cm

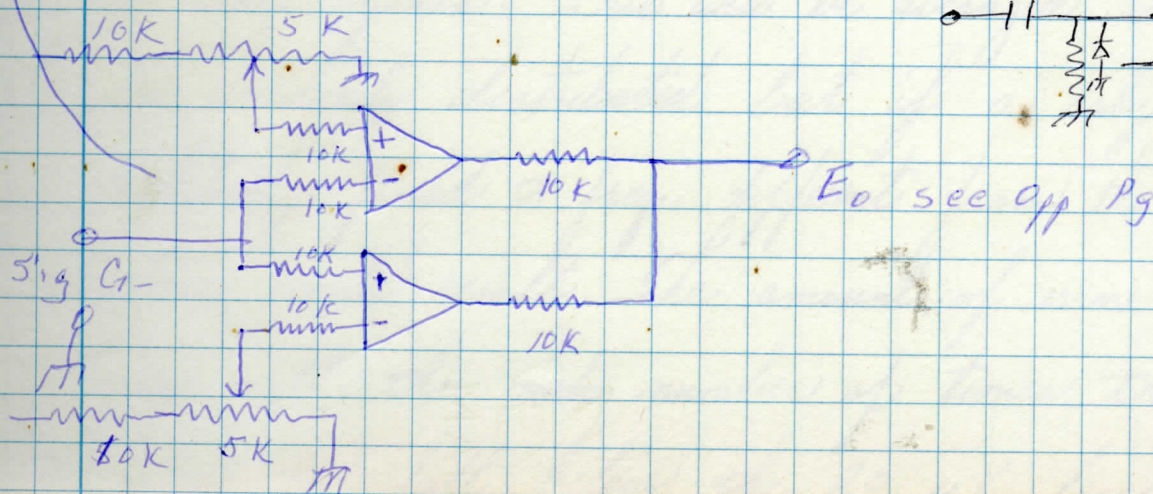
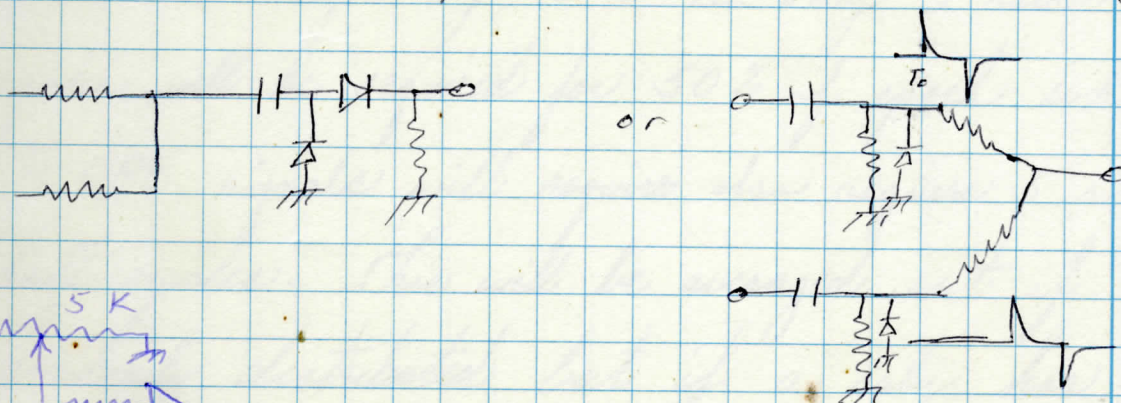
2) Voltage discriminator



or a full wave -

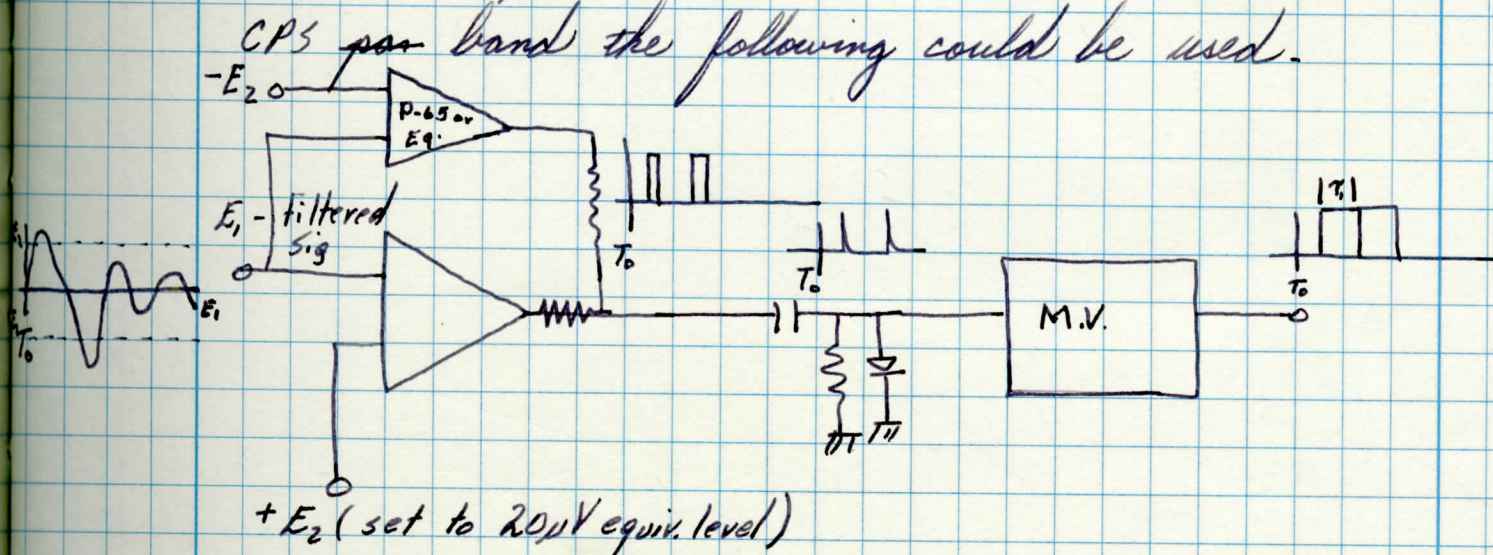


Above scheme looks reasonable. Outputs must be mixed and used to trigger a scaler or other arrangement.



3) Time dependent discriminator

The activity is scored in discrete one second intervals if the activity $\geq 50\%$ - There will be some problem in ^{precisely} time scoring a band of frequencies $\therefore$ resort to complex circuits. For example: in the 8 to 12 CPS par band the following could be used.



If the ~~max~~ uni-vib. is set to some standard width say $\frac{1}{2}$ of $\frac{1}{f}$ or $.5 \times 100 \text{ ms}$ for 10 N. then 12 N signals will be scored high by 20% i.e. only 5 rather than six cycles will be required for 50% of epoch while the 8 C.P.S. signals will ~~require~~ also require 5 rather than 4 half cycles. This will be averaged out if the frequencies are randomly distributed but if a subj. has a relatively fixed α freq. different from the center freq. errors could result. The amount of error will also vary with the ~~max~~ number of times that the signals exceed and fall below the 20 uV level.

4 Mar. '66

The basic scheme shown on the preceding pages is being implemented in Biomedeng. by Fromme Jeter et al. Two LH 42 D active filters have been acquired from Spectrum instruments, Tuckahoe N.Y., continuously variable from .02 to 20 KC on both high & low sides & slopes of 42 db./octave. Curves have been run on the filters & adequate calibration. After abrupt cessation of a signal (sine) ~ 3 cycles are required to reach zero.

So far they have: 2 filters, 1 level detector - (too complex), tape playback facilities including search, a one pulse/sec. signal and 160 pps. divider (1 min. pulse), a relay for up to 60 sec. summation; still needed are the events meters for the one second epochs and a rapid ~~pro~~ developer. See next pg.¹⁵ for planned arrangement.

Currently scheduled to see Hawkins UNC, on 9+10, Dr. Procter Henry Ford 11th, Heath 16th

EEG Meas-

Freq. Resp. Curves
Grass

" + Recorder

Harmonic Dist.

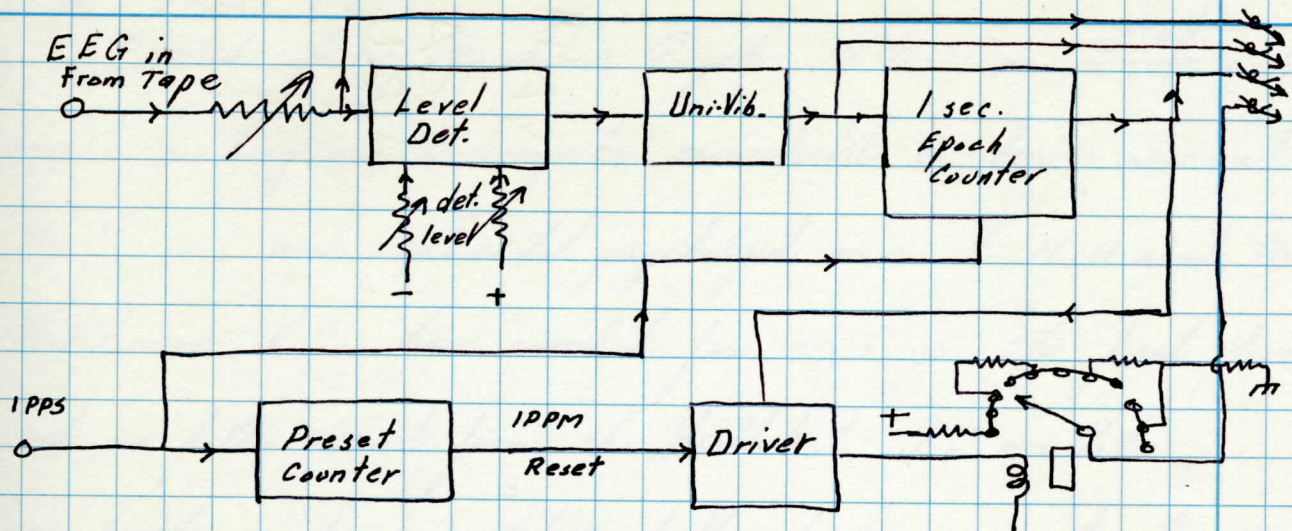
Noise Meas-

Calib. 1. $25 \pm 50 \mu V$ at 1 hr. periods at 2, 4, 10, 13, cps

2. 20 K Res - ≈ 0 in. at start & end of run -
Res CK-

3. Res. CK - Q1hr

4. Record at .3 LF + 70 HF. $\approx 60 \sim$ filt. in

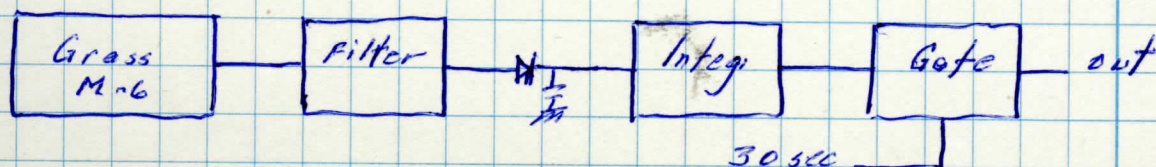


12 Mar. 66

Visited Dave Hawkins, Psych. U.M.C. on ~~Pres.~~ ^{Pres.} whose group is working on a 'computer' incidental to brain research.

Mr. [?] an experimental psychologist now at NIH and Mr. Stan Hutchinson E.E. have worked for ~ 1 yr. The first device used a filter derived from the Heathkit R.C. oscillator, very broad, and a rectifier followed by an integrator. A time The deeper stages of sleep were scored to a high degree of accuracy 80-90% but lighter stages were not so successful. In addition there was ambiguity between lighter + deeper phases stages caused by fast activity on the Δ activity. This early unit is being revised to a digital scheme using zero crossing. Frequency discrimination will be accomplished from this and the ~~frequencies~~ periods of a given spectral range summated over 30 sec. epochs. They plan to begin operations to this device in June.

Their records are now being manually scored on a modified D.K. procedure. Hawkins pointed out the confusion that occasionally arises between the deep REM sleep of animals + the light REM sleep of humans.



Diag. CKT.

Fri.

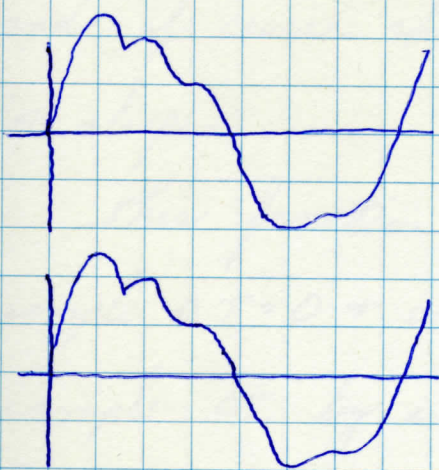
Spent day in Lorn Proctor chief Neuro-Psy Henry Ford Hosp. -
and H. Cram Ph.D. neurophysiology, Dr. Renss Ph.D. neurophysiology
then C. de Vries a Dutch EE. They have a variety of programs
extending over a number of years supported by the AF + NASA
dealing primarily in performance decrement.

The most interesting of these involved a rapidly fatiguing
procedure in EEG analysis - A meter is fed a slow sine wave
 $\sim .5$ C.P.S. and observed by the subject

16 Mar.

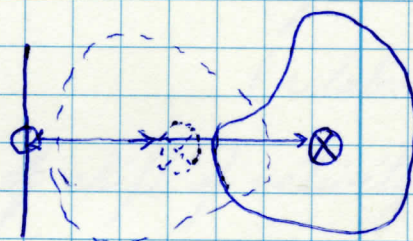
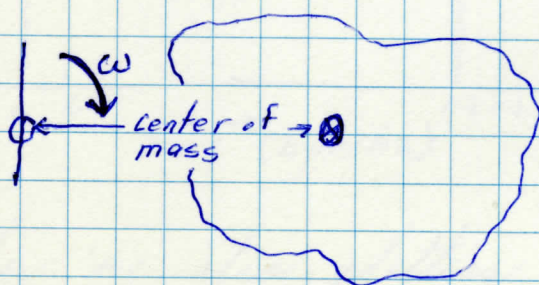
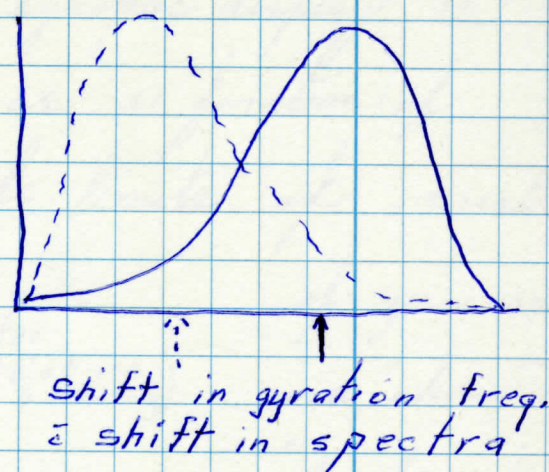
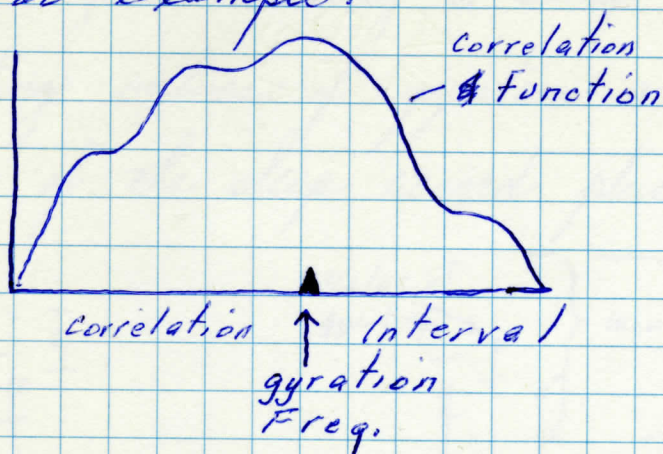
Spent day @ Dr. Werth, chief neuro-psychiatry Tulane Med. School New Orleans, ~~and~~ Mr. R. Jerome (Jerry) Edwards and Mr. Bernard Saltzberg. Their chief efforts are supported by NIH and consist of sleep studies (depth + surface electrodes), GSR, heart rate $\pm$ normals + abnormal) recorded on FR 13000 Ampex + Gross Polygraph and Mod 6 EEG. All analysis is done on an IBM digital ^{computer} ~~recorder~~ and includes comparison of power spectral analysis, gyration frequency, frequency of zero crossing, rate of change of crossing, skewness of both first and derivative crossings, correlation. Some of aspects of interest as I recall:

cross
auto



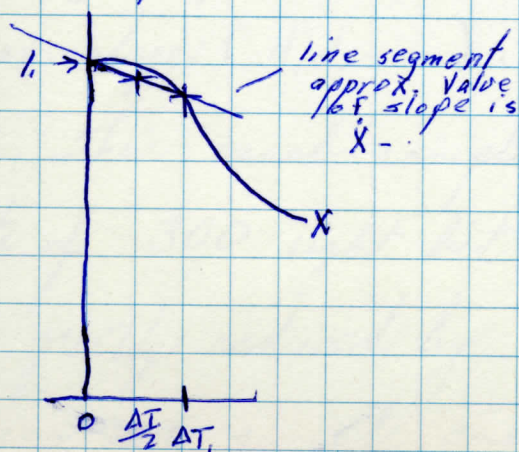
If two identical functions are regular infinite series they may be auto correlated by comparison at increasing increments of time ΔT . This will yield a spectra and by various manipulations a variety of other functions may be obtained. One of these functions is the gyration frequency. This is described as analogous to the center of mass in a rotating mass problem.

For example:



Since the spectra are normalized at $\Delta T = 0$ this represents a combination of spectra change + amplitude and of course should be sensitive to changes that occur in sleep.

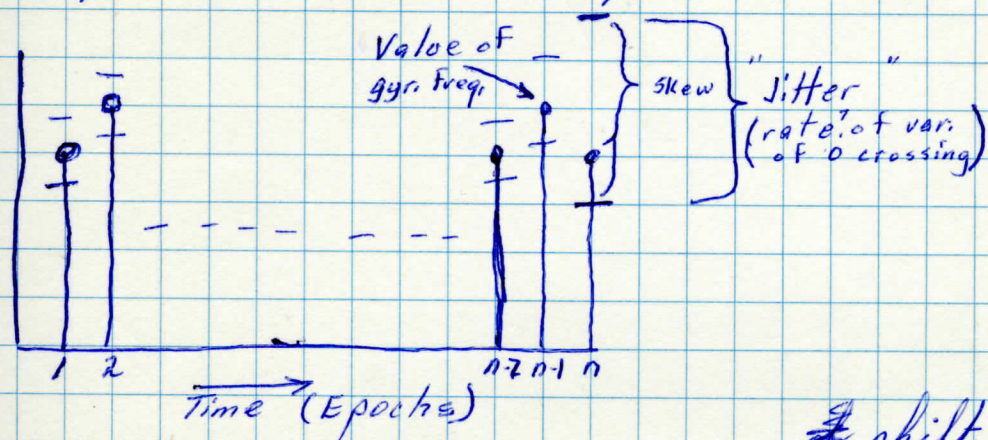
This function may be derived the first correlation sample, $\Delta T = 0$ + correlation function = 1, and the next sample ΔT , by way of two differentiations and some other manipulations. Value of 1st differential is obtained



by ~~line~~ line segment slope + 2nd by subtraction of $1 - X_{\Delta T}$ plus some manipulation. In practice it is obtained by subtraction of $X_{\Delta T} (1.0) - X_{\Delta T}$

16 Mar.

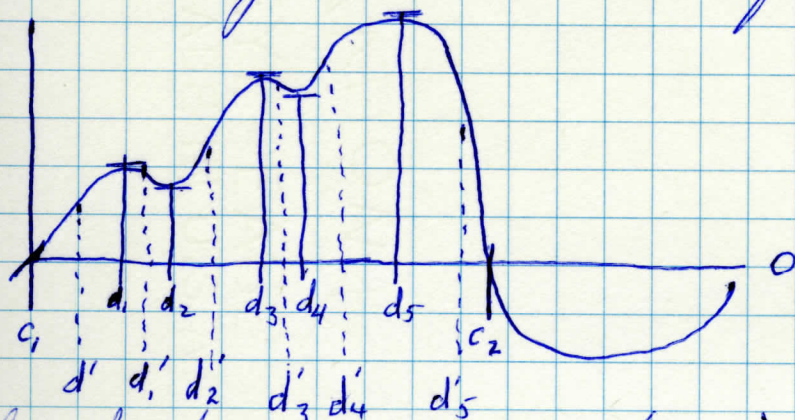
They are making a thing of "synoptic display" i.e. plotting values of gyration axis as a function of time of the sleep record plus the limits of variation



of zero cross.
and "skew"
of these limits
(related to ~~the~~

shift of activity).

They are also plotting the number of ~~epo~~ zero crossings per epoch. They are using 10 sec. epochs. Zero crossing is determined as follows:



Only positive going
cycles are used.

The fundamental
crossing is determined

when function crosses zero (c_1, c_2) and the 2nd derivative from zero inflection points ($d_1, d_2, \dots$) and other points from max. slope ($d'_1, d'_2, \dots$).

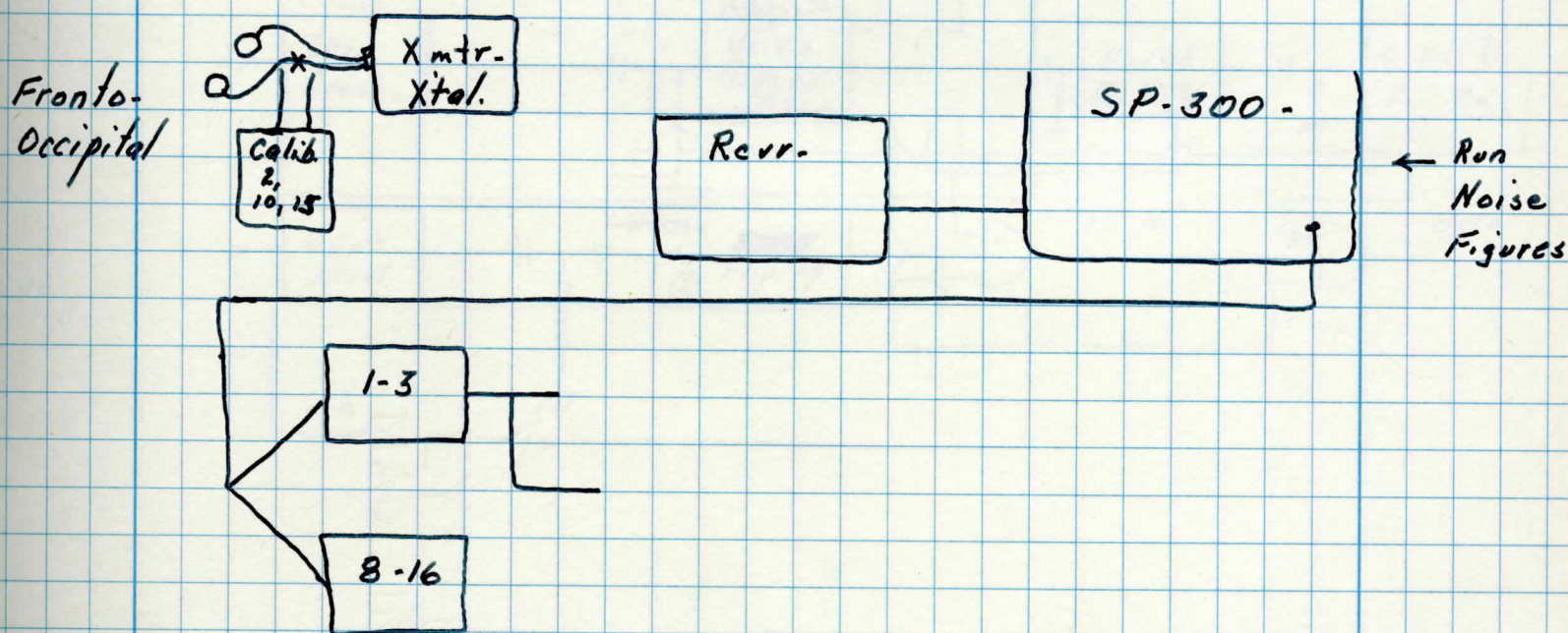
Their usual sampling technique employed is a sample rate of 300 eight bit samples/sec. This may be greatly reduced by an estimation of the correlation using not sample amplitudes but sample polarity

? math. of
zero crossing
? effect of
small signals
of high freq.
on large
LF signals

which may be obtained simply from zero crossing information. He shows a number of sleep records

27 Mar.

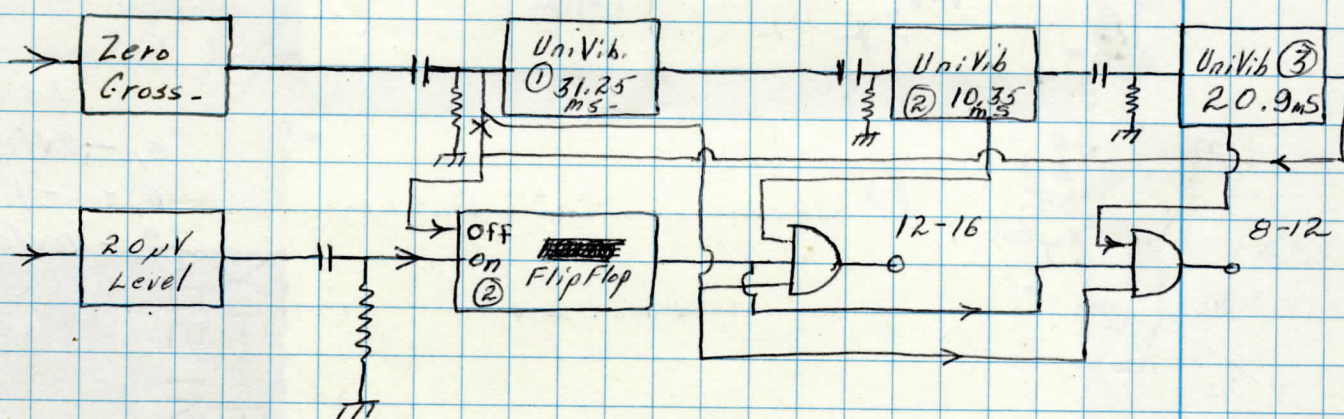
The Spectrum Inst. filters are not sharp enough esp. to separate the 8-12/13-16 band. Some alternate more simple scheme of recording & analysis is obviously required for Σ omme keeps $\uparrow$ complexity & we still have the data collection problem.
Data collection: ?



A time discriminator, "period analyzer," will be used to separate the 8-12 & 13-16 CPS. bands.

The following cpts. are needed:

Un.vib or other timer	F	T	T/2
Gate	CPS	m Sec.	m Sec
	8	125.0	62.5
	12	83.3	41.6
Integrator or counter	16	62.5	31.25

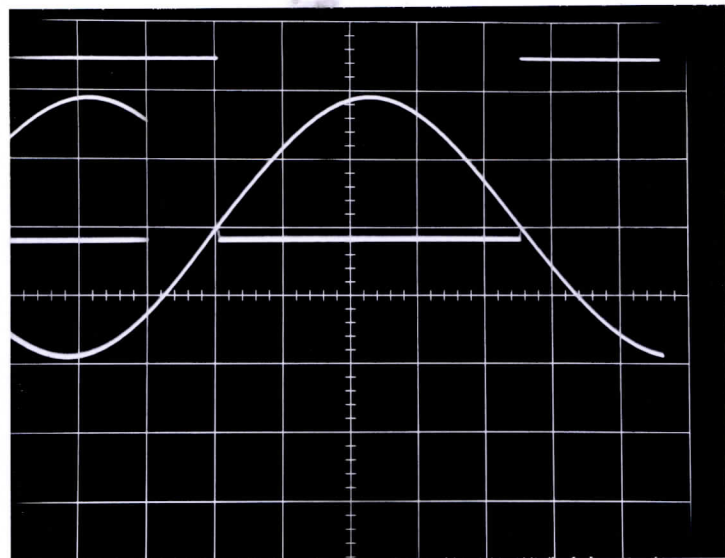


$$\begin{array}{r} .0625 \\ 16 \overline{) 1.000} \\ \underline{96} \\ 40 \\ \underline{32} \\ 80 \end{array}$$

$$\begin{array}{r} .0833 \\ 12 \overline{) 1.00} \\ \underline{96} \\ 40 \\ \underline{36} \\ 40 \end{array}$$

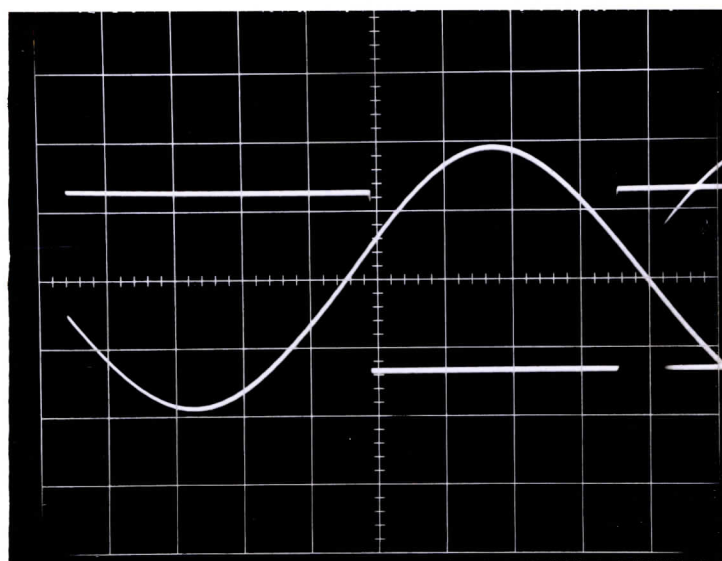
Photos from Exp. on Facing Page - $R_1 = 10k$ $R_2 = 100k$
1.2 CPS

①



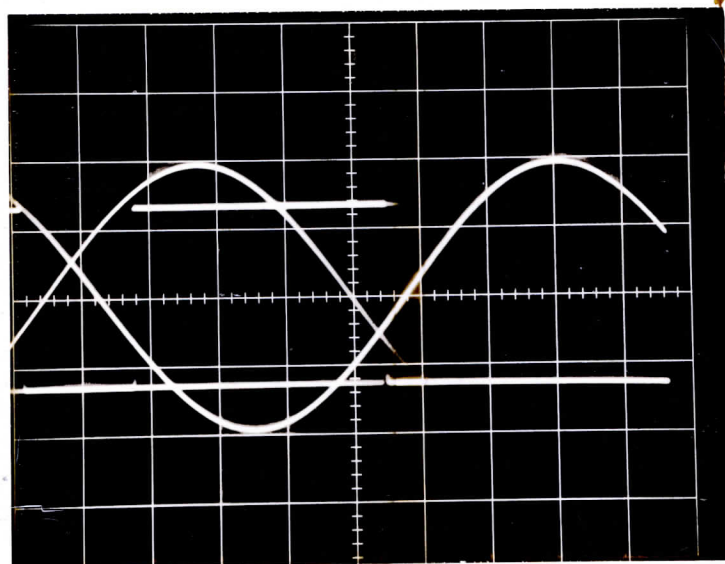
$$\left. \begin{array}{l} e_3 = 10V/cm \\ e_1 = 2V/cm \end{array} \right\} .1 S/cm \\ e_2 = 0$$

②



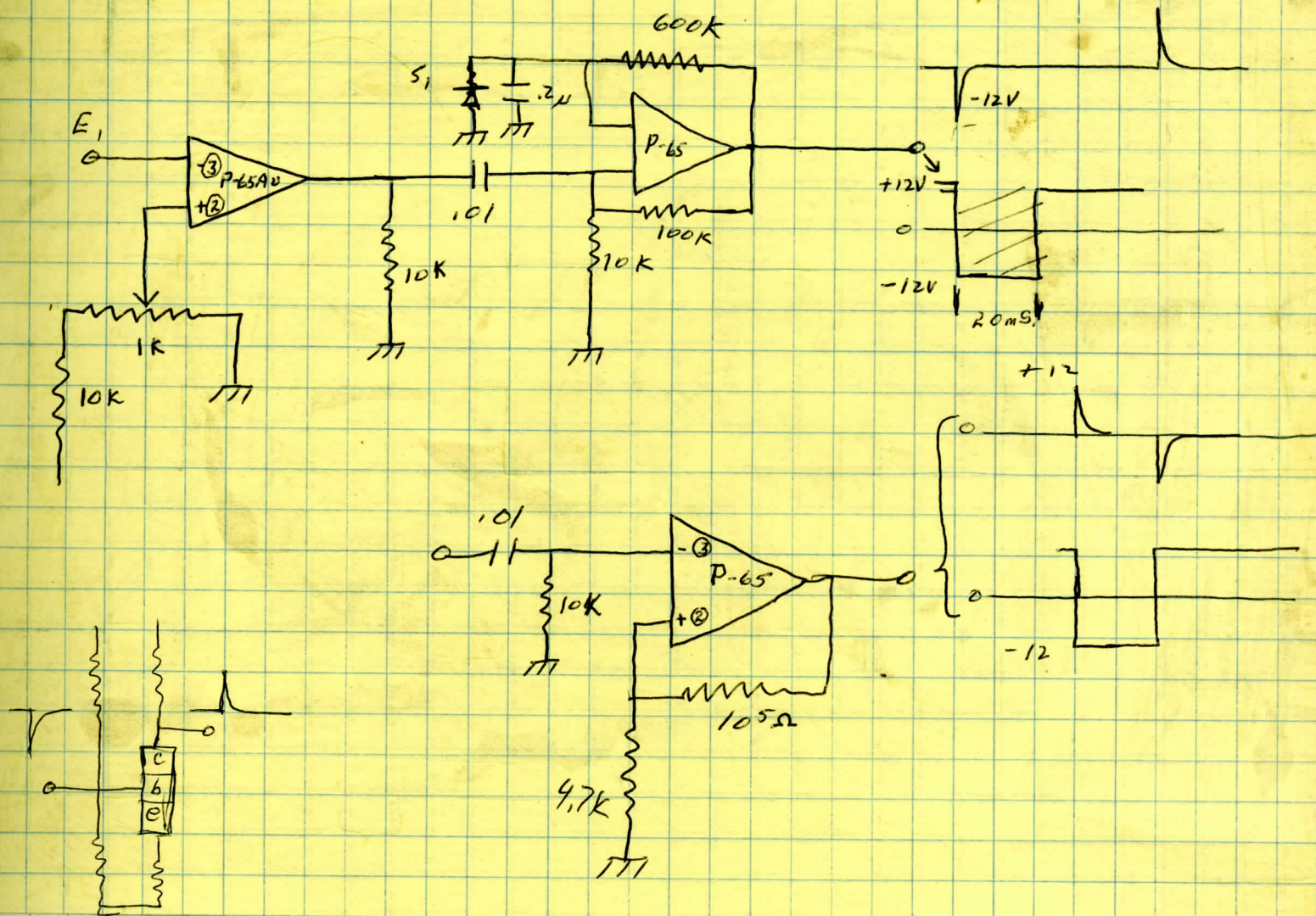
$$\left. \begin{array}{l} 1.2 CPS \\ e_1 = .2V/cm \\ e_2 = -.1 \\ e_3 = 10V/cm \end{array} \right\} .1 S/cm$$

③



$$\left. \begin{array}{l} 1.2 CPS \\ e_1 = .2V/cm \\ e_2 = -.1V \\ e_3 = 10V/cm \end{array} \right\} 10mS/cm$$

18/ Apr - Connection of Philbrick Op. Amps. as
Astable & Monostable multi-vibs.



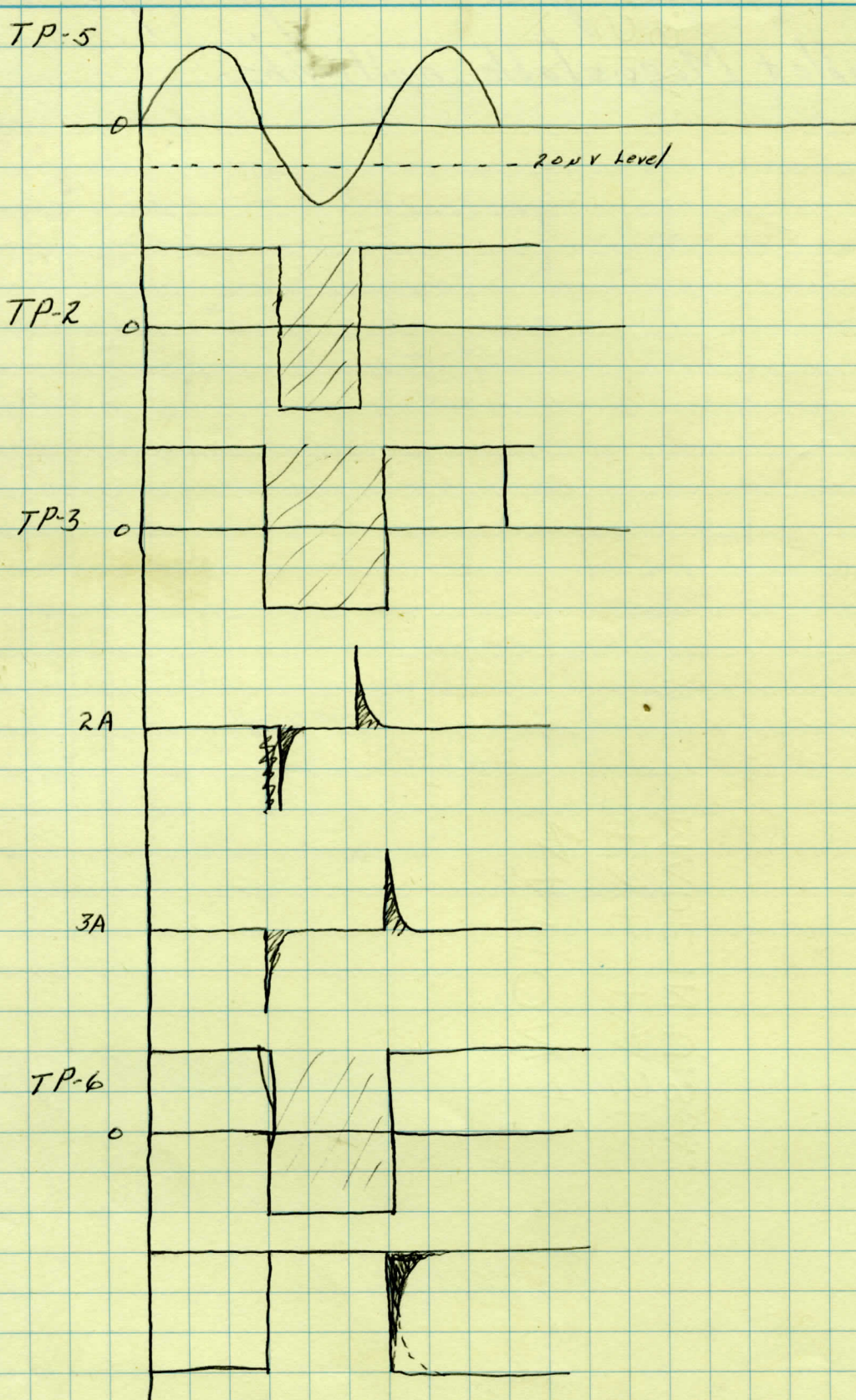
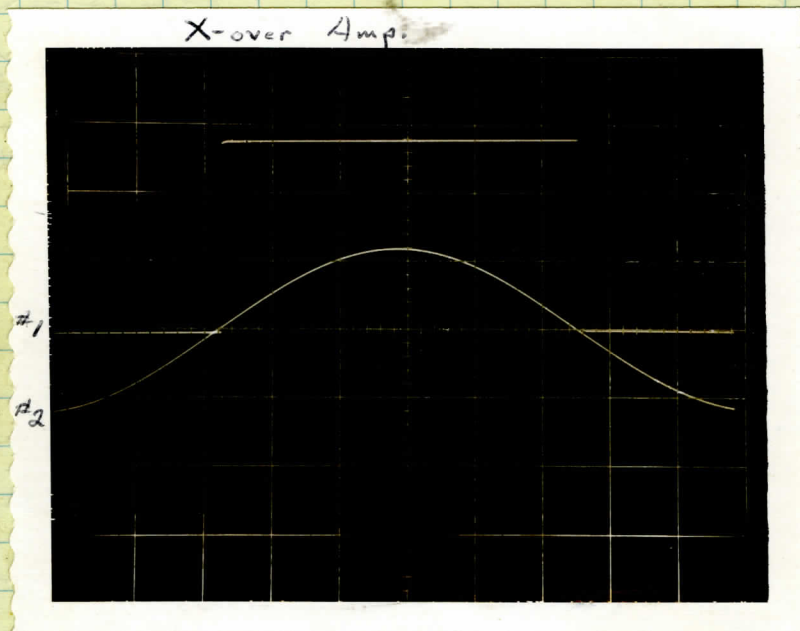


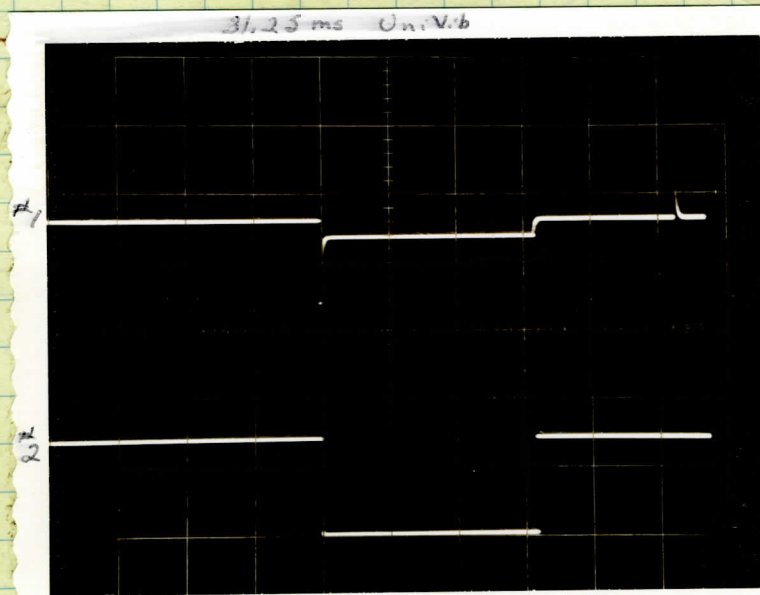
Photo of zero cross. + univib. on P-45



1. 10V/div

2. 5V/div

10 mS/cm



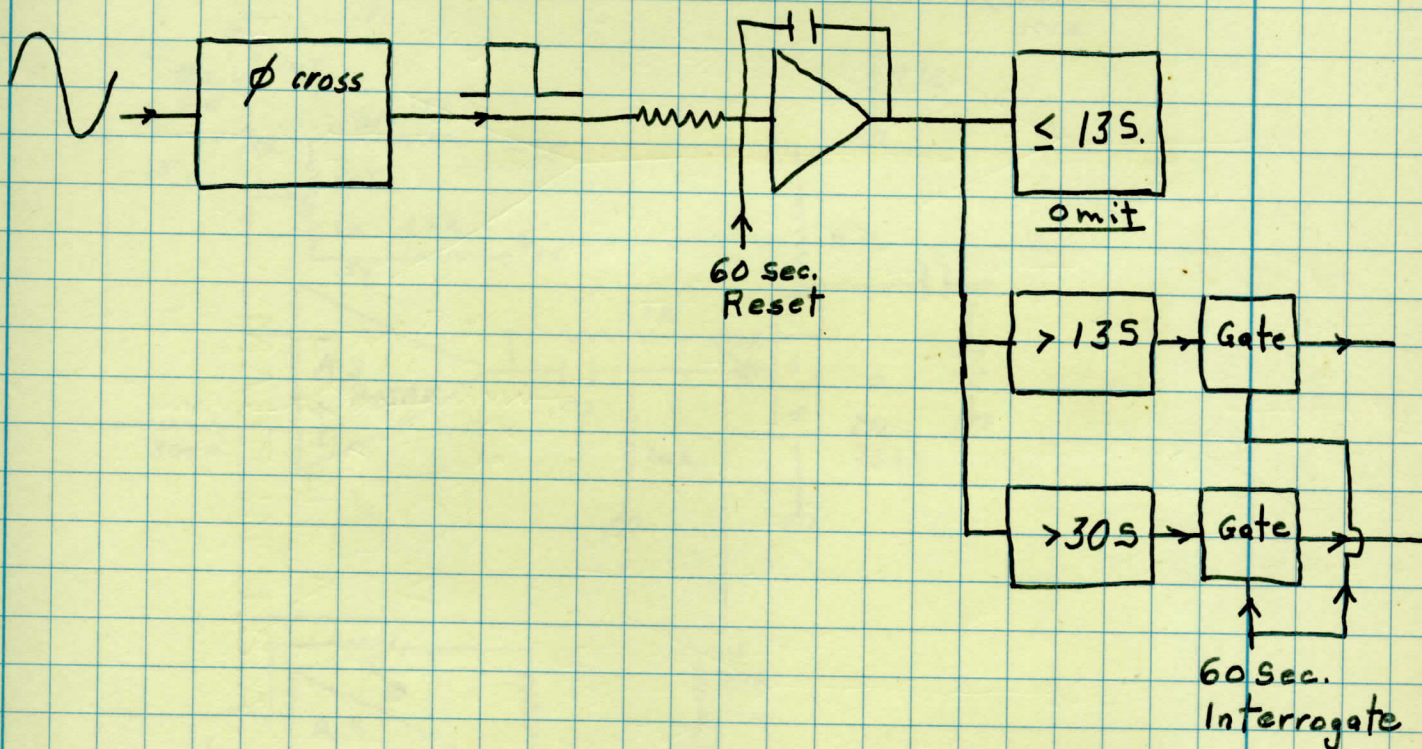
Low Freq. (Δ) detector

Freq - 1.3 CPS

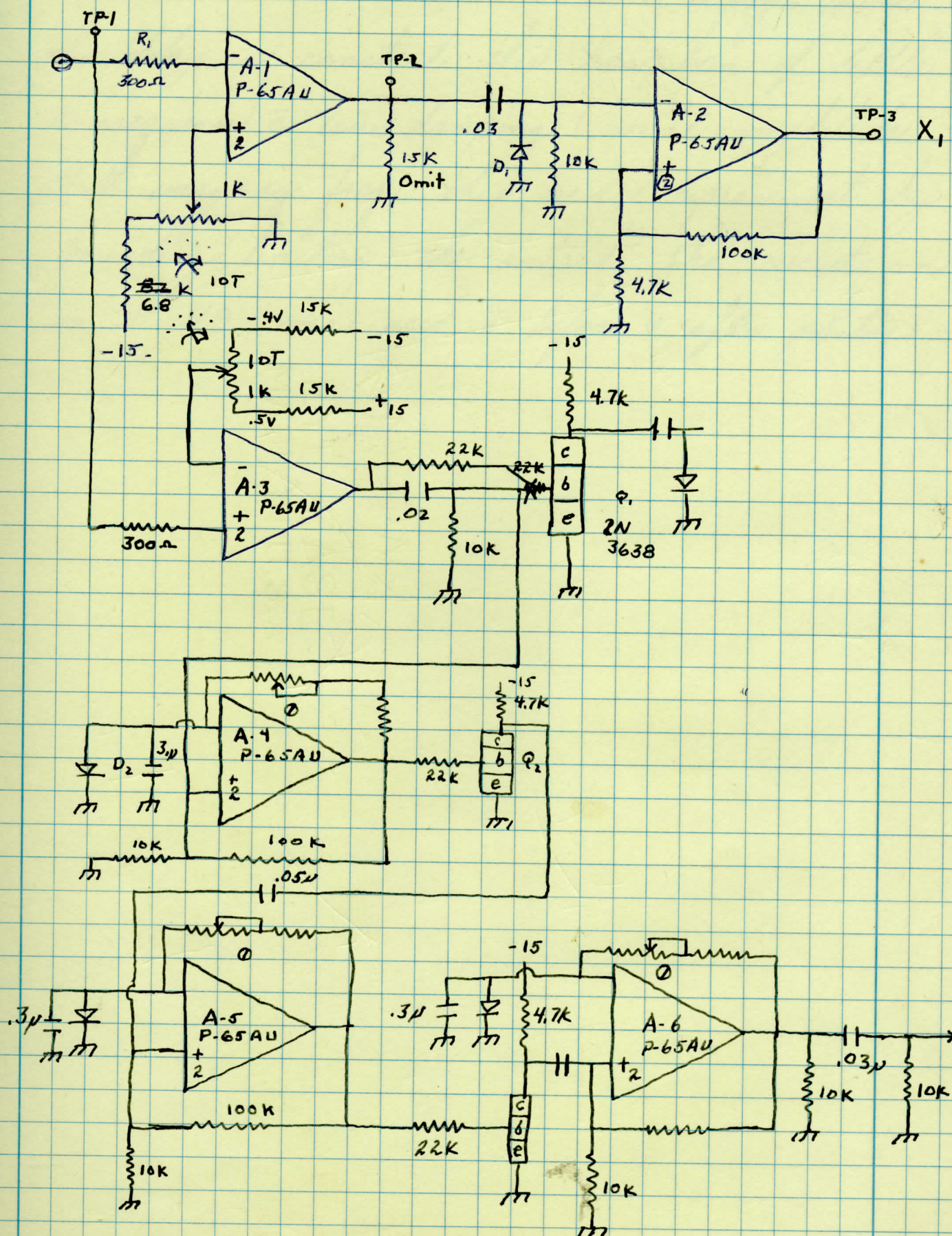
τ - 1.333 Sec.

$\tau/2$ - .5 - .166 "

Simplest Scheme -

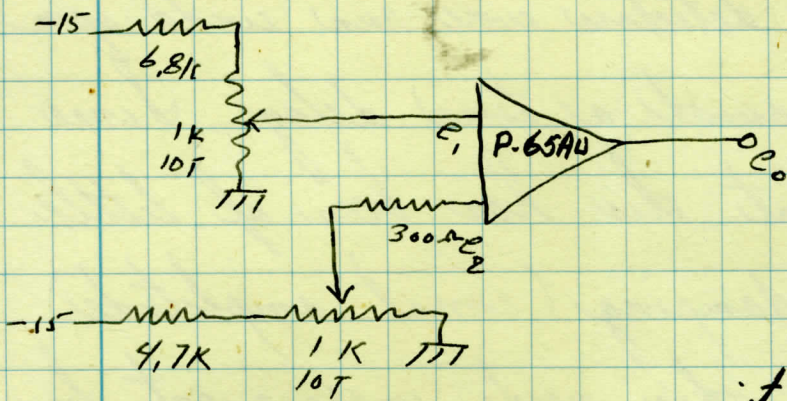


The ckt. on P-41 have been extensively revised.



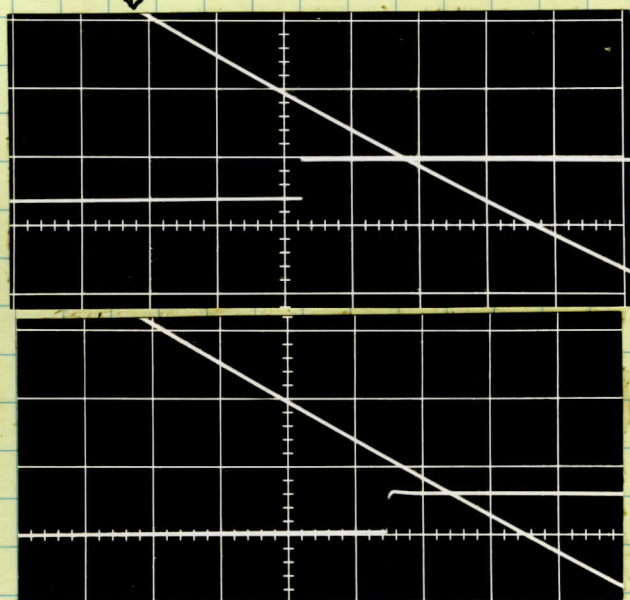
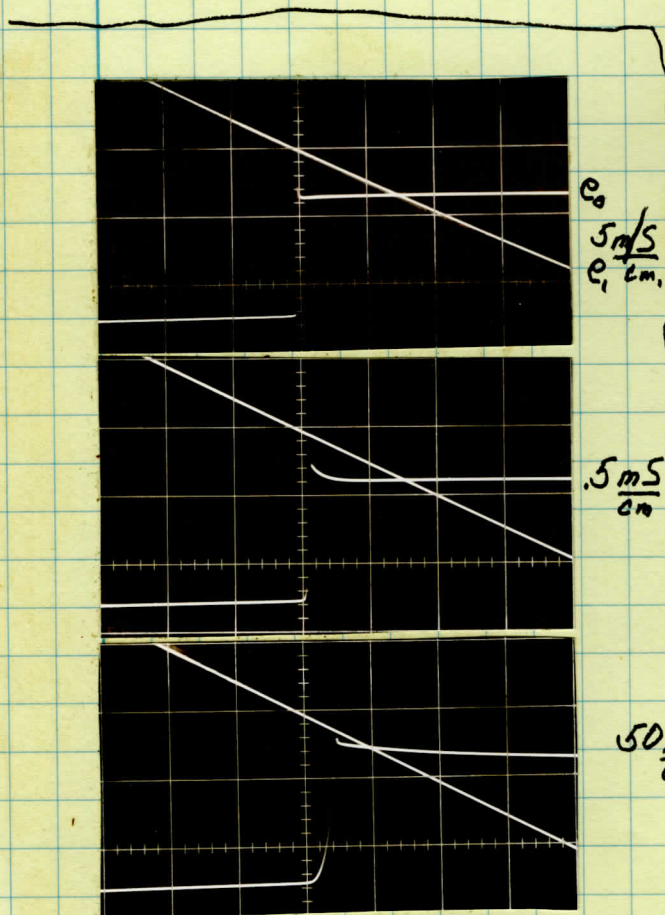
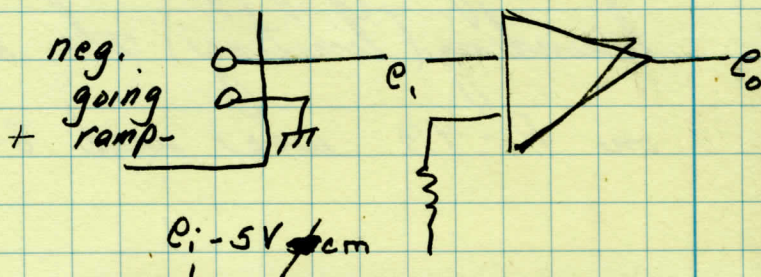
All diodes 1N2071 All trans. 2N3638

The zero crossing detectors were run wide open
in saturation which caused a time delay. Since
the delay is constant this has been of little
consequence in low damping (const. amplitude).
With varying freq. this needs improvement by
bounding (limiting) the output. The circuit on
on P-49 was used in before & after photos



The resolution of this ckt. is excellent at low speeds - At higher speeds it lags as shown below -

e_1	e_2	e_0
-717	-719	+
"	-718	+
"	-717	-
increased e_1 to -3.7		
-717	-718	+
-	-717	-



$e_0 \sim 2.5$

$\hookrightarrow 5mV/cm$

$\hookrightarrow 5mV/cm$

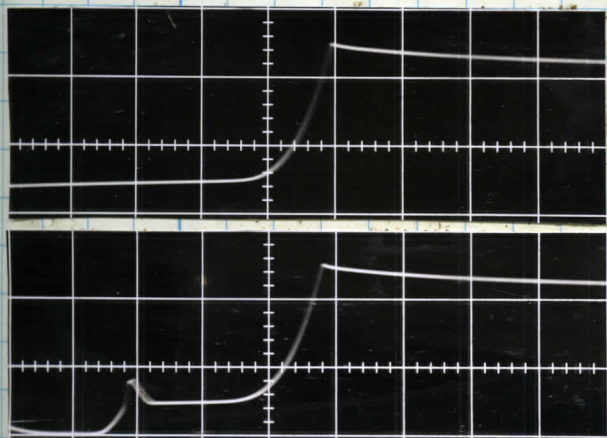
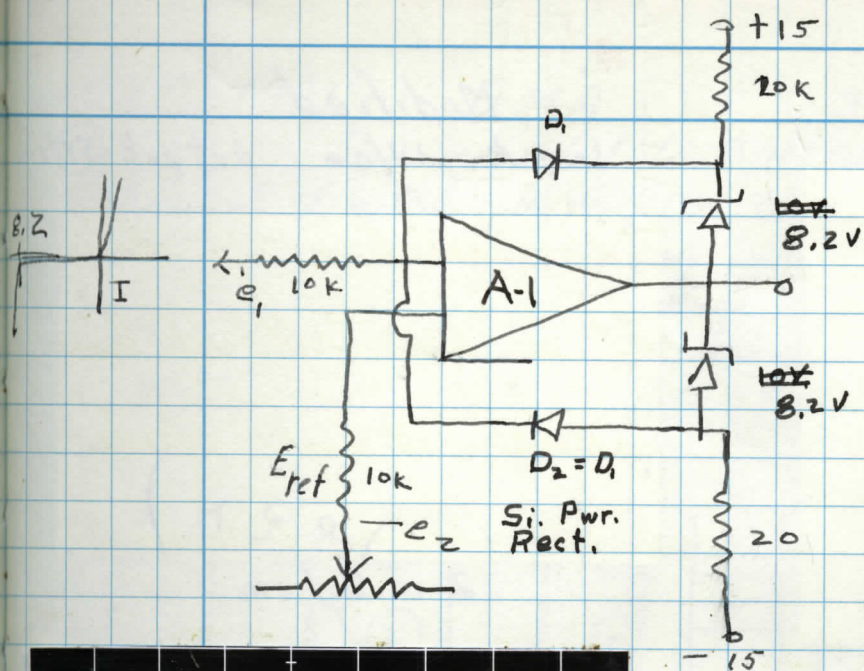
Mod. as top P-49

$\bar{e}$ P-45 Amp - $e_{in} = 5V/cm$

e_1 was neg. linear ramp.

$E_{ref} \approx 3.7$

$50mV/cm$

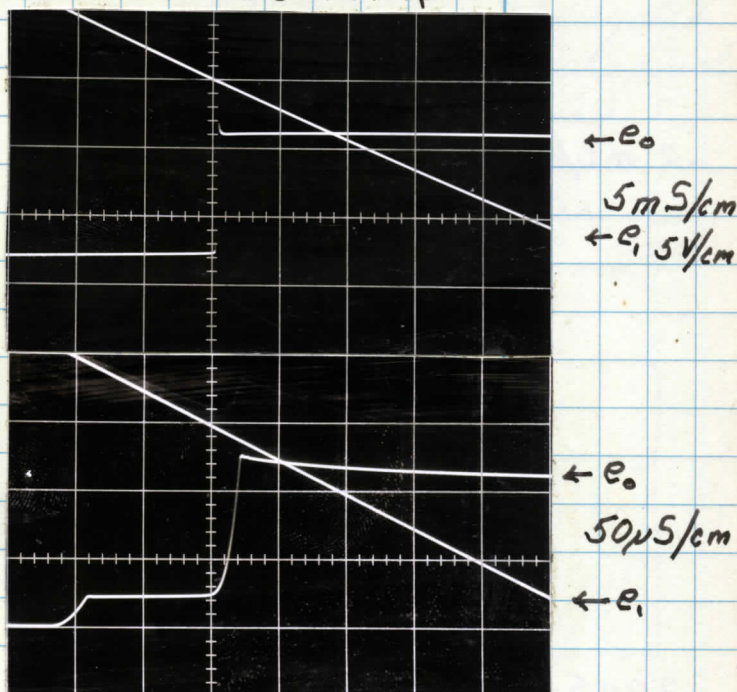


P-45

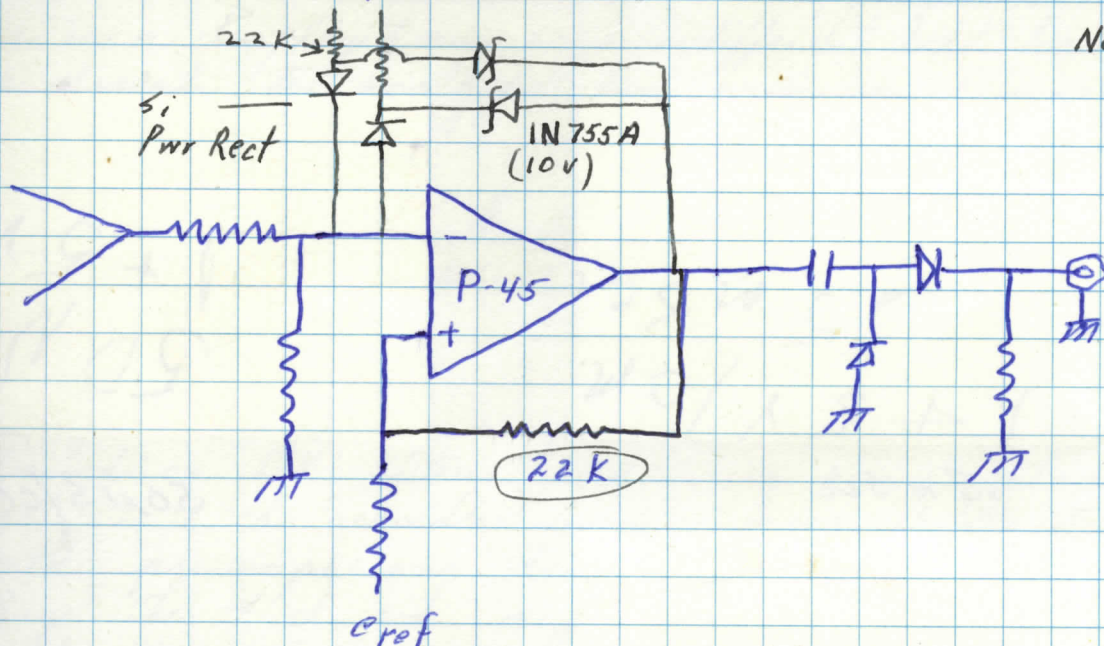
50μs/cm.

P-65

P-65 Amp



Bittle Unit Mod. as below

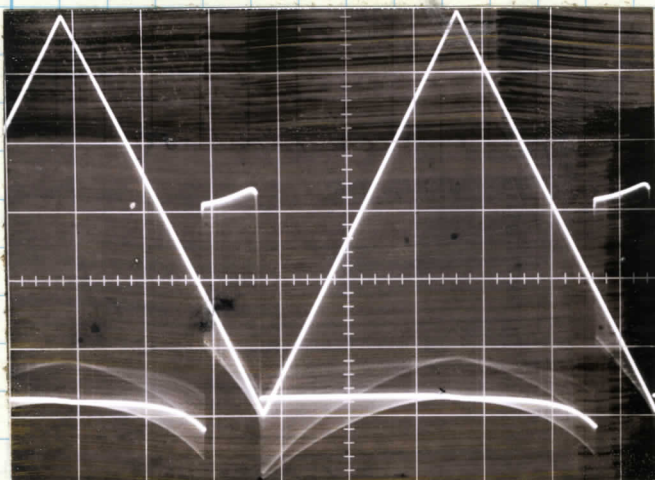
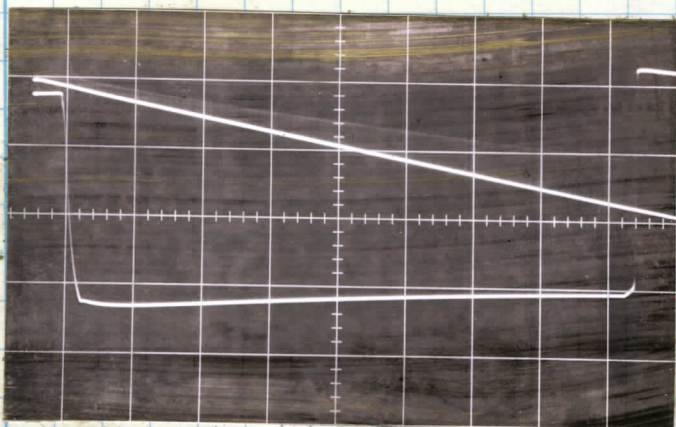


New comps. in ink -

Capacitance of the zeners slowed this ckt. down (i.e. output rise time was $\sim 25\mu s$.) Feedback caps. in μs range produced overshoot. The 22K res. was added to the results shown overleaf.

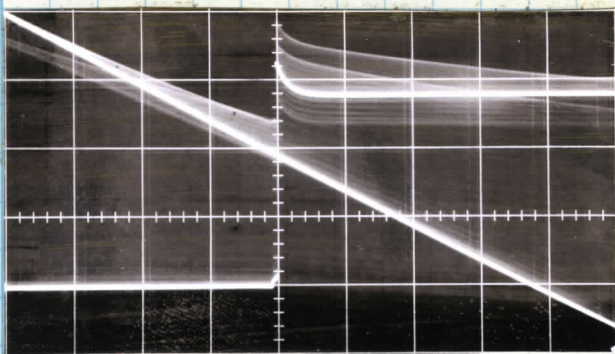
Unmod Bittle Unit

.2 mS/cm

20 μ S/cm

1V/cm

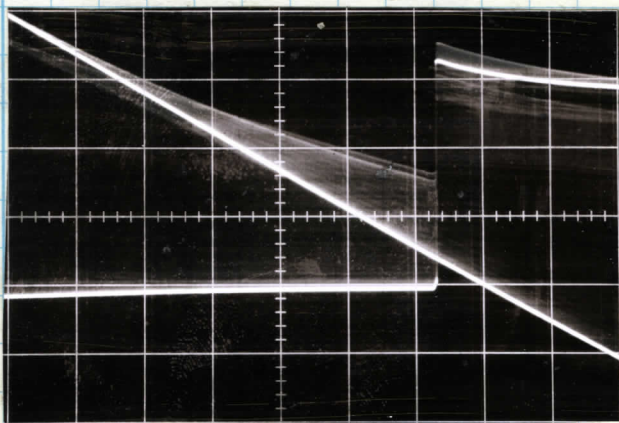
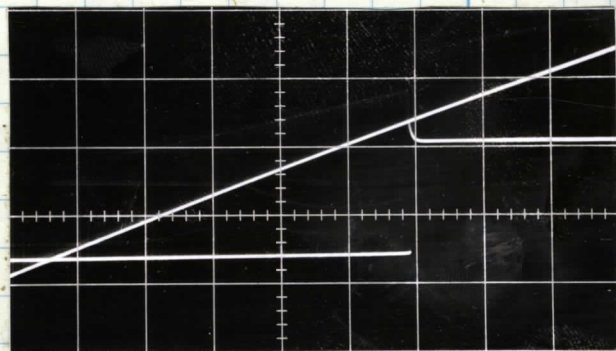
5V/cm



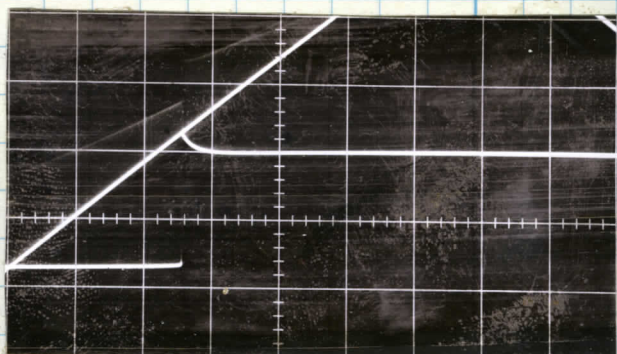
.5 m sec

1V/cm

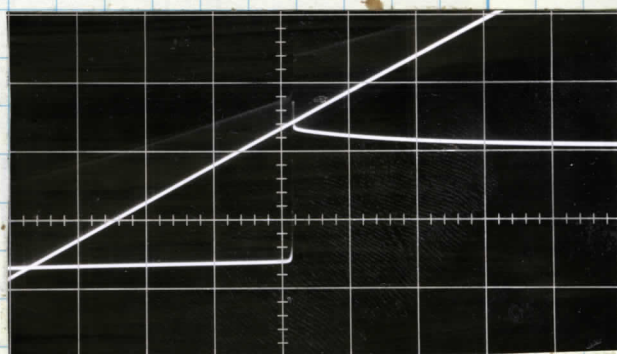
5V/cm

50 μ S/cmModified
input 1V/cm output 5V/cm.

2 m.S./cm.



.5 mS/cm.

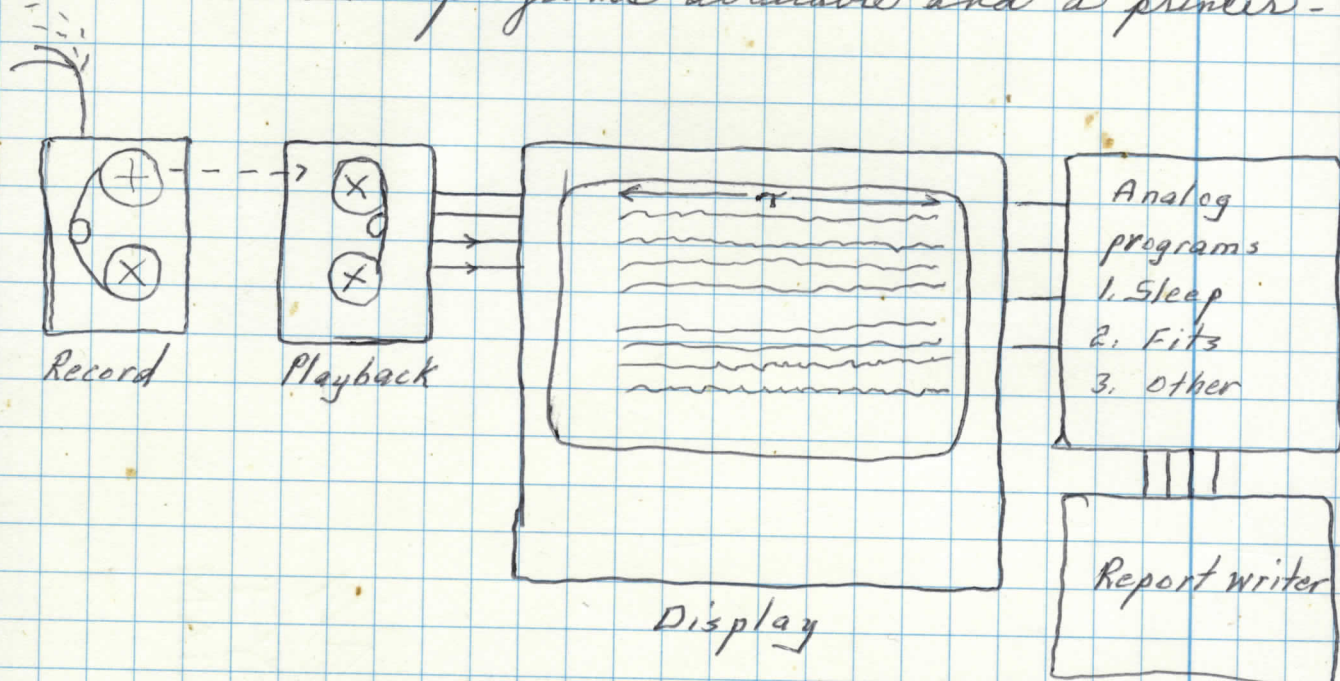
50 μ S/cm

28 SEPT. 1981

DMA

31 Mar

Recommended to BDM that he proceed to a simple system of limited B.W. 1-30-40 Hz and 2 or possibly 4 channels recorder, a display which might be a "slow" version of the EKG display, say 7-20 sec./line, an analysis unit & several programs available and a printer.



Reviewed available DMA hardware and either a 2 or 4 channel recorder will be built, playback is available as is a display (may require different ckt. board) but 1981 is closest to analyzer but will require analog pre-processing.

29 Sept. Briefed Cherry, Bryan, Sanctuary Hong & ? on above - BDM stated that he expected 2 channels or 4 -

31 Mar.82 Briefed above on simple approach to ~~sleep~~ sleep analysis based on DK criteria and using prior approach. It appears that a 4 ch. recorder using a copy of the OXFORD head mtd. pre amps and the above display unit will be avail. in Aug. The 4 ch. recdr. may be in May. It was agreed that a first order of business would be a library of tapes. My basic approach for sleep is as below.

