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A BASIS FOR EVOKED POTENTIAL ASSESSMENT OF CERTAIN VISUAL FUNCT--ETC(U)
JUN 81 D REGAN AFOSR-80-0161

F/G 6/16

A BASIS FOR EVOKED POTENTIAL ASSESSMENT OF CERTAIN VISUAL FUNCT--ETC(U)

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19 REPORT DOCUMENTATION PAGE

AFOSR-TR-81-0630

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A BASIS FOR EVOKED POTENTIAL ASSESSMENT OF CERTAIN VISUAL FUNCTIONS.

Final Technical Report

David/Regan

16 June 1980 - 30 June 1981

AFOSR-80-0161

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Halifax, N.S., Canada

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VISUAL EVOKED POTENTIALS; VISUAL TEST; TEST BATTERY; VISUAL ACUITY; CONTRAST SENSITIVITY; SPATIAL FREQUENCY; ELECTROPHYSIOLOGY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Evoked potential recording is a technique for recording electrical brain responses from scalp electrodes so as to assess human visual functions objectively. This report describes two evoked potential stimulators and methods for testing visual acuity and visual contrast sensitivity. These two electronic devices enable true contrast responses to be distinguished from responses to changes in local light intensity. This is achieved by dissociating the direction of contrast change from the direction of intensity change. The devices also

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allow different stimuli to be randomly interleaved under computer control. This procedure improves measurement accuracy by combining interleaving (to combat slow changes of the evoked potential with time) with signal averaging (to combat the unfavourable signal-to-noise ratio). Pattern and contrast evoked potentials are similar to those generated by the relatively inflexible optical technique, and the major EP component to pattern appearance is shown to be a true pattern response of the human visual pathway.

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Reason why 50% of the research aims
were not achieved during the one-year grant period

Due to some initial delay in establishing funding, a suitable post-doctoral assistant accepted another post, and a well-qualified graduate student had to be started on another project. I advertised the position in scientific journals and received about 30 applications from candidates interested in this type of research. I took up references for almost all of these applicants, and interviewed several. Unfortunately, none of the candidates met the demanding technical (electronic) and scientific demands of the project. Rather than appoint assistants whose abilities to meet the demands of this project were in any doubt, I continued to search for adequately qualified and capable assistants. Although assistants were found who were well qualified for other of our projects, unfortunately none were found suitable for this project during the period of the grant. In order to ensure that progress was made during the period of the grant, I undertook the technical and experimental work myself without assistants using equipment mostly borrowed from other projects and researchers. Although about 50% of the aims stated in the grant application have been achieved, due to lack of assistance, progress has been much less than I had planned and envisaged. However, expenditure has been much less than 50% of the total sum allowed, mainly because I did not intend to purchase the larger items of equipment until full achievement of the experimental aims could be confidently envisaged.

(c) STATUS OF RESEARCH EFFORT

Aims 2 & 3: Assessment of visual acuity; Assessment of contrast sensitivity at medium and low spatial frequencies and distinction between contrast EPs and local luminance EPs produced by pattern stimulation.

The major problem in interpreting evoked potentials produced by pattern stimulation is to distinguish between evoked potential components that are genuinely produced by contrast stimulation and components produced by local luminance changes (i.e. local flicker). A major proportion of all papers on pattern evoked potentials do not confront this problem. Consequently, there is a serious hidden defect in very many papers on pattern evoked potentials: they cannot be clearly interpreted since they confound contrast responses with local luminance response.

Examples of this confounding include the following findings:

- (a) Richards and I showed that although, as expected, evoked potential amplitude is attenuated by blurring a pattern of small checks, blurring a pattern of larger checks can increase evoked potential amplitude⁽¹⁾;
- (b) I showed that high spatial frequencies are "tuned" to a temporal repetition frequency about 8 cycles per second whereas low spatial frequency responses are tuned to a frequency of about 17 cycles per second.⁽²⁾

Thus, the shape of the grating modulation transfer function depends on the choice of temporal frequency.

Figure 1 illustrates the rationale of a test that has been developed that can counter this problem (see also Appendix 1). The test is to introduce a small luminance change into the stimulus and to compare evoked potentials recorded under the following two stimulus conditions: (a) when contrast and luminance increase simultaneously; (b) when contrast increases

while luminance decreases. This test can disentangle two constituents of pattern EPs. We have designed and constructed two visual stimulators that enable this test to be carried out and also enable the test to be combined with routine assessment of contrast sensitivity and visual acuity.⁽³⁾ One stimulator generates checkerboard patterns, and the other stimulator generates sinewave grating patterns. The sinewave grating

pattern stimulator also includes a multi-stimulus interleaving device that improves accuracy by reducing the effect caused by slow changes of the EP with time.

Appendix 2 contains a technical description of the variable-contrast checkerboard stimulus generator and Appendix 3 contains details of the variable-contrast sinewave stimulus generator and random interleaving computer programme.

In order to dissociate responses to contrast (pattern) from responses to changes in local luminance, it is necessary to separately record EPs to the appearance and disappearance of pattern. We first described pattern appearance and disappearance responses in 1969^(4,5) using an optical checkerboard-mirror stimulator. Figures 2, 3 and 4 show that our electronic checkerboard stimulator

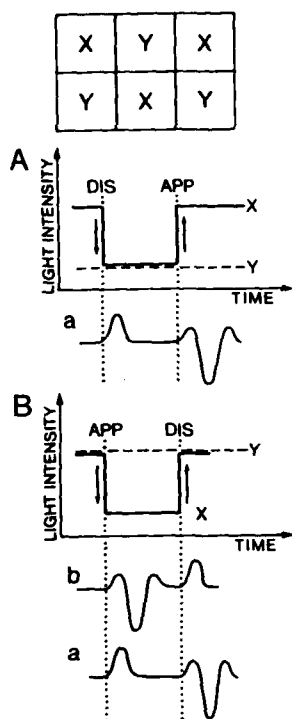


Figure 1. Test to distinguish between evoked potential components genuinely due to contrast change and evoked potential components due to changes in local luminance. See Appendix 1.

produces pattern appearance and disappearance EPs of similar form to those obtained by the optical technique.

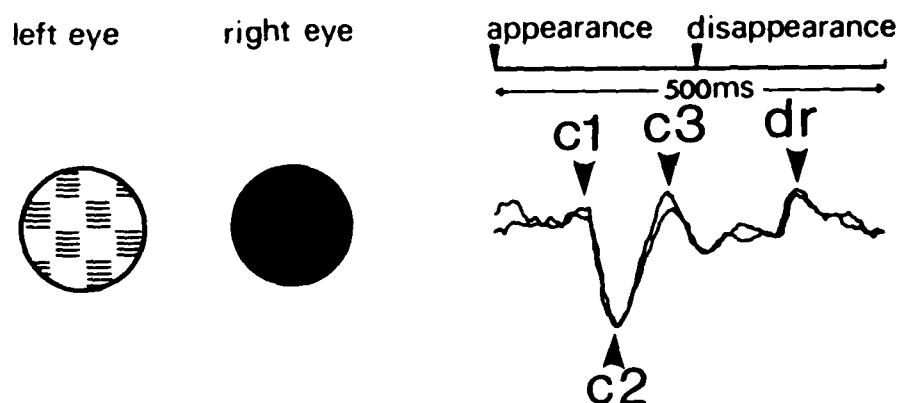


Figure 2. The appearance and subsequent disappearance of a stimulus pattern produce two quite distinguishable responses that have different cortical origins, different dynamics, different binocular summation and are differently affected by spatial frequency or check size. The appearance response consists of three components of which only C1 originates in striate cortex. Positive deflection downwards. Optical stimulator.

Components C1, C2 and C3 of the appearance EP are marked, and the pattern disappearance EP is also marked. The stimulus that generated the Figure 2 EPs involved no change of mean luminance: the transition from blank field to pattern and back again was accomplished with no change in total light flux. Figure 3 shows a recording in which increase of contrast was accompanied by a small increase of local luminance, and a recording in which the same increase of contrast was accompanied by a small decrease of local luminance.

Figure 3 demonstrates that the main component of EPs to contrast increase is indeed mainly responses to contrast change, and is not an artifact of local luminance responses. (This conclusion does not necessarily hold for all components, nor for all check sizes, nor for all

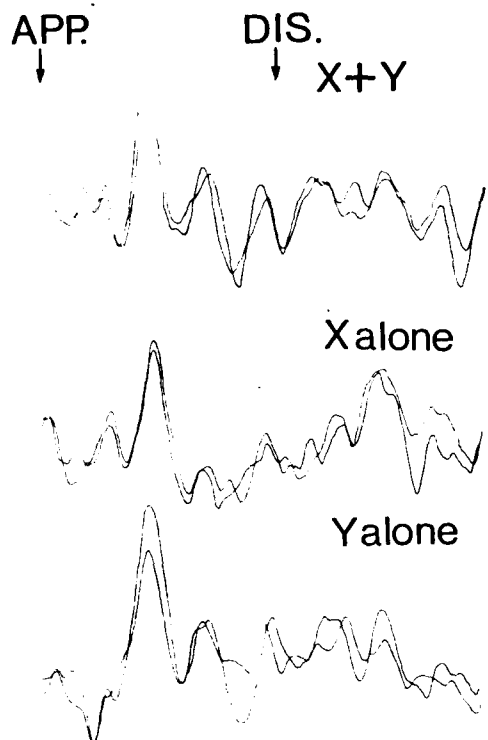


Figure 3. These evoked potentials were recorded while the subject viewed a pattern of checks that appeared (APP) and disappeared (DIS). X and Y signify alternate checks as marked in Figure 1. In the uppermost panel, checks appeared and disappeared with no change in mean luminance, since when X checks increased intensity Y checks decreased by exactly the same amount and vice versa. In the middle panel X checks only changed intensity while Y checks remained at constant intensity (Figure 1A). In the lowermost panel Y checks only changed intensity while X checks remained at constant intensity (Figure 1B). The traces show that the main appearance component was chiefly due to contrast change and not to local luminance change. Checks were 80 min arc and

A + B was 80% contrast. Stimulus rate 1.2 Hz, sweep time 800 msec, 50 sweeps, two repeats. Positive upwards.

electrode positions. The test must be repeated for each new stimulus condition.) To the best of my knowledge, Figure 3 is the first time that this stimulus manipulation has been carried out for an electronically-generated stimulus. Figure 3 shows that our electronically-generated display enables verification that an EP is a genuine contrast response, and this verification can be carried out under computer control in the course of routinely measuring visual acuity or contrast sensitivity.

Now we turn to the sinewave grating stimulator. This stimulator has the following facilities: (1) Successive presentation of four predetermined

contrast levels can be interleaved so that four EPs are recorded simultaneously. This interleaving procedure combats the disturbing effect of slow EP changes with time so as to improve the accuracy of measuring EPs for different contrast levels. The interleaving procedure is carried out by specially-constructed electronics controlled by a Commodore PET microcomputer. Averaging is achieved by means of a hard-wired four-channel averaging computer (Nicolet CA-1000). Grating stimuli are displayed on a CRT made by Joyce; (2) The direction of contrast change and local luminance change can be dissociated (as described for the checkerboard stimulator) so as to verify that the sinewave grating EPs are genuine responses to contrast and are not artifacts of responses to changes in local luminance.

Figure 4 shows EPs to the appearance and disappearance of a sinewave grating pattern of spatial frequency 2.5 cycles per degree. Reading from the top, the four traces are responses to gratings of contrasts 12.5%, 25%, 50% and 100% respectively. There are 50 sweeps for each trace, and the four stimuli were randomly interleaved in blocks of four. The stimulus cycle time was 600 msec and sweep time 500 msec. Figure 4 shows how the amplitude of the C2 component of the appearance EP rapidly increases with contrast only up to a contrast of 25-50%, and then saturates at higher contrasts. The disappearance EP, on the other hand, is only evident at the highest contrasts.

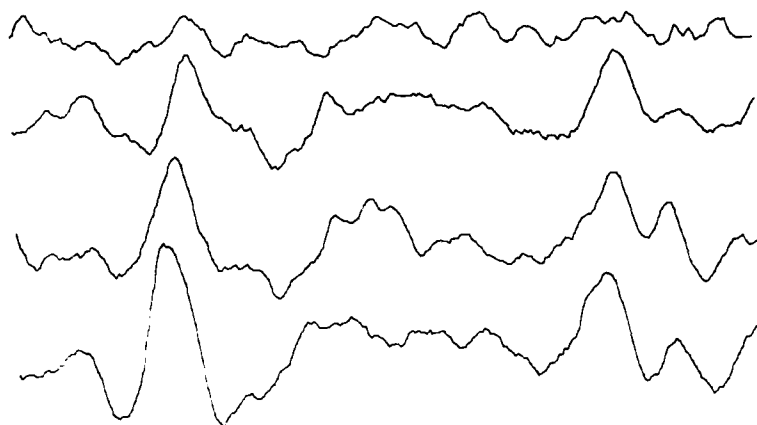


Figure 4. Averaged transient evoked potentials elicited by the appearance and disappearance of a sinewave grating pattern of spatial frequency 2.5 cycles per degree. Reading downwards from the top, contrasts were 12.5%, 25%, 50% and 100%. Fifty presentations of each contrast were recorded, interleaving in blocks of four. Stimulus cycle time 600 sec, sweep time 500 msec. Positive upwards.

Conclusions

Visual evoked potentials can be used to objectively assess visual acuity and visual contrast sensitivity.^(6,7) Human visual responses to pattern and to local changes of luminance can be disentangled. Electronically-controlled visual stimulators allow rapid computer-controlled recording methods to be used.

We have shown that electronically-controlled visual displays can be constructed that are adequate in the following respects:

(a) Stimulus edges are sharp even for 10 min arc checks in a 5° field, and contrast changes are sufficiently free from luminance artifacts so that the EPs to pattern appearance and disappearance are similar to those obtained with the best optical stimulators.

(b) Switching between pattern and blank fields is sufficiently well-balanced that artifact-free contrast EPs can be recorded down to near-threshold contrast levels.

(c) The direction of contrast change and the direction of local luminance change can be dissociated, both for checkerboard and for sine-wave grating stimuli, so that verification of contrast responses can be carried out (see Figures 1 & 3).

(d) It can be arranged that both stimulus contrast and spatial frequency are under computer control, as is the memory location in the averaging computer, so that the presentations of different stimuli can be randomly interleaved by the use of appropriate software. When combined with signal averaging, this procedure improves accuracy since it minimizes the disturbing effects of EP nonstationarity.

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APPENDIX 1

Pattern stimulation does not necessarily give pattern EPs

Presenting a patterned stimulus to the eye does not necessarily give an EP that is entirely (or even partly) specific to pattern, even when there is no change in total stimulus light flux.* For example, in pattern-reversal stimulation the bright and dim checks abruptly exchange places so that there is no change in total light flux. How, then, can there be any luminance stimulation? Indeed, if the receptive-field size for the luminance mechanism is very much larger than the check size, then there will be no luminance stimulation because each receptive field will "see" zero change in total light flux. However, if the receptive field for the luminance mechanism is about the same size as a check (or smaller) and there is some nonlinear distortion before spatial summation, then there can be a luminance response. Imagine that one receptive field is stimulated by repetitive changes of intensity at a frequency F Hz. Imagine that the neighbouring receptive field is similarly stimulated but in the opposite phase, so that the first receptive field is brightest when its neighbour is darkest. (Thus, the two receptive fields are on opposite sides of the contrast border whose contrast reverses at a frequency of $2F$ Hz.) The point of all this is as follows: it is known that, due to a rectifier-like nonlinearity, local luminance changes at F Hz will generate distorted signals containing a component at $2F$ Hz, so that after spatial summation (whose effect is to cancel the F Hz signals) there will be a residual $2F$ Hz

* Flashed-pattern stimulation may, of course, produce responses to luminance change as well as to pattern. In addition there may be EP components related to nonlinear interactions between luminance and pattern responses, but we do not discuss this form of stimulation here.

signal due to local luminance flicker; this residual signal has exactly the same frequency as genuine responses to contrast reversals. The important point is that this net response could occur in the absence of any pattern response (where a true pattern response is generated by a change in spatial contrast across a contrast border).

In general, an EP to pattern stimulation contains both a pattern-specific contribution and a local luminance contribution. Note that the two contributions have identical temporal repetition frequencies. As check size rises (or spatial frequency falls), the local-luminance contribution will grow relatively larger. A procedure for disentangling the two contributions has been described for pattern appearance/disappearance EPs.⁽⁸⁾ (Note that blurring does not distinguish them). For pattern reversal EPs Bodis Wollner and Hendley⁽⁹⁾ have discussed a way of distinguishing the two contributions.

The Amsterdam group's test is illustrated in Figure 1. The essential point is that in A, contrast decreases when total light flux decreases, whereas in B, contrast increases when total light flux decreases. Thus, changes of light flux are dissociated from contrast changes. The uppermost panel shows a check pattern with alternate checks marked "X" and "Y". The intensities of the X checks are modulated as shown in A (continuous line), and the averager is triggered by the modulating waveform. The other checks (Y) are held at a constant intensity, carefully preset to the level illustrated (dashed line). The EP in A is clearly myogenic, but note that it is not possible to say that the right hand section is characteristic of "pattern appearance" rather than "light flux increase". In B the stimulating squares (X) are the same as in A, but the constant

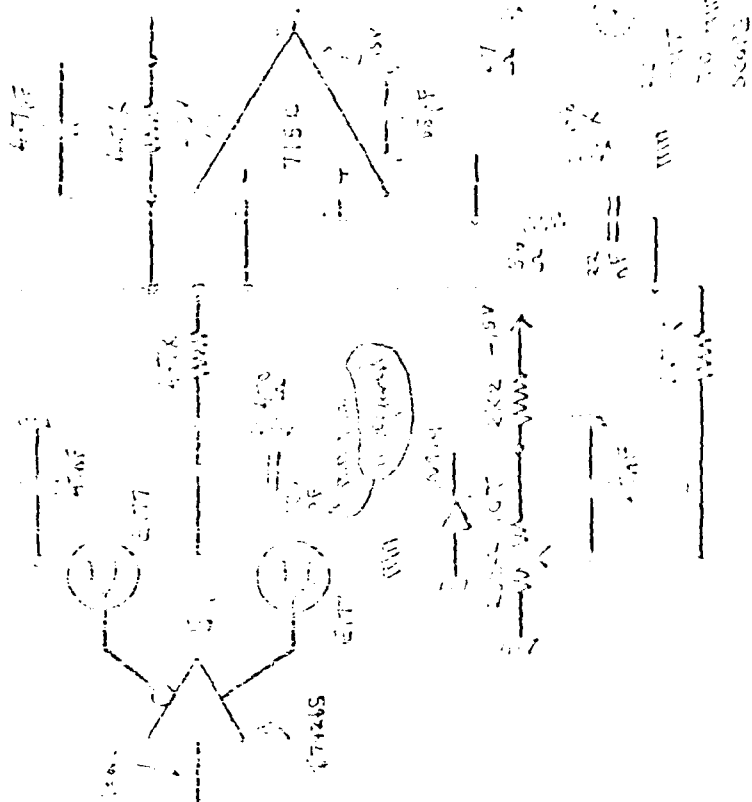
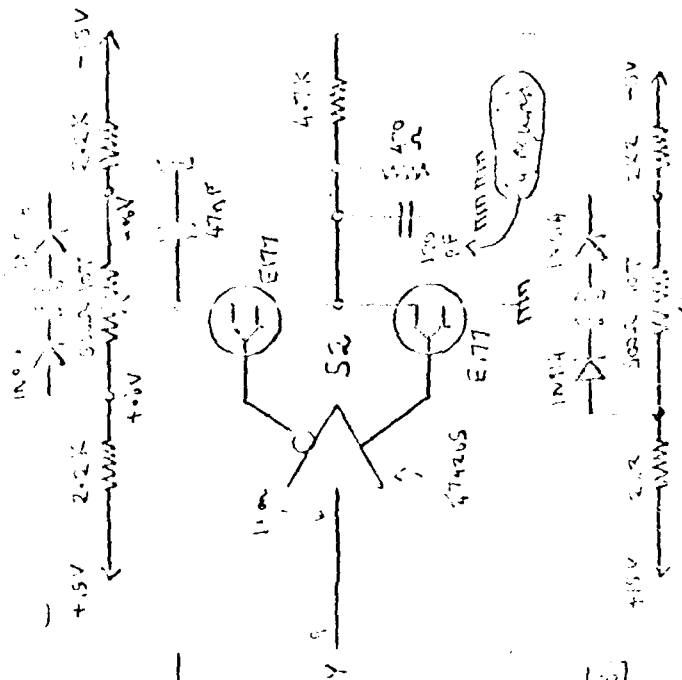
intensity of the Y squares has been preset to a different level. One possible outcome is illustrated by the EP waveform b. Here the EP asymmetry has reversed, showing that the first part of the waveform is a response to pattern appearance rather than to light flux increase. A second possible outcome is illustrated by the EP waveform a. The EP asymmetry has not been reversed by the stimulus manipulation. Thus, the second part of the waveform a is a response to light flux increase, and this test has given no evidence for a true response to contrast change. A third possible outcome is intermediate between the waveforms a and b. This would mean that the waveform contained responses to both contrast change and light flux change. By way of illustration, one application of this test has been to show that electroretinograms (ERGs) elicited by pattern stimulation are most probably responses to local changes of luminance rather than genuine contrast responses.⁽¹⁰⁾ Clearly, this test cannot be used when the EP is symmetric, as in the case of responses to pattern reversal.

References

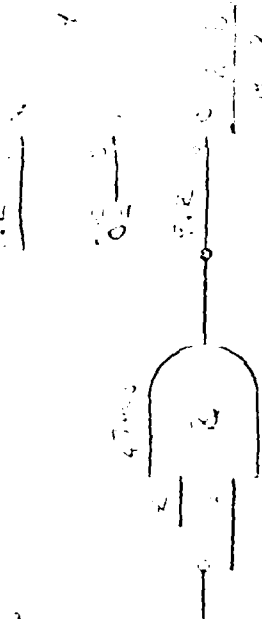
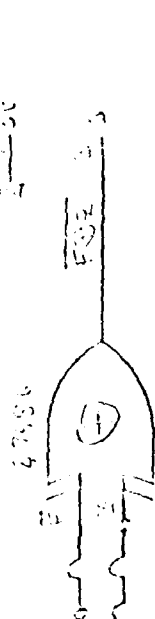
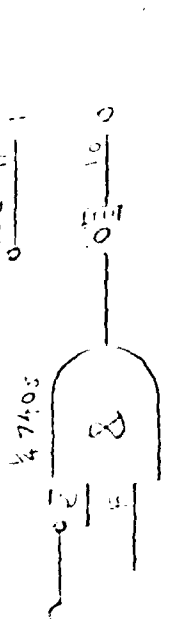
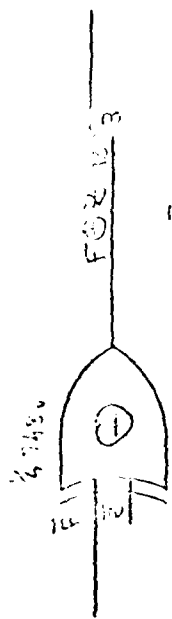
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ALTERNATIVE CHECKBOARD

16

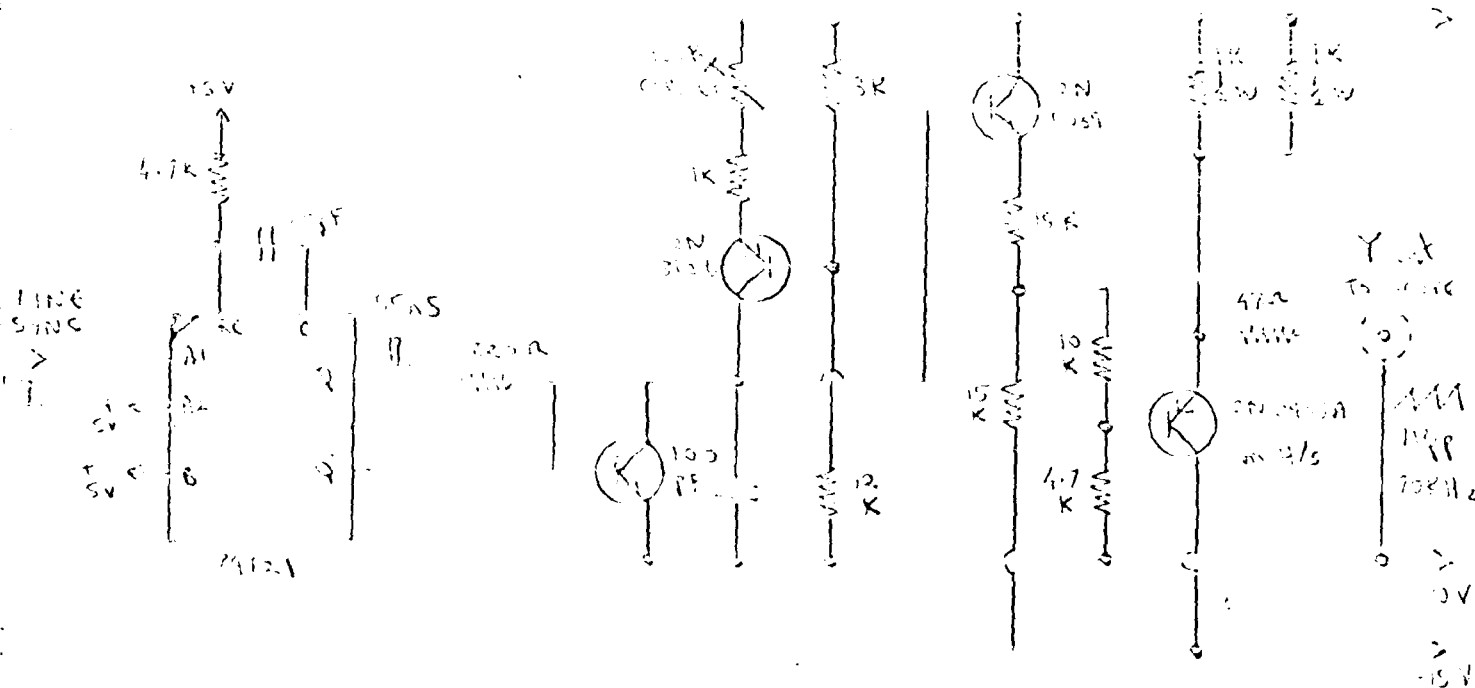
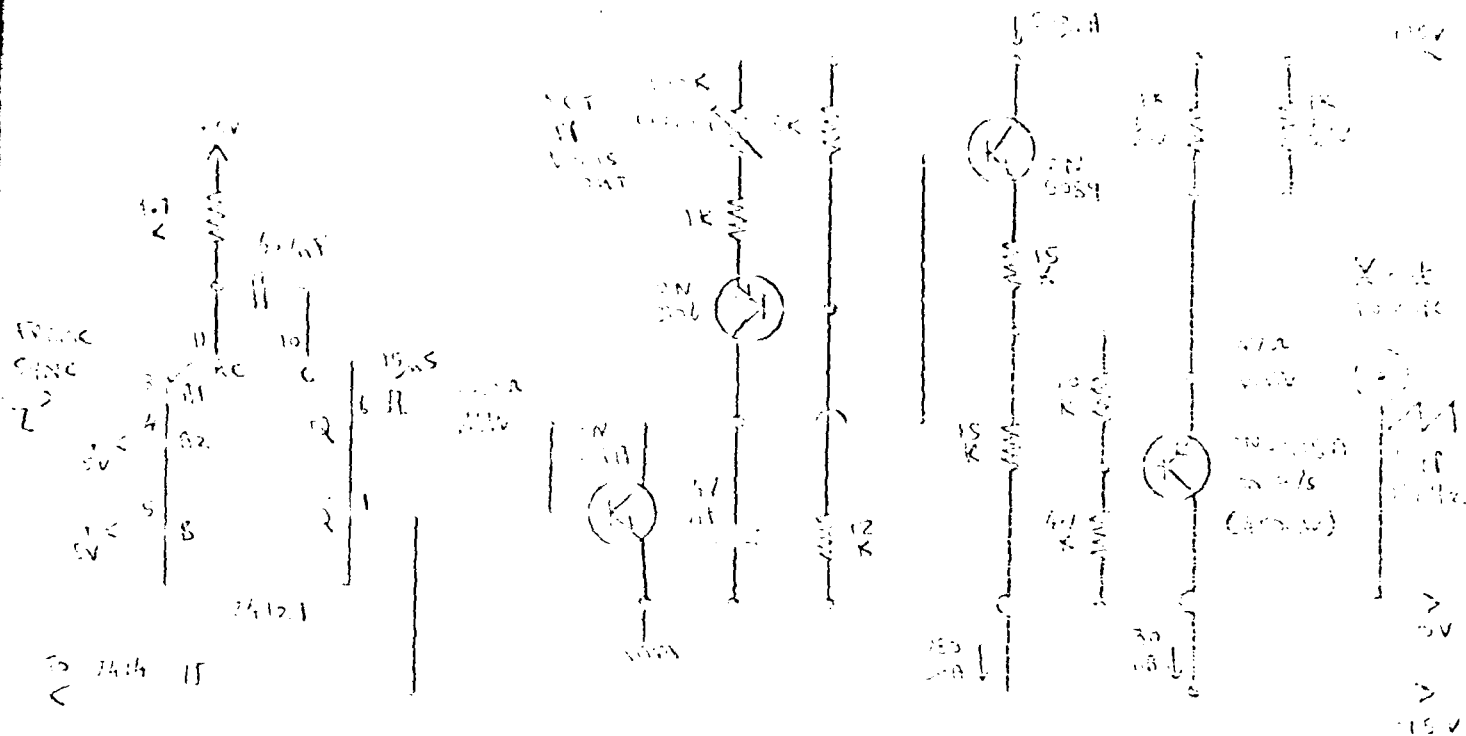


WAVE V V/FREQ
CH1 CH2

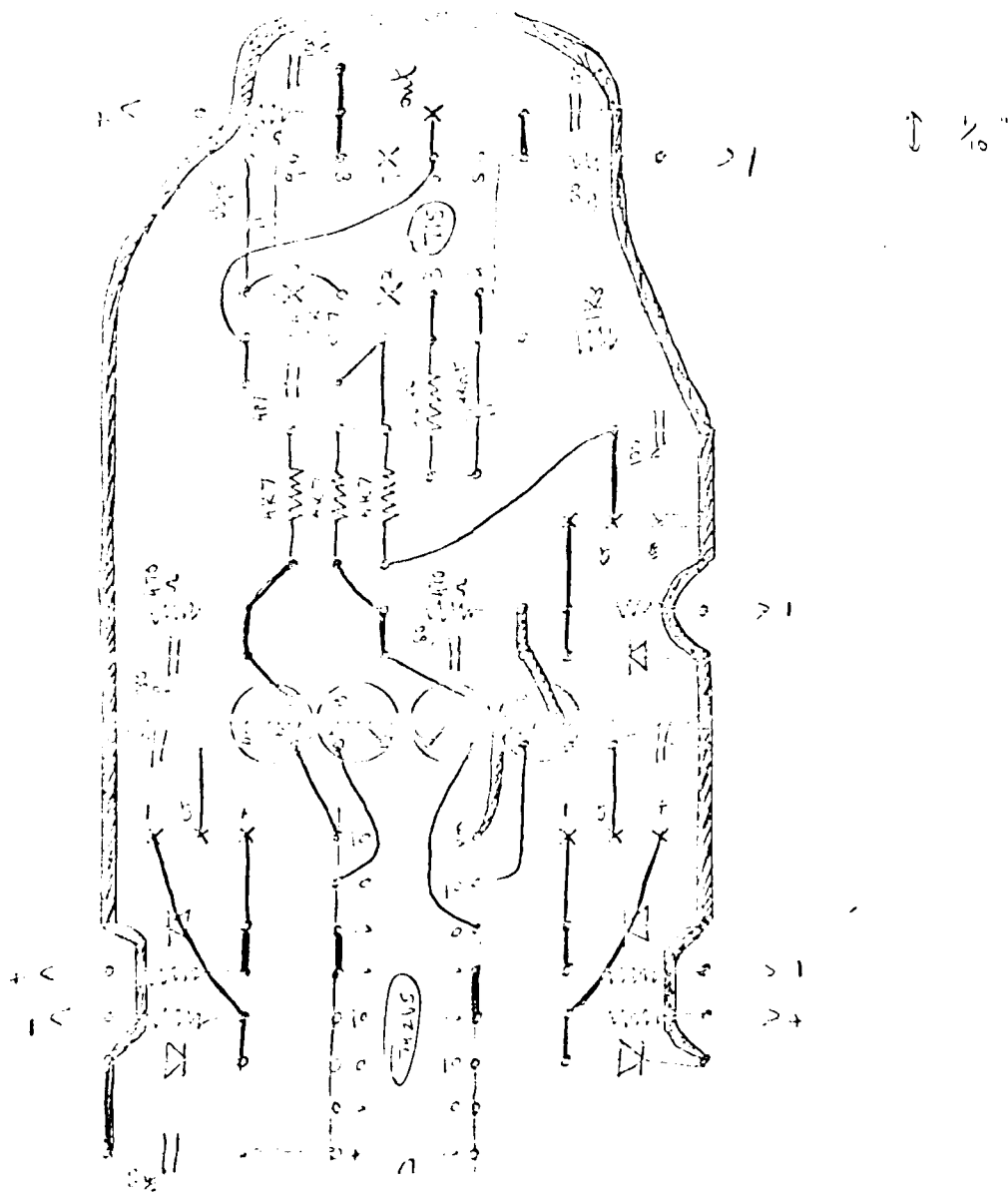


- Note 1: 7453 can be replaced in a 2P or 4P version of circuit.
- Note 2: The 150pF capacitor is optional.
- Note 3: The output of the first half of the circuit is connected to the input of the second half.
- Note 4: The output of the second half of the circuit is connected to the input of the third half.

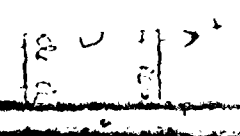
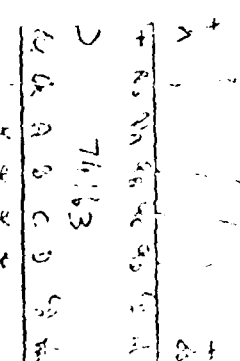
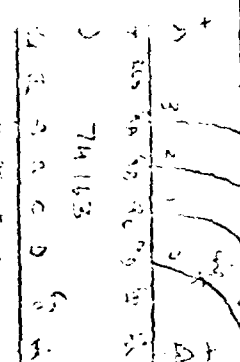
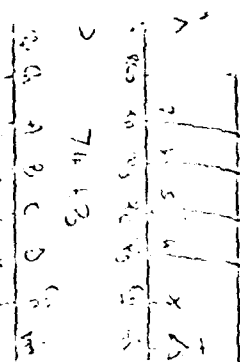
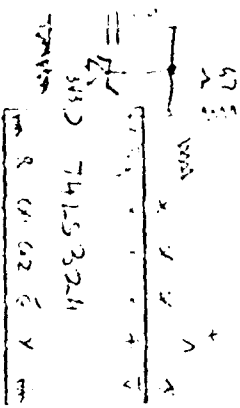
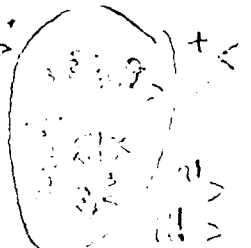
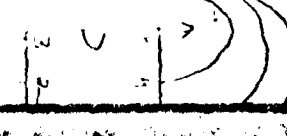
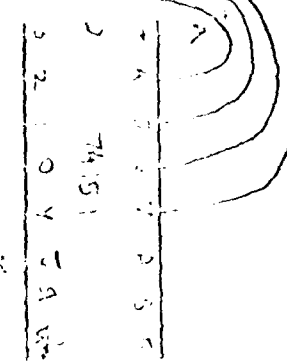
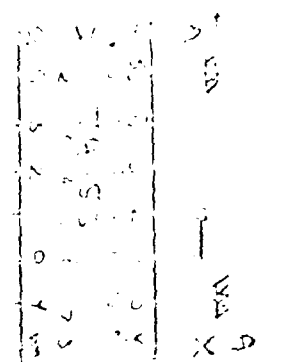
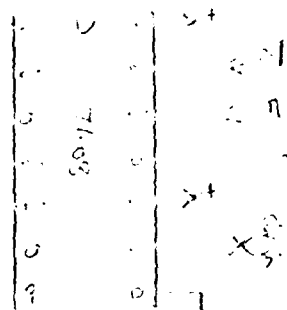
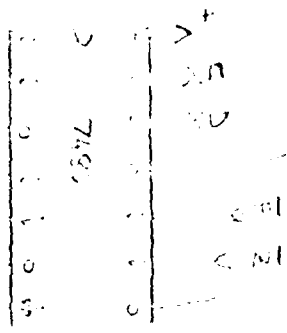
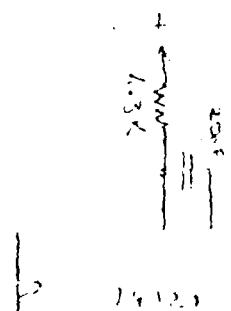
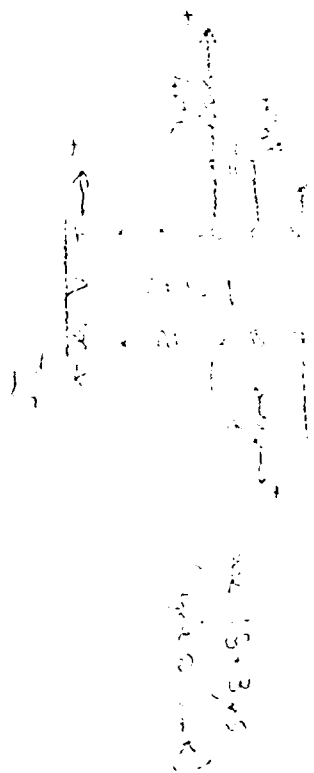
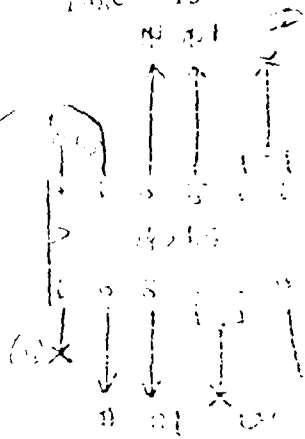
SELECT
STANDARD
CONNECTION



- Note 1: Input of the analog part of the circuit is fully digital.
Note 2: Be careful how you interpret logic and analog values.
Note 3: DAC output should be isolated from the chassis.



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Light

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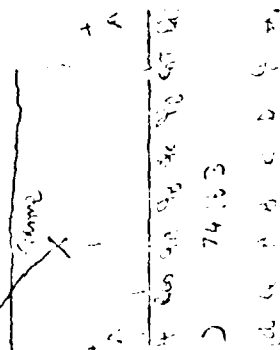
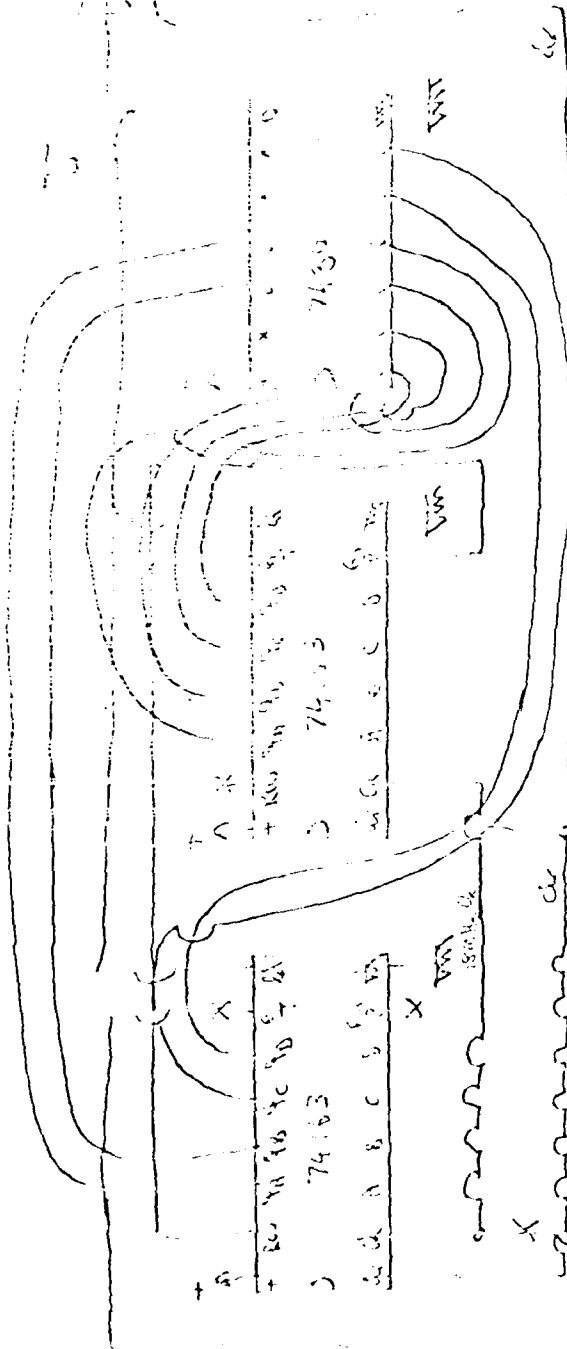
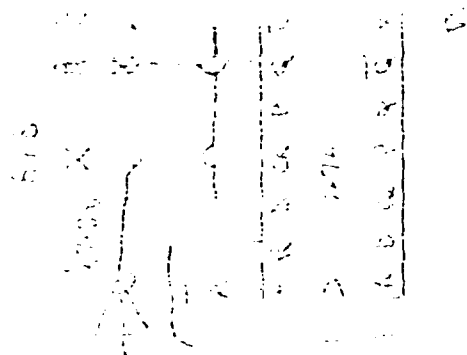
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Light

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ix. read 25ms

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ALTERNATE CHECKBOARD

21

PIN CONNECTIONS FOR RS 232 CONNECTOR.

1	Input	0 (15B)	} Sx Modulation Frequency.
2	Input	1	
3	Input	2	
4	Input	3	
5	Input	4	
6	Input	5	
7	Input	6	
8	Input	7 (15B)	} SELECT STIMULUS CONDITION H.
9	Input	A	
10	Input	B	} SELECT H OF CHECKS / LINE
11	Input	A	
12	Input	B	
13	Input	C	

14	Input	CLR	
15	Input		
16	Input		
17	Output	TRIGGER CHECK A (1)	
18	Output	TRIGGER CHECK B (1)	
19	Output	TRIGGER CHECK A OR CHECK B (1) 15ms	
20	Input		
21	Output	FRAME RESET PULSE (17) 15ms	
22	Input		
23	Input	A	} SELECT H OF CHECKS / FRAME
24	Input	B	
25	Input	C	

APPENDIX 3 - Sinusoidal Grating Stimulator

..?

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[illegible]


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2470 REM
2480 REM      LDR      #0              ! RESET BRITFACT FLAG
2490 REM      STR      BRCTIF
2500 REM
2510 REM      JSR      WAITFOR          ! WAIT TRIGGER OUT
2520 REM      LDR      CON
2530 REM      ORR      #80
2540 REM      STR      TRFLEPT
2550 REM
2560 REM      JSR      WAITFOR          ! ***** STIMULUS ONSET
2570 REM      LDR      #0
2580 REM      STR      TIME              ! RESET TIMER
2590 REM
2600 REM      JSR      WAITFOR          ! WAIT END OF PRESENTATION
2610 REM      LDR      TRFLEPT
2620 REM      AND      #80
2630 REM      ORR      BRCTIF          ! -1 IF NOT HIT
2640 REM      STR      BRCTIF
2650 REM      LDR      TIME
2660 REM      CMP      TIMEFIP
2670 REM      BNE      LOOP3
2680 REM
2690 REM      JSR      WAITFOR          ! WAIT TRIGGER OUT
2700 REM      LDR      CON
2710 REM      STR      TRFLEPT
2720 REM
2730 REM      JSR      WAITFOR          ! ***** STIMULUS ONSET
2740 REM      LDR      TRFLEPT
2750 REM      AND      #80
2760 REM      ORR      BRCTIF          ! WAIT END OF SCAN
2770 REM      STR      BRCTIF
2780 REM      LDR      TIME
2790 REM      CMP      TIMESO
2800 REM      BNE      LOOP4
2810 REM
2820 REM      LDR      #0
2830 REM      STR      JFYCLK              ! CLEAR JUMPY CLOCK
2840 REM
2850 REM      JSR      WAITFOR          ! CHECK BRITFACT
2860 REM      LDR      TRFLEPT
2870 REM      AND      #80
2880 REM      ORR      BRCTIF
2890 REM      BNE      LOOP6              ! IF BRIT NOT RE PRESENT STIMULUS
2900 REM
2910 REM      CLI                      ! DISABLE INTERRUPT
2920 REM      RTS                      ! EXIT TO BASIC
2930 REM
2940 REM      WAITFOR LDR      OR1RST          ! WAIT OR1 SUBROUTINE
2950 REM      LOOP   LDR      OR1INP
2960 REM      AND      #2
2970 REM      BEQ      LOOP
2980 REM
2990 REM      LDR      TIME              ! INCREMENT TIME
3000 REM      CLC
3010 REM      ADC      #1
3020 REM      STR      TIME
3030 REM      RTS
3040 REM
3050 REM
3060 REM *****
3070 REM LTRUN ASSEMBLED

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5105 10114

8110 FROM INTERUN.BIN

51.00 10.14

8150	MEM	825	!	0339	!	00	!	0		
8160	MEM	827	!	033B	!	00	!	0		
8170	MEM	828	!	033C	!	00	!	0		
8180	MEM	829	!	033D	!	00	!	0		
8190	MEM	830	!	033E	!	00	!	0		
8100	MEM	831	!	033F	!	00	!	0		
8120	MEM	832	!	0340	!	78	!	120		
8130	MEM	833	!	0341	!	20	03	03	32	202 3
8210	MEM	836	!	0344	!	00	03	03	123	53 3
8220	MEM	839	!	0347	!	00	4F	03	141	79 232
8230	MEM	842	!	034B	!	20	03	03	32	202 3
8240	MEM	845	!	034D	!	00	03	03	123	59 3
8250	MEM	848	!	034E	!	00	22	03	141	54 232
8260	MEM	851	!	0353	!	58	!	03		
8270	MEM	852	!	0354	!	09	03	!	169	0
8280	MEM	854	!	0356	!	00	05	02	205	5 2
8290	MEM	857	!	0359	!	00	F9	!	126	249
8300	MEM	859	!	035B	!	78	!	120		
8310	MEM	860	!	035C	!	00	4F	03	123	79 232
8320	MEM	863	!	035F	!	29	40	!	41	64
8330	MEM	865	!	0361	!	00	F9	!	210	249
8340	MEM	867	!	0363	!	09	00	!	169	0
8350	MEM	869	!	0365	!	00	0F	03	141	63 3
8360	MEM	872	!	0368	!	20	03	03	32	202 3
8370	MEM	875	!	0375	!	20	05	03	123	59 3
8380	MEM	878	!	037E	!	00	00	!	9	128
8390	MEM	880	!	0379	!	20	02	03	141	54 232
8400	MEM	883	!	037B	!	00	04	03	32	202 3
8410	MEM	886	!	037C	!	00	03	!	169	0
8420	MEM	888	!	037B	!	00	0C	03	141	63 3
8430	MEM	891	!	037B	!	40	03	03	32	202 3
8440	MEM	894	!	037F	!	00	4F	03	123	79 232
8450	MEM	897	!	0381	!	29	00	!	41	128
8460	MEM	899	!	0383	!	00	3F	03	13	63 3
8470	MEM	902	!	0386	!	00	3F	03	141	63 3
8480	MEM	905	!	0389	!	00	0C	03	123	60 3
8490	MEM	908	!	038C	!	00	3D	03	205	61 3
8500	MEM	911	!	038F	!	03	03	!	208	234
8510	MEM	913	!	0391	!	20	03	03	32	202 3
8520	MEM	916	!	0394	!	00	38	03	123	59 3
8530	MEM	919	!	0397	!	00	22	03	141	54 232
8540	MEM	922	!	039B	!	20	03	03	32	202 3
8550	MEM	925	!	039D	!	00	4F	03	123	79 232
8560	MEM	928	!	039E	!	00	00	!	41	128
8570	MEM	930	!	0392	!	00	0F	03	13	63 3
8580	MEM	933	!	0395	!	00	0F	03	141	63 3
8590	MEM	936	!	039B	!	00	0C	03	123	60 3
8600	MEM	939	!	039B	!	00	3E	03	205	62 3
8610	MEM	942	!	039C	!	00	03	!	208	234
8620	MEM	944	!	039D	!	09	00	!</		

3690	REM	962	!	0302	!	58	!	83		
3700	REM	963	!	0303	!	00	!	96		
3710	REM	964	!	0304	!	00	!	0		
3720	REM	965	!	0305	!	00	!	0		
3730	REM	966	!	0306	!	00	!	0		
3740	REM	967	!	0307	!	00	!	0		
3750	REM	968	!	0308	!	00	!	0		
3760	REM	969	!	0309	!	00	!	0		
3770	REM	970	!	030A	!	00	41	08	173	65 232
3780	REM	973	!	030D	!	00	40	08	173	77 232
3790	REM	976	!	030F	!	29	02		41	2
3800	REM	978	!	0312	!	10	09		210	249
3810	REM	980	!	0314	!	00	30	03	173	00 3
3820	REM	983	!	0317	!	13			24	
3830	REM	984	!	0308	!	09	01		105	1
3840	REM	986	!	030B	!	30	30	03	141	00 3
3850	REM	989	!	030D	!	60			96	

READY.

STIMULUS PRESENTING THE HORIZONTAL GRATING

THE PROGRAM DOES

Switch on PRT
 Check cassette is in recorder
 Type LOAD then hit 'Return'
 Press 'Play'

While PRT is loading:-

- Switch on Joyce (check it is set to 100 (maximum))
- Switch on Nicolet
- Switch on Nicolet

Rewind the cassette
 Type PRT then hit 'Return'

If not 0 then there has been a load error. Switch off PRT and try again. If two load errors, contact K.I.B.

Type PRT then hit 'Return'

Switch on Flashing box

Follow instructions of the program CAREFULLY

NOTES 1) Hit 'Return' after every entry

2) All entries have a default value (it appears beside the flashing cursor). Simply hitting 'Return' will enter this value. To alter the value type the new value over the old and hit 'Return'

3) Each question has only a limited range of acceptable answers. Where appropriate this is given in brackets after the question. If you enter a value outside this range you will have to contact K.I.B. (and it probably will not be possible, anyway).

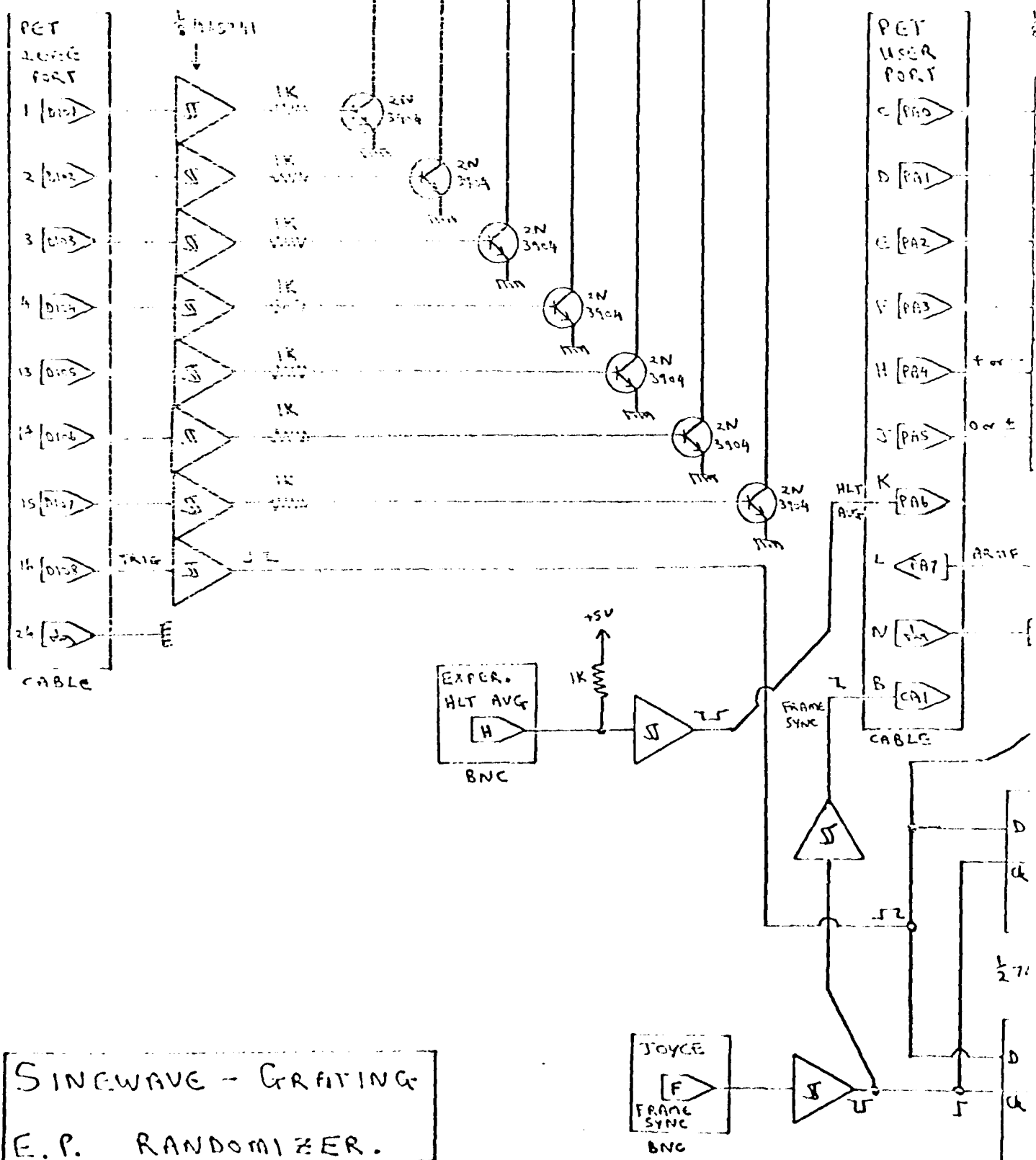
4) If you want the grating to be presented with approximately equal on and off intervals, then:-

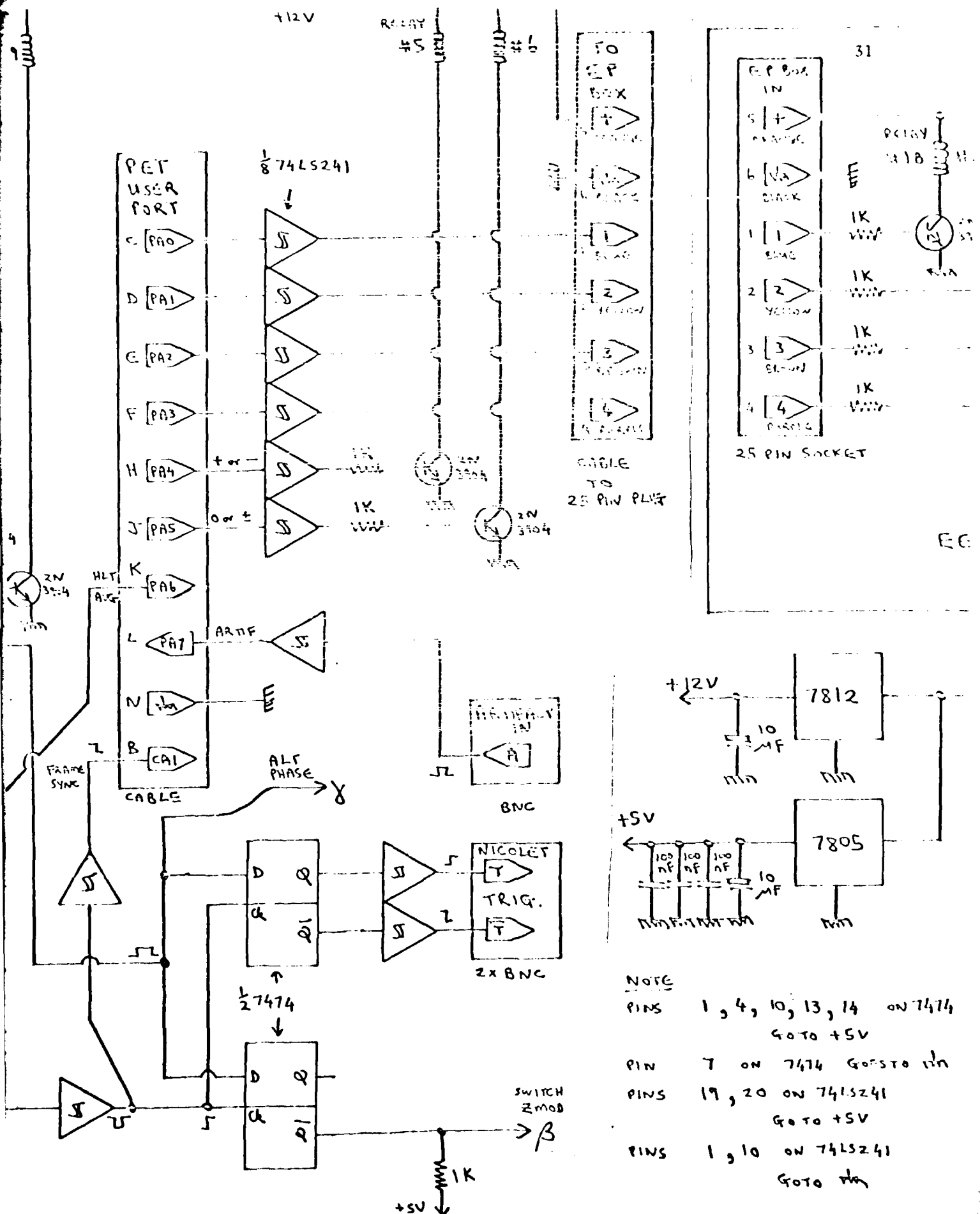
On grating presentation time must = Nicolet scan time + 125 ms.

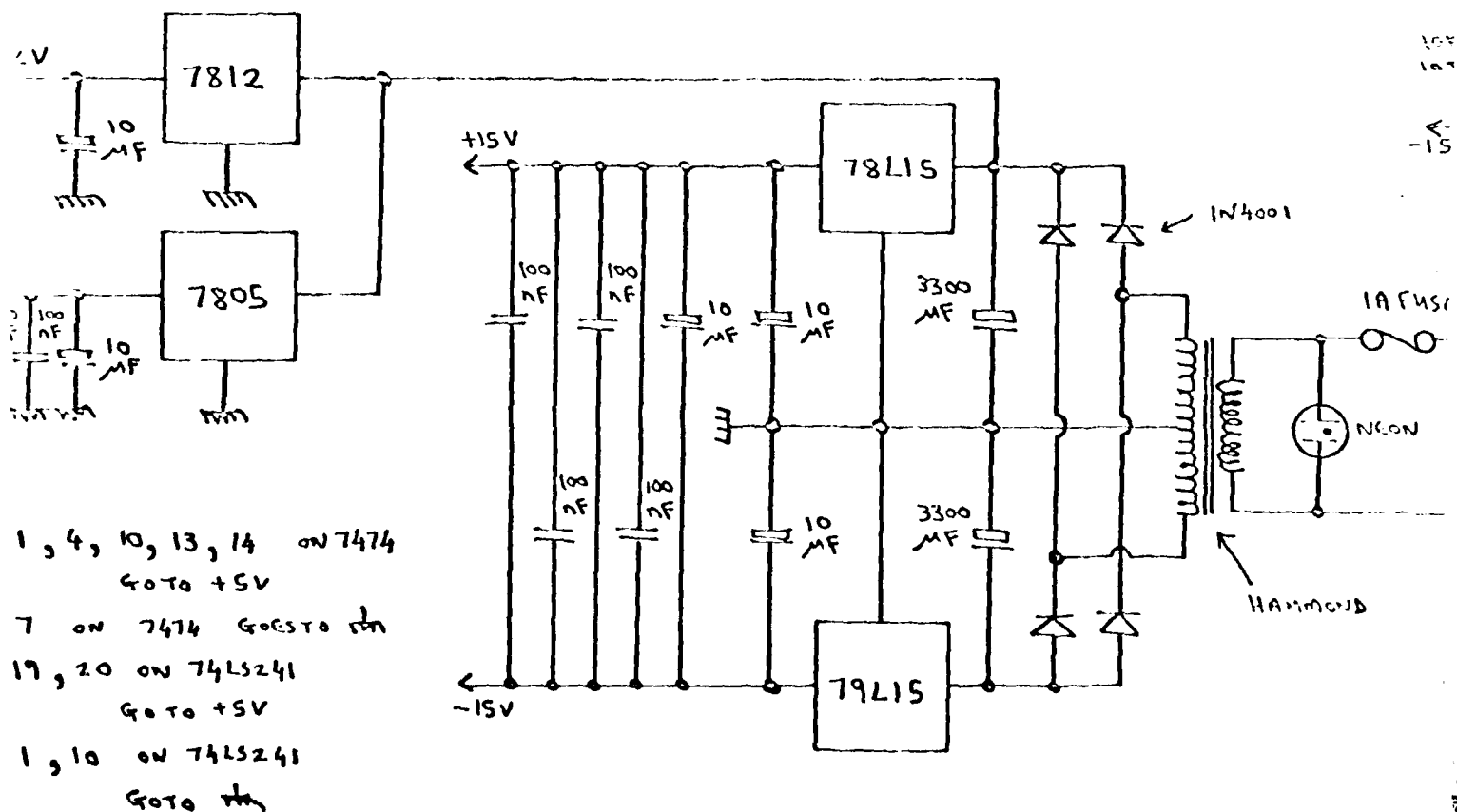
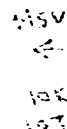
5) It is not possible to have $GPT < 30ms$ or $GPT > HST + 100ms$

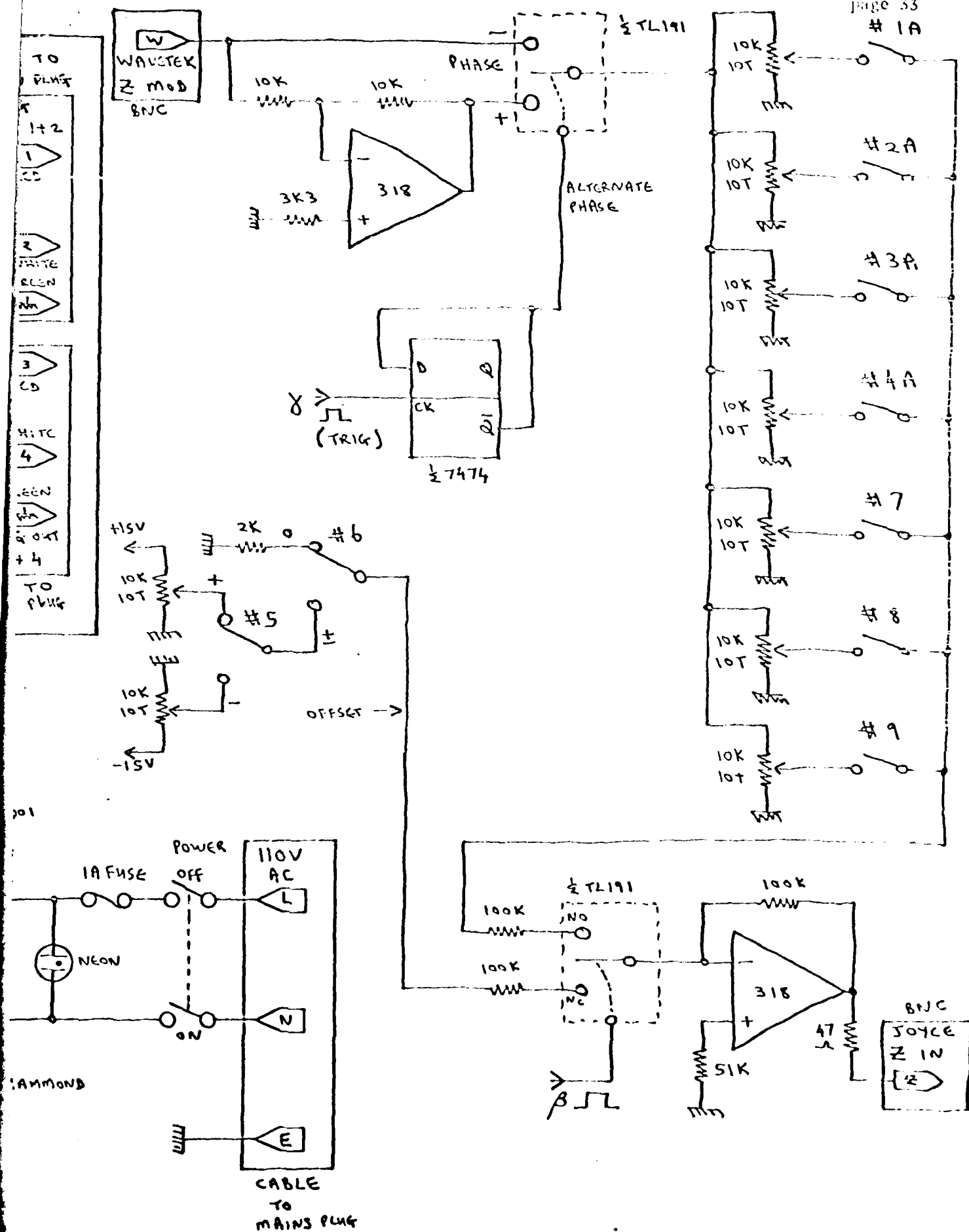
CONTRAST P.T.B. CALIBRATION:-

Pat #1	=	12.5% Contrast
#2	=	25%
#3	=	50%
#4	=	100%
#5	=	6.25%
#6	=	33.3%
#7	=	66.7%









(d)

D. Regan

PUBLICATIONS

34

(not including abstracts)

Books

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111. Regal, D.M., Tibbles, J.A.R. & Regan, D. Comparison of evoked potentials in a visually-disordered infant and his normally-sighted twin.
112. Regan, D. The concept of visual channels; its relevance to ophthalmology and the performance of skilled tasks involving eye-limb coordination. Psych. Rev., submitted.
113. Regan, D. Psychophysical tests of vision and hearing in patients with MS. Demyelinating diseases: Clinical and basic electrophysiology. Proc. Vail Conf., MS Society of U.S.A. Raven Press, 1981.
114. Kruk, R., Regan, D., Beverley, K.I. & Longridge, T. Correlations between visual test results and flying performance on the Advanced Simulator for Pilot Training (ASPT). Aviation, Space & Environ. Med., in press.
115. Quine, D.B., Regan, D. & Murray, T.J. Delayed auditory tone perception and delayed BAEPs in multiple sclerosis. Submitted.
116. Quine, D.B., Regan, D., Beverley, K.E. & Murray, T.J. Auditory FM channel loss in multiple sclerosis: one possible cause for problems in understanding speech. Sensory Processes, submitted.
117. Regan, D., Beverley, K.I., Kruk, R. & Longridge, T. The relevance of the channel theory of vision for the design of simulator imagery. Proc. Image II Conf., Arizona 1981.
118. Regan, D. Comparison of transient and steady-state methods. Proc. N.Y. Acad. Sci., 1982, in press.
119. Regan, D. Binocular vision. In Encyclopaedia of Physics. Pergamon Press, 1982.
120. Regan, D. & Beverley, K.I. How we avoid confounding the direction we are looking with the direction we are moving. Science, submitted.
121. Kaufman, L. & Regan, D. Visual perception of complex motion. In Handbook of vision. In preparation.
122. Regan, D. Visual evoked potentials. In Handbook of electrophysiology. Elsevier, 1982. In preparation.
123. Quine, D.B., Regan, D. & Murray, T.J. Auditory loss specific to frequency change in patients with multiple sclerosis and noise-induced hearing loss.

(e) LIST OF PROFESSIONAL PERSONNEL ASSOCIATED WITH THE RESEARCH EFFORT

D. Regan, D.Sc. (Higher doctorate in Science & Medicine, London, 1974); Ph.D. (Physics, Imperial College, London, 1964); M.Sc., DIC (Physics, Technical optics, Imperial College, London, 1958); ARCS, B.Sc. (Physics, Imperial College, London, 1957).

(f) INTERACTIONS

Invited participant in Workshop on visual aspects of flight simulation, NASA/NATO, Ames Research Center, California (1980).

Invited speaker at Workshop on Visual Cues in Flight Simulation, NRC Committee on Vision, Phoenix, Arizona (1980).

Invited speaker at Atlantic Provinces Ophthalmologists Society annual meeting, Halifax, Canada (1980).

Invited lecture at Workshop on Physiological Basis of Evoked Potentials, Sloane Foundation, Carmel, California (1980).

Invited lecture on physiology of motion and depth vision, Satellite Symposium of International Physiological Congress, Braunlage, West Germany (1980).

Invited lecture on the physiology of binocular vision, annual meeting of the International Society for Clinical ERG, Amsterdam (1980).

Invited lecture on motion perception and skilled tasks. Concordia University, Montreal (1980).

Visiting Professor series, invited lecture to Ophthalmology Department, Tufts University, Boston (1981).

Two invited lectures on visual diagnostic methods at Neuro-ophthalmology Course, Bascom Palmer Eye Institute, Miami (1981).

Invited lecture on visual and auditory tests in multiple sclerosis at a Workshop on Basic and Clinical Electrophysiology of Demyelinating Disease, U.S. Multiple Sclerosis Society, Vail, Colorado (1981).

Invited lecture at Evoked Potentials Conference, McMaster University, Hamilton, Ontario (1981).

Invited lecture on motion in depth. Neurosciences Program, University of Wisconsin, Madison (1981).

(With M. Cynader). Lecture on motion in depth neurons to the Association for Research in Vision and Ophthalmology (ARVO), Sarasota (1981).

Invited lecture on evoked potentials, New York Academy of Sciences, New York City (1981).

Discussion and presentation on evoked potentials at Wright-Patterson Air Force Base Seminar (1978). Seminar at Williams AFB (1979). Meeting on vision in aviation, Williams AFB (1980). Member of NRC Committee on visual simulation in flight training. Member of NIH (NEI) Ophthalmology panel writing 1981-86 five year plan for funding.

(g) PATENTS

No patents arising from this grant.

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