THE RECORDING, RETRIEVAL AND ANALYSIS OF SOME ELECTROPHYSIOLOGICAL MEASURES RELEVANT TO PSYCHOLOGY.

ROBERT M. BARNES.

Presented in Fulfilment of the Degree of
Master of Science in Psychology at
Rhodes University.

November, 1980.

CONTENTS

CONTENTS 1

PREFACE 6

CHAPTER 1 INTRODUCTION 8

- 1.1. The Nature of Electrophysiological Signals 11
- 1.1.1. The Heart Beat 13
- 1.1.2. The Electrical Activity of Muscles 18
- 1.1.3. The Electrical Activity of the Brain 23
- 1.2. The Analysis System 28

CHAPTER 2 AROUSAL 30

- 2.1. The Concept of Arousal 30
- 2.2. The Electroencephalograph 31
- 2.3. The Electromyograph 33
- 2.4. The Electrocardiograph 34
- 2.4. Summary 35

CHAPTER 3 DATA CAPTURE AND ANALYSIS 38

- 3.1. The Electrophysiological System 39
- 3.1.1. The Electrodes 40
- 3.1.2. Amplification 41
- 3.2. Analogue and Digital Data 42
- 3.2.1. Aliasing 46
- 3.3. The Analysis of Digitized Signals 48
- 3.3.1. Amplitude Analysis 48
- 3.3.2. Frequency Analysis 51
- 3.3.2.1. Fourier Analysis 53
- 3.4. Conclusion 57

CHAPTER 4 THE DATCAP ANALYSIS SYSTEM 58

- 4.1. The 6800 Computer System 58
- 4.1.1. Peripheral Devices 59

4.2. The Signal Processor Unit 59

4.3. The Software Specifications of the System 62

4.3.1. The System Programs 64

4.3.2. Assembly Language Subroutines 65

4.4. Operation of the Data Capture System 67

4.4.1. Subprogram FOURIER 68

4.4.2. Subprogram CARDIO 71

4.4.3. Subprogram INTEGRATOR 73

4.4.4. Output from Program OLDCAP 74

4.5. The Assessment of Change in Arousal State 75

4.6. General Conclusions 83

REFERENCES 86

BIBLIOGRAPHY 93

APPENDIX A TECHNIQUES IN PHYSIOLOGICAL RECORDING

A.1. Care of Electrodes A-1

A.2. Application of Electrodes A-2

A.3. Optimum Locations for Recording the Various bands of E.E.G. Activity A-8

APPENDIX B DATCAP OPERATING MANUAL

B.1. Operating the system B-1

B.1.1. Communication with the DOS 68 system B-2

B.1.2. The System Disk B-3

B.2. The Software Specifications B-4

B.2.1. Program DATCAP B-4

B.2.2. Program OLDCAP B-8

B.2.3. Subprogram TIMER B-9
B.2.4. Subprogram FETCH2 .... B-13

APPENDIX C THE STANFORD SLEEPINESS SCALE (S.S.S.)

APPENDIX D SCHEMATIC DIAGRAMS OF THE SIGNAL PROCESSOR
1 Power Supply and Data Buffer
2 Preamplifier and Filters (Single Channel)
3 Peak-Detector and Integrator
4 Analog-to-Digital Converter and Frequency Measure

NOTES

FIGURES

1.1.1.(a) The E.K.G. of a Single Cardiac Cycle 15

1.1.1.(b) The Structure of the Human Heart 16

1.1.2. The Structure of a Skeletal Muscle 20

1.1.3. The Arousal-Related Structures in the Human Brain 25

1.1.3.1. Frequency Bands of the E.E.G. 26

2.4. The Relationship between the Measures of Arousal 37

3.1. The Electrophysiological Recording system 39

3.2. The Sampling of an Analogue signal 43

3.3.1.(a) Rectangular Integration 49

3.3.1.(b) Trapezoidal Integration 50

3.3.2. Simple Frequency Analysis 52

3.3.2.1. An application of the Bergland Fast Fourier Transform 56

4.1. The DATCAP system 58.1

4.2. A single channel of the Signal Conditioner Unit (Block Diagram) 60

4.3. Filter selector switch settings 61

4.3.1. The front pannel of a single channel of the Signal Conditioner Unit 63

4.4.1.(a) FOURIER output (Banded) 69

4.4.1.(b) FOURIER output (Unbanded) 69

4.4.1.(c) FOURIER output (SQR Transform) 70

4.4.1.(d) FOURIER output (LOG Transform) 71

4.4.2. CARDIO output 72

4.4.3. INTEGRATOR output 73

4.4.4. OLDCAP output 74

4.5.1. Regression analysis: Subject 1 Morning 78

4.5.2. Regression analysis: Subject 1 Afternoon 79

4.5.3. Regression analysis: Subject 2 Morning 80

4.5.4. Regression analysis: Subject 2 Afternoon 80

A.1. Cardiac Electrode Placement A-4

A.1.1. The connection of the Cardiac Electrodes A-5

A.2. The Standard E.M.G. Neck Electrode Placement A-6

A.3. The "10-20" System of E.E.G. electrode Placement A-7

B.2.1.(a) DATCAP program source B-8.1

B.2.1.(b) DATCAP program flowchart B-8.6

B.2.2.(a) OLDCAP program source B-9.1

B.2.2.(b) OLDCAP program flowchart B-9.4

B.2.3.(a) TIMER program source B-13.1

B.2.3.(b) TIMER program flowchart B-13.4

B.2.4.(a) FETCH2 program source B-16.1

B.2.4.(b) FETCH2 program flowchart B-16.3

PREFACE

Perhaps the most difficult type of work that any academic can tackle is work which falls on the outskirts of his dicipline and yet, by virtue of the type of information that it provides in his field, must be explored.

I began with a peripheral interest in electronic design and computer programming and at the end, I am able to say that I know a lot more about both of these topics in their applications to psychology, but, this is not always the best way to obtain a post-graduate degree. There is a trend in modern research that I do not like: Expertism. I fully realise that the consultation of experts in a field is quite inevertable in modern times where fields are so complicated that the average student is only able to study a small part of his own dicipline, let alone other, unrelated diciplines. But, I call for a return to a holistic view of the academic world and for researchers to be willing to get to know the technology that is gradually becoming part of psychology. It takes time to gather the information and even more time to learn how to apply it but a knowledge of modern technology is very important. I have tried to be an active participant in the construction of the electronic devices used for this work, rather than rely on others to build a system to my specifications which is never a very satisfactory arrangement.

The speed at which computer development is proceeding is enough to lead even computer scientists to be wonder-struck by its implications. The system that I have begun work on is not sophisticated by modern standards, but it is a beginning. There is a lot of potential for expansion and subsequent advances in technology can be incorporated into the general idea of the system.

I would like to extend my sincere appreciation to Prof. H.W. Page for his invaluable criticisms and supervision of this research project.

Thanks must go to Jeff Lucas and Barry Guthrie of the Physics Department who suffered my continued presence in their laboratory during the development of the DATCAP system and were able tutors when my lack of sure technical foundation became apparent.

I wish to thank the members of staff of the Psychology Department for their support and encouragement during the course of this work espicially Dr Chris Stones and Mrs Pam Mac Kenzie for their assistance in preparing the manuscript.

Les Stretch deserves special mention for her warmth and encouragement in the difficult stages of this research when she was able to give me the support necessary for maintained patience.

This work was partially funded by a grant from the Human Sciences Research Council.

1

INTRODUCTION

> Human bodies are in space and are subject to the laws that govern all other bodies in space. Bodily processes and states can be inspected by external observers. So a man's bodily life is as much a public affair as are the lives of animals and reptiles and even as the careers of trees, crystals and planets.
>
> (Ryle, 1959)

In the progression of any particular science one can observe a shift in the level of observation used to accumulate data for study. This is clearly illustrated in the Humanities where each progressive step, each level of complexity leans more heavily on the advances of the Physical Sciences to improve their methods. This increase in complexity leads directly to the study of increasingly smaller parts of the originally unified object of study and the whole is often lost in the moras of data concerning its analysed parts.

Yet, in the progress towards a fuller understanding of the human organism, care must be taken to preserve the "man" in "human organism" rather that seeing only a collection of, admittedly, inter-related organ systems. With this in mind, the temptation to become blind to the whole by empirical "tunnel vision", and see only the dissected parts, can, in a way, be averted.

As a science moves away from the stage of direct observation of the outward appearances where the "What" question prevails towards the deeper questions of "Why" and "How", a change in methodology occurs and the age of theoretical models is born wherein the observable phenomena are incorporated into explanatory models with, hopefully, general applications. Yet, as these theories emerge, more questions arise which require investigation and the progression of complexity continues.

Much is already known about the externally observable behaviour of man, yet little is known about the nature of the reactions within the body that accompany this behaviour. Theories exist in profusion predicting the nature of these reactions and yet Psychology still finds itself unable to ascertain the nature of the relationship between the physiology and the behaviour of the organism.

Yet, the quest for a closer understanding of these reactions continues not only as an academic exercise, but often with an application in the "world out there". The refinement of a methodology that can provide insight into the nature of the bodily reactions that are not readily observable, has a secure place in the subject matter of Psychology.

Of particular contemporary interest are the methods of psychophysiology, defined by Hassett (1978) as "... the scientific study the bodily processes in behaviour and conscious experience" (p.3).

The general aim of the work undertaken is to contribute towards the development and establishment of a psychophysiological research laboratory where presently none exists. The specific aim is to design, develop, construct and interface a signal conditioning and data capture unit for electrophysiological phenomena and then analyse these. The initial focus is on the study of physiological arousal.

Duffy (1972) proposes that the description of behaviour at any particular moment in time requires the consideration of two basic aspects:

a) Direction: The approach or withdrawal of the organism with respect to aspects of the environment.

b) Activation: The intensity of the response of the organism to the environment (which can be extrapolated to arousal).

In defining the concept of Activation, the above mentioned author indicates that "the organism as a whole is sometimes excited, sometimes relaxed, and sometimes in a variety of intermediate conditions." This, she proposes, leads to the development of the concept of Activation.

In the course of this work, attention is paid to the selection of valid indicators of arousal from amongst the organs of the human body that emit some form of electrical signal during the ongoing life of that organism.

1.1. The Nature of Electrophysiological signals

Broadly, Biological Signals (signals recorded in some way from a living organism) is a term used to indicate any biological variable whose amplitude fluctuates over time, either in a regular or irregular manner (Shaw, 1967 p.407). Although it is true that some signals recorded from organisms do fluctuate regularly over time with fairly constant negative and positive maxima, this is by no means true for all signals, leading to the signals being classified into broad categories.

This categorical sub-division of physiological signals recorded electrically from the organism, finds a parallel in the method used to analyse these signals, each signal type having an analysis method best suited to extracting useful data from some sample of the over-all signal.

Shaw (1969) presents a list of the attributes of these signals which can be used to classify them.

AMPLITUDE can be measured at regular intervals or whenever it reaches a maximum. It may be measured from some line below the minimum amplitude giving rise to a measure of peak amplitude. On the other hand, the mean-line of the signal may be used to replace the base-line and then the magnitude of negative and positive excursions about this line can be measured giving rise to peak-to-peak (or trough-to-trough) amplitude.

The MEAN AMPLITUDE of a signal gives information as to whether there is an equal number of positive and negative excursions of that signal about the mean-line, in which case the mean amplitude will be small, or whether negative or positive excursions predominate, in which case the mean amplitude will be of greater magnitude and have a sign indicating which excursion predominates.

Whereas the above mentioned attributes can be extracted from all biological signals, the REGULARITY OF FLUCTUATIONS is only meaningful when discussed in relation to some biological signal which exhibits periodicity. Any method of signal analysis that uses words like "rate" or "frequency" imply that the analysed signal can be described in terms of this attribute.

The SHAPE of the signal is of importance when dealing with those biological signals that have certain components that are repeated periodically or that can be elicited by some stimulus.

The RANDOMNESS of a biological signal is really an attribute of all the other attributes mentioned above. It is on the basis of this attribute mainly, that the biological signals used in this research can be categorised into three classes.

The first class of signals used here is exemplified by the heart-rate which is a simple signal in that it is regular in the sense that deviations from the general shape are not common. The second class of signal which has a high degree of randomness with respect to both amplitude and frequency is illustrated by the surface-recorded electromyograph. The Electroencephalograph represents a class of signals which may be called complex sinusoids as, although there is randomness with respect to both amplitude and frequency, this signal can be seen as the sum of some infinite number of sine-wave components.

1.1.1. The Heart-Beat

It is difficult to conceive of a man unaware of his heart beating in his breast, indicating to both himself and to others that he is alive. Even before the discovery of the circulation of the blood and the resultant conception of the heart as a vital pump in the vascular system, the loud and fast beating of the heart of a frightened, or in some other way excited individual, must have been recognised as an indicator of the ongoing "internal" state of the individual.

Brown (1972) uses the measurement of heart-beat as a hypothetical problem illustrating the general trend in the development of human physiology. He traces the development of the heart-beat from an auditory or tactile phenomenon through to the techniques used in modern cardiotachometry. The most important single step in this progression is the discovery that there is a similtaneous change in the electrical state of the heart to accompany the sensory phenomenon: electrocardiography was born. With the development of better equipment (amplifiers, display units etc.) greater accuracy of measurement became possible and the role of the electrocardiograph, not merely as an indicator of vitality, but also as an accurate indicator of cardiac malfunction, became established.

The Electrocardiograph (E.K.G.) can be used as an indicator of heart-rate (H.R.) by means of either manually counting the number of times it reaches peak amplitude over time or, with more sophistication, by means of electronic counting device such as a tachometer.

The heart of a vertebrate, when removed from the body of a recently killed animal and maintained in a medium similar to the body will continue rhythmically contracting for an extended period of time. This is by virtue of the presence of a "pace-maker" in the heart muscle which maintains a "basal rate" of contraction of the heart. The anatomical features involved in the genesis of the intrinsic heart-beat are shown in FIGURE 1.1.1.(b).

FIGURE 1.1.1.(a) illustrates the electrical activity of the heart over a single cardiac cycle as recorded by an E.K.G.

FIGURE 1.1.1.(a)

The electrocardiographic recording of a single cardiac cycle showing the components of the heart-beat.

P-wave: The original pulse from the Sino-Atricular node at the onset of the cycle.

Q-R-S complex: The contraction of the ventricular myocardium after the impulse has been transmitted down the Bundle of His from the Atrio-Ventricular node.

T-wave: The relaxation of the myocardium and the re-polarization of the ions.

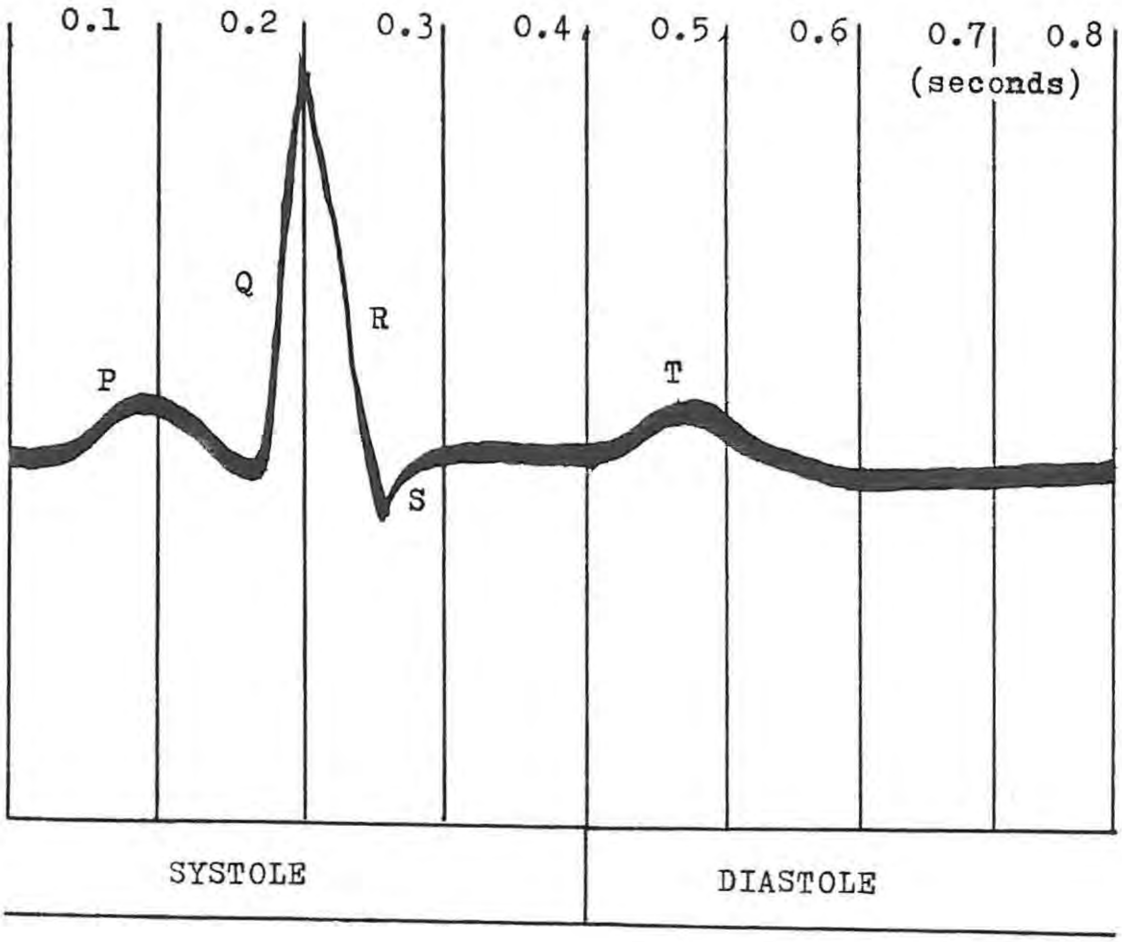
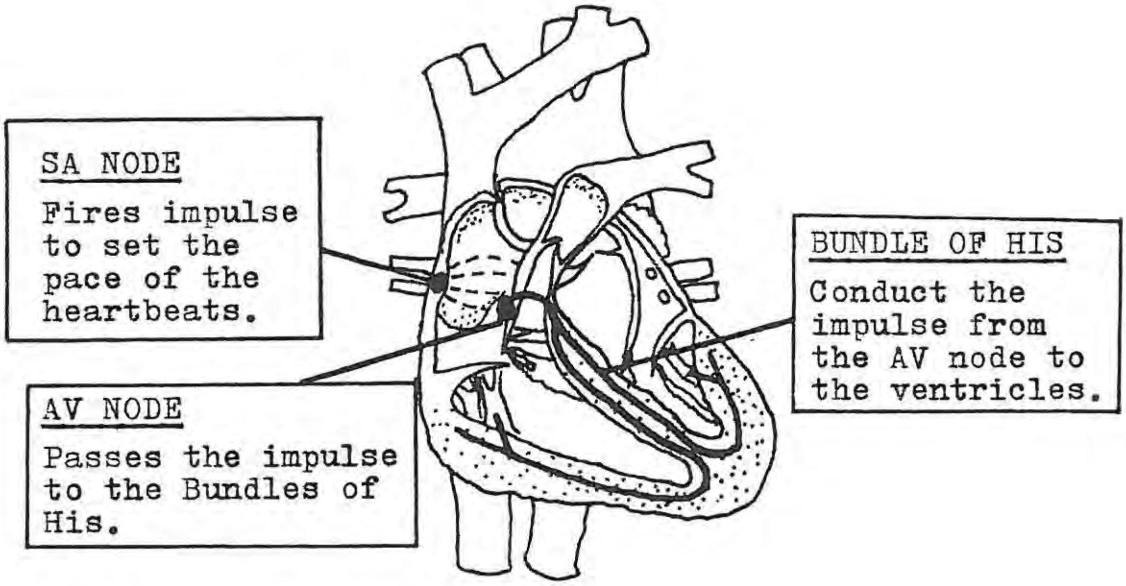


FIGURE 1.1.1.(b)

The anatomical structures of the Human Heart showing the structures involved in the genesis of the heart-beat.



The intrinsic nature of the heart-beat cannot account for changes in H.R. due to overall bodily state and thus it is not surprizing to find that there are channels of communication between the heart and the autonomic nervous system (Gunn, Wolf, Block and Person, 1972).

a) The Vagus nerve: The tenth cranial nerve in vertebrates, a root of the parasympathetic nervous system, passes down from the brain outside of the spinal column and reaches the heart. It causes a decrease in H.R. after exertion or shock.**

b) The Adrenal Glands: Adrenalin (Epinephrene) reaches the heart muscle from the adrenal glands via the blood-stream. This hormone causes the increase in heart rate associated with sympathetic activation. Schneiderman, Dauth and Van Dercar (1974) indicate the presence of cardiac accelerator nerves, part of the somatic-sympathetic nervous system, which also send adrenalin to the heart muscle.

The external control of H.R. is a function of the Autonomic Nervous System (A.N.S.) and thus one can propose that H.R. be used as an indicator of Autonomic Activation.

** See N1.1

Brenner (1967) points out that the electrical events of the myocardium are transmitted through the body fluids and eventually arrive at the surface of the body where they can be detected by means of dermally placed electrodes. The side of the heart nearest to any particular electrode has its activity reflected in that electrode temporally sooner than to any other electrode.

Standard electrode placement positions are used when recording an E.K.G. and these are shown in Appendix A.

1.1.2. The Electrical Activity of Muscles

Goldstein (1972) points out that when man first became aware of electric current, he began to search for a similar activating force in the contraction of muscles which could replace the Cartesian concept of "animal spirits" with a more contemporary concept, "animal electricity". It was not too great a step to discover that muscles contracted when an electric current was applied to them. The heart, essentially a muscle, was found to behave in this way as well. If an electrical current causes a muscle to contract, then the electrical activity of muscles must be recordable.** Electromyography, the recording of the electrical activity of muscles, was established.

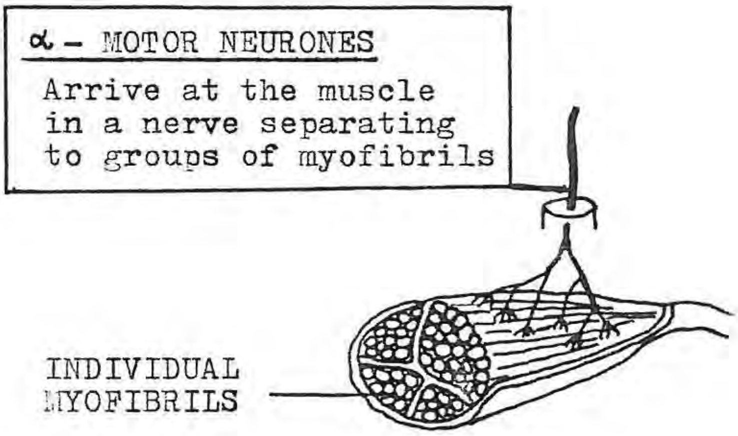
Skeletal muscles are controlled via the spinal motor neurones which make contact with the surface of the muscle fibers and transmit neural impulses to them causing them to contract. The muscles, like the neurones, are classed as "excitable tissue"

**See N1.2

and follow the general trend of threshold stimulation. The expected "all-or-none" nature of muscles is not obvious due to the multi-unit design of any particular muscle. Any skeletal muscle consists of large numbers of myofibrils, spindle shaped cells containing the all important proteins Actin and Myosin. Each of these "motor-units" conform to the all-or-none rule, but not all of these units need contract at the same time. The fact that we can observe graded muscle contraction suggests that the number of fibrils contracting at any one time determines the force of overall muscle contraction. This, in turn, suggests that any single skeletal muscle must be innervated in a complex manner.

FIGURE 1.1.2.

The Structure of a skeletal muscle: Macrostructure

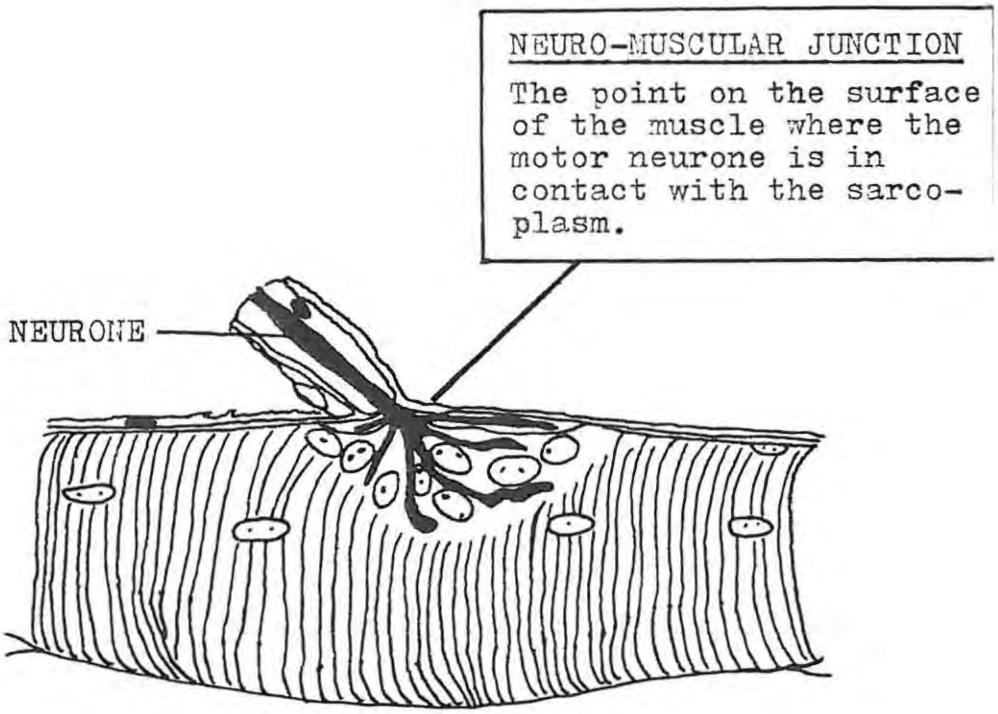


α - MOTOR NEURONES

Arrive at the muscle
in a nerve separating
to groups of myofibrils

FIGURE 1.1.2.

The structure of a skeletal muscle.



NEURO-MUSCULAR JUNCTION

The point on the surface of the muscle where the motor neurone is in contact with the sarcoplasm.

The structure of muscles leads to two methods of recording the electrical activity:

a) Individual motor-unit activity can be recorded by means of a micro-electrode being placed near the myofibril and another electrode placed in a relatively inactive site on the body to act as a "reference electrode". This "mono-polar" configuration of electrodes with only one "active" electrode is suggested by Lippold (1967) to be the best method of intra-muscular recording.

b) The gross activity of a skeletal muscle can be recorded by means of either surface electrodes placed over the muscle of interest, or shallow sub-cutaneous electrodes placed on the muscle. Here again the mono-polar recording configuration could be used and would give rise to a mono-phasic record of muscle action. If two electrodes are placed on the same muscle then a biphasic result is obtained. (See Lippold, 1967 pp. 251-252)

It is generally assumed from the outset that the electrical activity recorded from a muscle is in some way related to the "tension" of that muscle at the time of recording. Lippold (1967) cites evidence that indicates the "absence of a quantitative relationship between the amplitude of action potentials in a muscle and its tension" (p.257). This tends to point away from the use of the action of individual myofibrils in detecting muscle tension and confirms the use of gross recording techniques which are able to take advantage of the multi-unit structure of the muscle. Goldstein (1972) points out that there is a temporal delay between the arrival of the action potential at the muscle and the onset of contraction due to the electrical event being the stimulus to contract rather than the result of the contraction. The above mentioned author author cites researchers who have found that the Electromyograph (E.M.G.) does provide a "fairly good indication of tension in skeletal muscles" (p.333).

As is often the case in the recording of electrophysiological phenomena, the electrodes used in the recording are placed in standard positions. The standard placements adopted are from the Allan Memorial Institute and are given in Appendix A.

In contrast to the activity of the heart, the skeletal muscles are prone to fatigue and thus their action is not even constant over time. The changes in muscle action potentials over time are provided by Lippold (1967).

a) Action potentials become smaller in amplitude and longer in duration.

b) Large, slow waves appear in the E.M.G. possibly due to the resting potentials of the myofibrils not being reinstated each time.

c) Synchronous firing of large numbers of myofibrils may account for the increased amplitude observed.

Frusfield (1971) indicates that current methods of E.M.G. analysis include counting the rate of spike production or some method of amplitude assessment. The general trend in amplitude analysis appears to be towards the use of temporal integration of the signal (Lippold, 1967). Dowling, Fitch and Wilson (1968) advocate the use of frequency analysis of the E.M.G., and although Goldstein cites evidence to suggest that the frequency range of the E.M.G. may be as large as 2 Hz. to 10 KHz., Friedmann (1951) states that the E.M.G. can be "adequately represented by frequencies between 10 and 70 Hz." (cited Goldstein, 1972).

1.1.3. The Electrical Activity of the Brain

Although the electrical potentials of the brain were first observed by Caton in 1875, it was not until 1929, almost half a century later, that Hans Berger first recorded these potentials from electrodes on the scalp (Kiloh, Mc Comas and Osselton, 1972).

This delay can be attributed mainly to the lack of technology with respect to amplification and display methods which resulted in Berger's original recordings being viewed with a high degree of scepticism. Although this problem has been overcome, a problem still remains with respect to the use of the Electroencephalogramme (E.E.G.):
What is the relationship between the scalp recorded potentials and the activity of the underlying brain tissue?

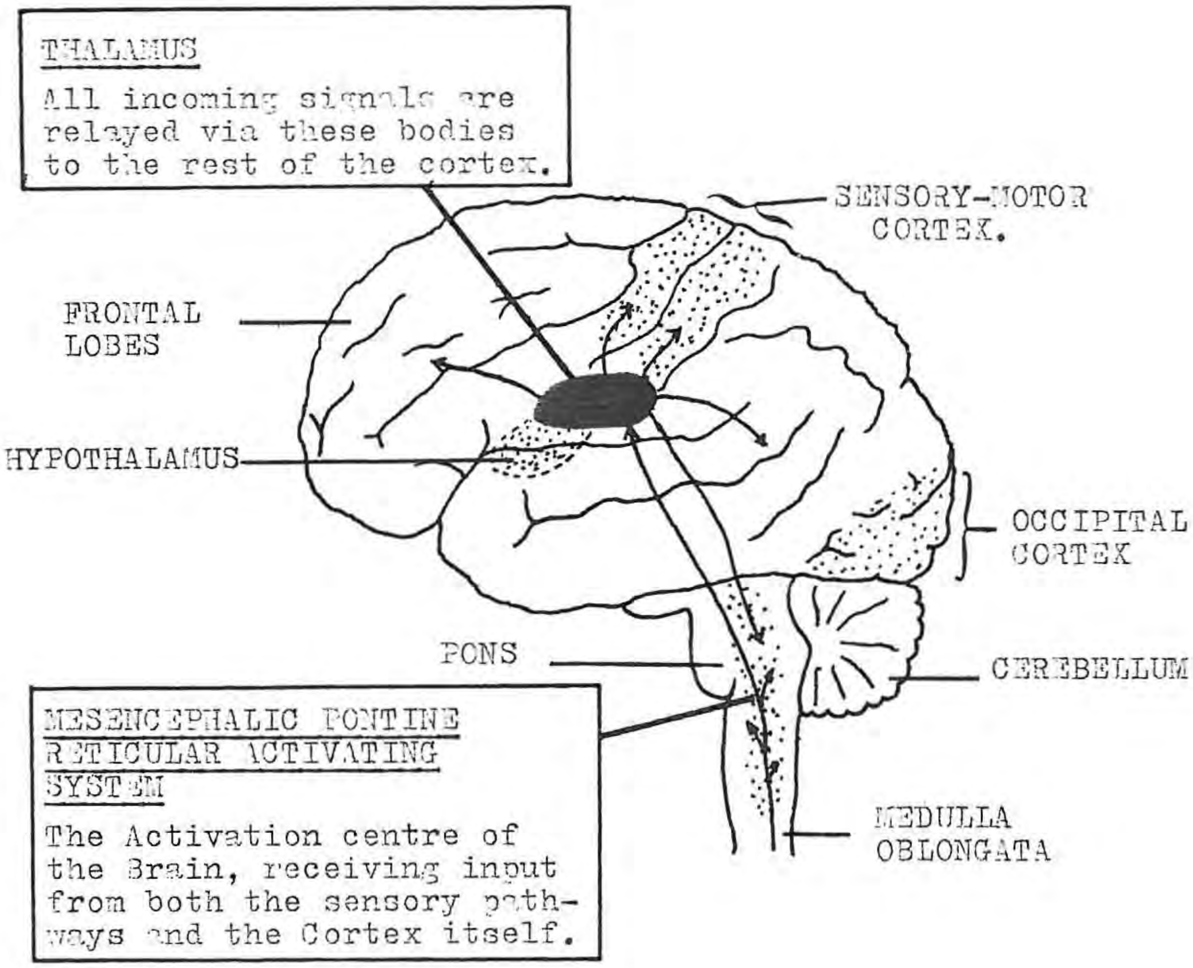
Margerison, St. John-Loe and Binne (1967) point out that "while it is reasonable to assume that the E.E.G. is related to cerebral function, it is very difficult to proceed to the nature of the relationship" (p.353).

They continue to analogise the use of the E.E.G. in trying to understand the functioning of the brain to "... blind men trying to understand the workings of a factory by listening at the outside walls" (p.353).

And yet, in view of these criticisms of the E.E.G., its place in both research and clinical assessment is well established. The use of an exosomatic technique allows ease of application and there is evidence that the E.E.G. gives an indication of cerebral functioning (Kiloh et al, 1972, p.21).

FIGURE 1.1.3.

Diagram showing the parts of the brain important to the maintenance of arousal.



THALAMUS

All incoming signals are relayed via these bodies to the rest of the cortex.

MESENCEPHALIC PONTINE RETICULAR ACTIVATING SYSTEM

The Activation centre of the Brain, receiving input from both the sensory pathways and the Cortex itself.

The role of the E.E.G. in arousal research became established after the work by Moruzzi and Magoun (1949) led to the discovery that stimulation of the Mesencephalic Reticular area of the brain-stem resulted in behavioural alerting and electrical changes in the brain similar to those which followed peripheral stimulation (Shagass, 1972). The frequency of the E.E.G. has subsequently been used to indicate the "behavioural state" of subjects from Sleep, on the one hand, (Oswald, 1966) and activation during mental tasks, on the other (Walter, Rhodes and Adey, 1966).

The E.E.G. has been classified into frequency bands. This is shown on the table below.

FIGURE 1.1.3.1. Frequency Bands of the E.E.G.

Name	Frequency	State
DELTA	< 4 Hz.	Deep sleep.
THETA	5 - 7 Hz.	Drowsy.
ALPHA	8 - 13 Hz.	Awake, eyes closed.
BETA	14 - 30 Hz.	Awake, alert.
GAMMA	> 30 Hz.	Excited, sleep deprived.

Although the E.E.G. is classified by frequency, a method quite acceptable when dealing with sinusoid signals, it is not useful to present the dominant frequency at any particular time as a complete description of the signal. It is preferable to display the spectrum of the frequencies present in the trace and these may be expressed as power present in the bands.

In adults, it has been found that the E.E.G. of a particular subject is similar under similar conditions. The same is not true between subjects and thus it is said that although the E.E.G. is intrasubjectively valid, the intersubjective validity is questionable (Hawkes and Prescott, 1973).

The information derived from the E.E.G. discussed thus far, is described by Goff (1974) as "... a continuous series of potential oscillations which are not related in a specific way to sensory input." (p.102) This definition is given to introduce the other type of information that can be derived from the E.E.G., event related potentials.

These potential changes are found to have fixed temporal relationships with stimuli presented to the subject and may be analysed out of the E.E.G. trace by means of a variety of averaging techniques (Goff, 1974). Event related potentials are further subdivided into those changes in the E.E.G. that occur after the presentation of the stimulus (known as Average Evoked Potentials - A.E.P.) and those occuring before the presentation of the stimulus and generally associated with expectation (known as Contingent Negative Variation - C.N.V.).

> The C.N.V. is described by Mc Adam (1974) as:
> "A vertex negative slow wave which develops during the fore-period while subjects are performing a fixed fore-period task" (p.245).

Although there is much research indicating that the event related potentials are indicators of arousal state (Shagass, 1972), they will not be dealt with here due to the additional difficulties that they introduce as far as equipment is concerned.

The recording of the E.E.G. presents certain technical difficulties most of which arise from the high degree of amplification that is necessary to increase the amplitude of the surface recorded cerebral potentials to signals suitable for display. Apart from the 50 Hz. mains interference, electrode related artefacts and contamination by other biological signals, such as heart-beat, constitute a problem in the recording of the E.E.G. This has led to the development of special amplifier technology and the introduction of filtering circuitry to the E.E.G. amplifier.

The standard electrode placements for the E.E.G. are shown in Appendix A along with a discussion on the elimination of electrode artefacts.

1.2. The Analysis System

Signals can be displayed on paper and analysed visually, but too much information is compressed into this display for easy identification of Arousal state. For the purpose of this work we shall examine a computer based, real-time analysis methodology which will be able to examine the state of consciousness of a subject from data derived immediately from that subject or from data previously stored on disk.

Some technical issues are discussed in the Appendices and Geddes (1970) provides an excellent discussion of many of the technical issues involved in this work that it is not practical to discuss here.

2

AROUSAL

> "I conclude that man as a whole is a larger affair ... than any single method of minute inquiry - be it chemical, physical, pathological, microscopial (sic.) or psycho-physical - will ever unfold. ... There is work enough for as many methods of study as are rationally based, have the definite aim of a concrete mental organization to be studied, and work definitely and progressively for it by observation of the facts, exclude not one another, but know that in the end they must bring, and knowing, strive to bring, their results into harmony."
>
> Henry Maudsley, 1900

2.1. The Concept of Arousal

The English language contains a large number of words grouped together into what may be termed the "linguistic system of arousal". This multiplicity of words is paralleled in the physiological indication of arousal with "low intercorrelations between measures of physiological arousal" (Taylor and Epstein, 1967, p.514). These authors report this as "embarrassing to those who propose a general activation or arousal syndrome" (p.514). Indeed it would be convenient to find that all the physiological measures used to indicate arousal correlated highly and allowed the establishment of an arousal continuum continuing from deep sleep through to the excited states on the high activation end (Malmo, 1959).

The low intercorrelations hardly seem surprizing in terms of the degree of differentiation of the vertebrate nervous system. It has already been implied that the different organ systems could be indicators of different types of arousal or arousal in different sections of the nervous system. Bearing this in mind, it is clear that measures of autonomic arousal need not indicate the same temporal trend as measures of central nervous system arousal.

The embarrassment at the low correlations between measures is the product of over simplification of the vertebrate nervous system which in fact constitutes a multi-organ, multi-factorial, response system. In short, the notion that the a concept of arousal relies on high correspondence between measures is faulty.

2.2. The Electroencephalograph

The E.E.G. has been found to be an important instrument in discerning between states of consciousness. A clear relationship exists between the nature of the E.E.G. trace and the arousal of the subject being recorded. Duffy (1951) describes this relationship:

"Brain waves are typically large and slow

> during sleep, faster and smaller during waking relaxation and very fast and small during mental effort" (p.33).

This finding has been demonstrated by many workers who report a high degree of reliability in estimates of state of consciousness based on the E.E.G.. Oswald (1966) holds the opinion that:

> " ... the E.E.G. provides the most sensitive index we have of the presence or absence of sleep, and one measure of the kind of sleep" (p.21).

Walter, Rhodes and Adey (1967) have successfully used the E.E.G. to discriminate amongst states of consciousness ranging from aroused states to sleep.

Dolice and Waldeier (1973) used the E.E.G. to ascertain the degree of increase in the arousal level of subjects either relaxing or performing a mental arithmetic task. They report a consistent trend towards increase in frequency with increase in "mental effort".

The increase in frequency of the E.E.G. is accompanied by a decrease in amplitude which Malmo (1959) reports to be " ... a 'flattening' of the E.E.G. tracing ... consistently found associated with increased alertness" (p.368).

The "Alpha blocking" response is found in higher vertebrates, including man, and is associated with the presentation of arousing stimuli. Lindsay and Wicke (1974) report that the same effect can be ellicited by direct stimulation of the Reticular Activating System. This reaction is often referred to as "disintegration" or "desynchronisation" of the Alpha rhythm.

2.3 The Electromyograph

In a series of publications between the years 1947 and 1949, Kennedy and Travis proposed a method whereby electromyographic potentials from subjects involved in a variety of vigilance tasks, could be used to monitor "lookout alertness." They were able to demonstrate a relationship between muscle spike emission rates and reaction time (Kennedy and Travis, 1947 (a), (b), 1948; Travis and Kenedy, 1949).

Surwillo (1956) indicates that although frequent connections are made between the electrical activity recorded from the skeletal muscles and a number of arousal related phenomena, little in the way of an explicit formulation of this relationship has emerged.

Goldstein (1972) in presenting an overview of the literature on the E.M.G., holds the opinion that the E.M.G. is a fairly reliable indicator of arousal with some intrasubjective validity over time. He indicates that the Frontalis muscle gives the best indication of arousal for research situations.

2.4. The Electrocardiograph

Of all the purported electrophysiological indicators of arousal state, the most difficult to understand is the heart rate. Malmo (1959) indicates that there is a decrease in heart rate as the subject moves towards deeper stages of sleep although Oswald (1966) points out the deviation from this trend in Rapid Eye Movement (R.E.M.) sleep. A positive correlation between E.E.G. and H.R. is reported by Darrow, Pathman and Kronenberg (1946) although this relationship appears to hold for only lowered states of arousal as a decrease in H.R. is proposed with increased arousal. The latter finding arises from the work of Lacey and Lacey from 1948 onwards (reviewed by Hahn, 1973). The conclusion from this work may be stated as:

> "Cardiac decelleration leads to sensory facilitation."
> (Hahn, 1973)

Hahn cites the following note from Headrick and Graham (1969):

> "Heart rate is an extremely complex response,
> affected not only by the stimuli impinging on
> the organism, but also by task requirements,
> respiration, state of the organism, species

> investigated and changes due to repeated presentation of the stimulus" (Hahn, 1973, p.67).

Although the changes in H.R. observed in some experimental situations are rather difficult to place in a causal framework, research by Welch and Richardson (1972) does indicate that H.R. can be used to classify sleep stages. This evidence supports the use of H.R. as an indicator of arousal even if it is only easily understood in low arousal situations.

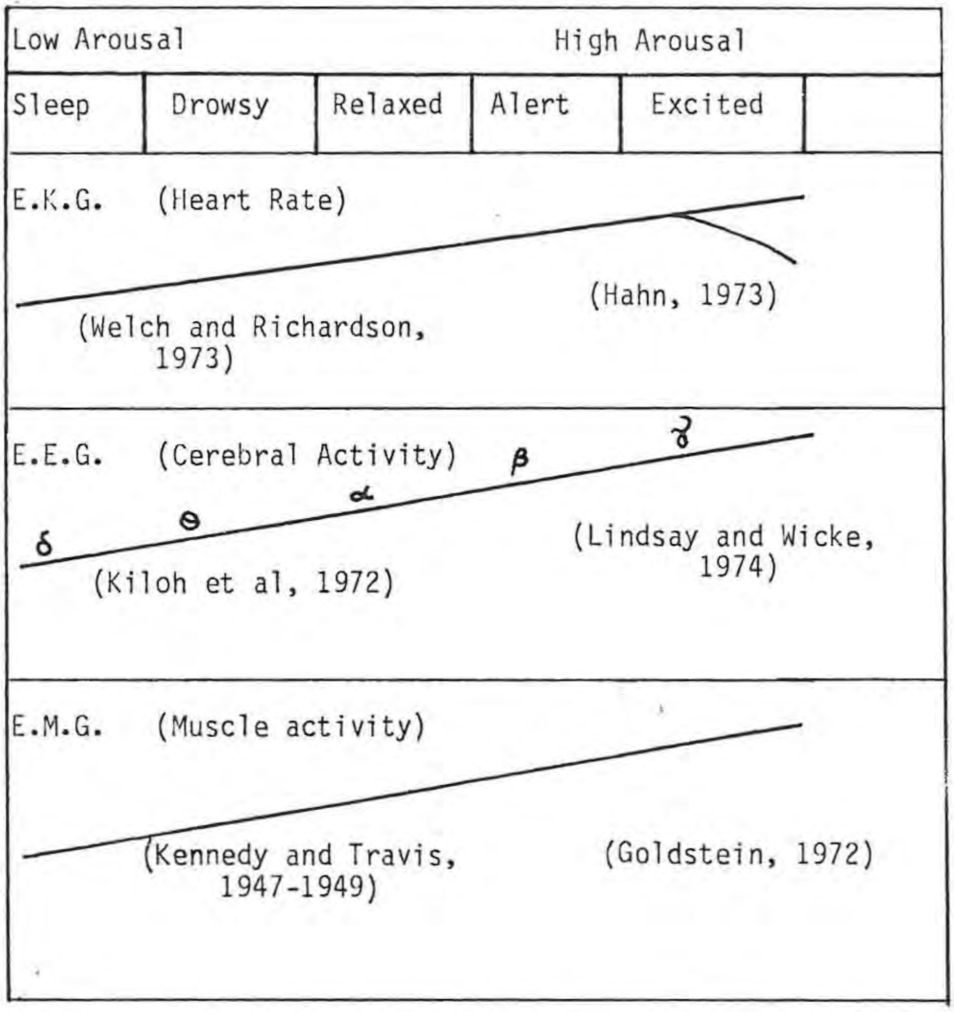
2.4. Summary

The physiological phenomena that have been discussed above all seem to have some relationship to arousal, although this relationship is often not very well formulated. The E.E.G., the nearest measure of cortical arousal that the scope of this work affords, can be used as a "yard-stick" for the efficacy of the other indicators of peripheral arousal. This, points out Malmo (1959), is seen in terms of the activation concept which involves the bombardment of the cortex with pulses arising in the Reticular System. He continues to point out that there are, however, "some real difficulties in defending the position that the R.A.S. is a unitary intensity-mediating mechanism", among these being the hetrogenous nature of the Reticular System.

The use of peripheral indicators of arousal does not meet with the complete approval of the more neurophysiologically orientated workers. This mistrust seems to have a solid foundation in terms of the complexity of the arousal response, but these indicators of arousal are temptingly easy to use, and an indication of the expected trends can be extracted from the literature on their use. The quantity of the change in these measures cannot be generalized due to the reported low intersubjectivity. The diagram below (FIGURE 2.5) summarises the expected trends.

FIGURE 2.5.

The Relationship Between the Measures of Arousal used in this work.



3 DATA CAPTURE AND ANALYSIS

Smith and Schade (1970) indicate five aspects of primary importance in obtaining information from any particular electrophysiological signal.

a) Sensing:
The transduction of the biological signal from the organism, its amplification and conditioning.

b) Transmission - interfacing:
The connection between the signal conditioning stage and the storage unit, be it a polygraph, magnetic tape or transistor memory.

c) Recording - storage:
The storage or retrieval of the data to or from the storage unit.

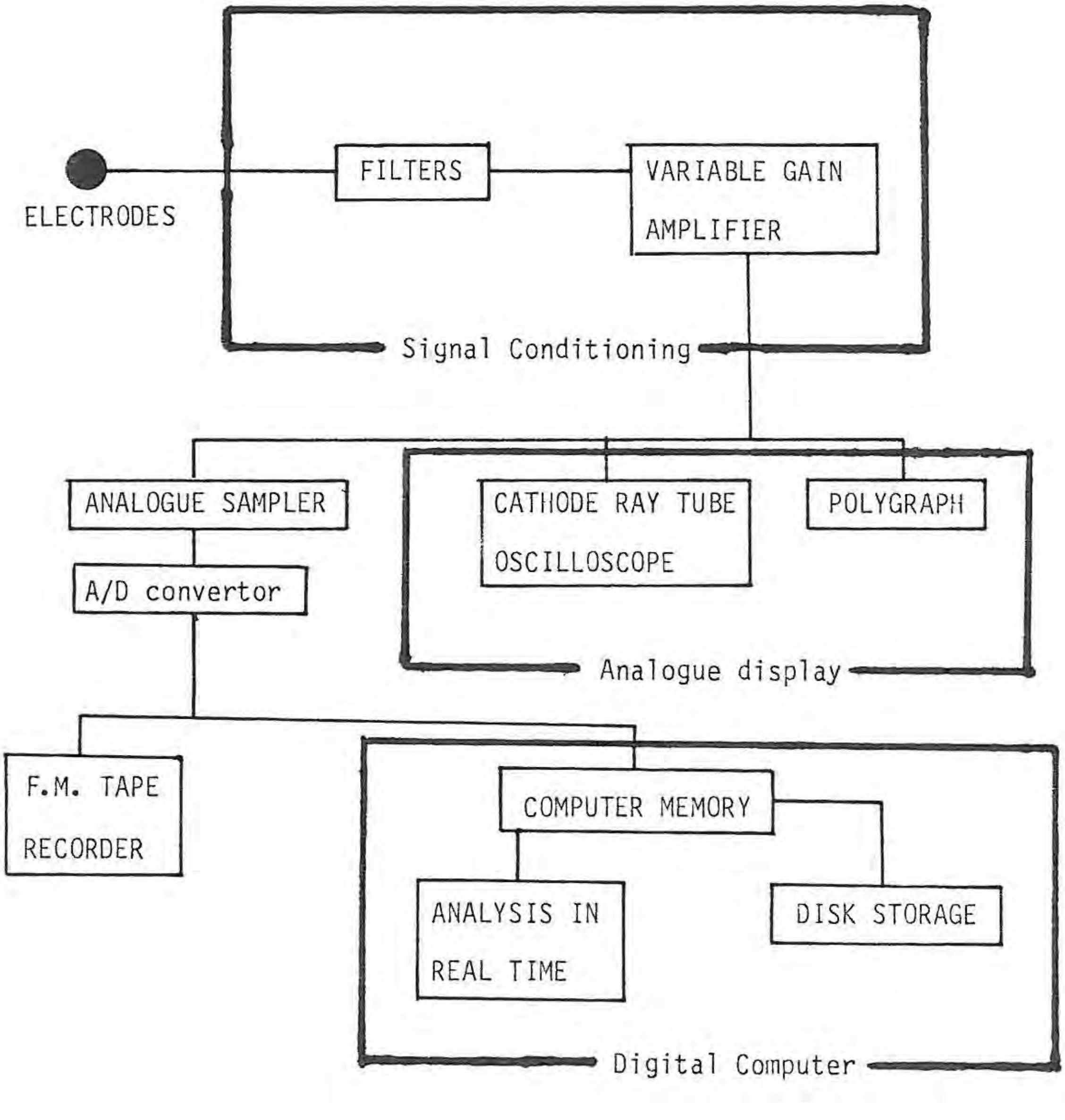
d) Computation:
The reduction of the data by some method of analysis, or the transformation of the original data into a form that is easier to interpret.

e) Interpretation:
The use of the results derived from the computation phase to arrive at conclusions about the phenomenon that is being examined.

3.1. The Electrophysiological System

FIGURE 3.1.

The General structure of an Electrophysiological Recording system.**



** See N1.3

3.1.1. The Electrodes

The electrode signifies the direct link between the subject and the recording equipment. Although there are a large number of different kinds of electrodes, each with their peculiarities, some general comments can be made.

The placement of the electrodes is usually standardised to achieve consistency in recordings from one institution to the next. The choice of the electrode sites is usually based on ease of application of the electrodes and the optimum coverage of the particular organ from the perspective of surface electrodes. The "10-20" system of E.E.G. electrode placement covers the head uniformly from the nasion to the inion and from ear to ear. The placement of the E.K.G. electrode on the body provides a number of different "angles of observation" of the electrical activity of the myocardium (Dubin, 1974).

The use of external (exosomatic) electrodes involves the use of electrode paste which acts as the connection between the subject's skin and the metalic electrode. The paste is usually viscous to impede desiccation and the resultant loss of contact with the skin. An abrasive agent is usually added to the paste to assist in the removal of some of the corneous outer stratum of the skin when it is applied and, thus, further enhance conduction.

The electrodes are kept in position on the skin either by means of mechanical stays such as rubber belts or casques, or affixed to the skin by means of a quick drying adhesive such as Collodion. Care must be taken to ensure the elimination of electrode movement and yet maintain maximal contact with the skin.

In the recording of bi-phasic signals, the use of non-polarizing electrodes is suggested. The most commonly employed electrode of this kind is the Silver-Silver Chloride electrode which strongly resists the polarization of the metalic ions preventing artefact production (Margerison et al, 1967).

The impedance between a pair of electrodes is of importance when dealing with signals of small amplitude. The use of the stick-on cup electrodes is best in achieving the desirable impedance of between 1 and 10 kilo-ohms.

3.1.2. Amplification

Of the three characteristics involved in the determination of the fidelity of any recording system, all are in some way related to the matching of the amplifier to the input signal (Geddes, 1970).

a) Amplitude linearity:
For any increase in the input to the amplifier, a corresponding increase in output must be observed.[**]

[**] See N1.4

b) Bandwidth:

The dynamic frequency range of the amplifier must be greater than the range of the signal frequencies.

c) Phase linearity:

This characteristic is related to the time-constant of the amplifier which may be seen as the delay between the input becoming zero and the output of the amplifier becoming zero.

The main use of variable time constant amplifiers is the adjustment of the damping-factor of the polygraph display.

3.2. Analogue and Digital Data

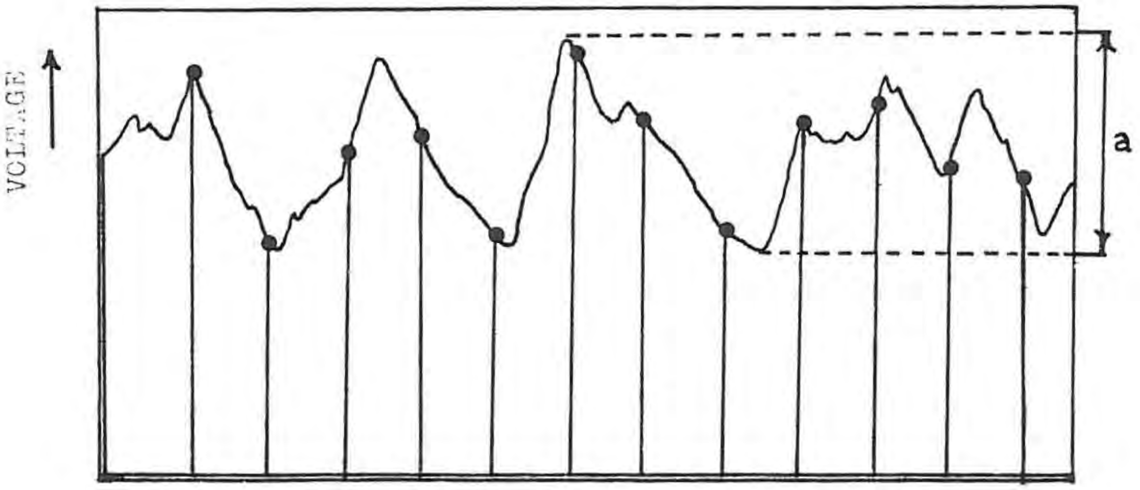
The customary display of physiological phenomena as a series of continuous fluctuations by either the use of a cathode ray tube oscilloscope or a polygraph is termed Analogue Display. This display method is of use only when visual methods of analysis are employed and as this work deals with the application of a digital computer to this analysis, it is digital data that we must derive.[**] It is necessary to change this analogue signal into a series of digital points separated by some finite time period, the resulting collection of points is then known as a finite time series.

[**] See N1.5

This conversion is achieved by means of a device known as an Analogue to Digital converter (A.D.C.). The sampling rate may be achieved by either the use of the internal timing pulses from the computer, or from an external timing device such as a digital

FIGURE 3.2.

The sampling of an analogue signal



counter interfaced into the computer.

The above diagram (FIGURE 3.2.) illustrates a typical situation. An analogue signal is shown with its absolute amplitude indicated as a and the time interval between sampled points as Δt. The points shown on the trace are the points at which an amplitude would be recorded.

The determination of the "sampling interval", Δt, is an important process in signal sampling. It has been shown to be determined by the highest frequency that we wish to analyse from the signal. This highest frequency should be known and can be fixed by the use of a low-pass filter. The result can be seen as a fairly narrow-banded signal (implying that the frequency spectrum is fairly narrow). Having established this, Δt can be determined by the Shannon Sampling Theorem:

$$\Delta t < \frac{1}{2 F_h} \qquad \ldots (1)$$

Where F_h is the highest frequency (Hz.) which is to be represented in the analysis of the signal.

Smith and Schade (1970) point out the inefficiency of this theorem when applied to narrow-banded signals as it prescribes a sampling rate, a feature that is useful in wide-banded signals where the frequency range is from Direct Current (0 Hz.) through to some large highest frequency. The above mentioned authors introduce the modification made to this formulation by Woodward

(1953), stating that for narrow-banded signals the trace can be "adequately represented" by a series of samples taken at a minimum rate of twice the width of the spectrum. The minimum epoch length is calculated in the same way as is shown in (1) if the minimum frequency analysed is 0 Hz..

Implicit in the discussion of sampling rate is the understanding that the signal being sampled can be said to comprise an unlimited number of sinusoids combined algebraically, F at h being the sinusoid with the highest frequency that is of interest in the analysis of the signal into its sinusoid components. The compounding can be represented as:

$$X_t = a_1 \sin (f_0) + a_2 \sin (f_1) \dots a_n \sin (f_{n-1}) \dots \quad (2)$$

Where X_t is a finite time series, a is the amplitude of any component sinusoid and f is the frequency of that sinusoid.

Although much of this discussion implies that the use of sampling is limited to compound sinusoids, this is not so. The sampling theories mentioned here are specifically tailored to the specifications of this type of signal and care must be taken to ensure that the general rules are complied with when sampling compound sinusoids.

A non-periodic signal may be represented as some function of time:

$$X = W(t) \qquad \ldots(2a)$$

Where W is some function of time, t.

3.2.1. Aliasing

The limitations placed on the highest frequency sinusoid that can be fitted to a time series that have been discussed thus far have been related to the determination of sampling frequency. A further limitation on the maximum frequency that can be analysed from a time series is a product of the equal "spacing" of the points taken from it. As the frequency of the sinusoid to be fitted to the data increases, we eventually arrive at a point where the oscillations are no longer discernable. As transcendental functions (Cosines or Sines) are used to fit the frequency to the data, frequencies are now fitted in a systematic manner to the data, even if the particular frequency is not present. This phenomenon is called aliasing.

Bloomfield (1976) presents mathematical proof of this phenomenon and concludes that the limits of the frequency of a sinusoid to be fitted to a discrete time series and still avoid aliasing are:

$$0 \leq \omega \leq \frac{\pi}{\Delta t} \qquad \ldots (3)$$

The maximum frequency shown in (3) is known as either the

Nyquist frequency or the Folding frequency as the spectral points calculated above this frequency will be a mirror immage of the points below it.

The Nyquist frequency can be calculated in Hertz as:

$$F_n = \frac{1}{2\Delta t} \qquad \ldots (4)$$

The representation of frequency as ω is in terms of radians per unit time.

1 radian = 0.159155 Hz.

π radians = 0.5 Hz.

3.3. The Analysis of Digitized Signals

The categorisation of Biological Signals into three classes has already been discussed in a previous chapter.

a) Periodic sinusoidal signals (Compound).

b) Periodic non-sinusoidal signals (Complex).

c) Random signals.

Any signal can be further identified in terms of Amplitude and Frequency and it follows that the mathematical analyses of digitized data are specific to one of these properties.

3.3.1. Amplitude Analysis

The magnitude of a signal at any moment can be ascertained directly from a digitized time series (being proportional to the result of the Digital conversion). The examination of all the data hardly qualifies as a reduction of the data and it is often useful to have a single index summarising the amplitude of an epoch. The primary method used in summarising epochs in this way is integration or more simply, summation.

$$A = \sum_{i=1}^{n} x_t \qquad \ldots (5)$$

Where A is the total amplitude, n is the number of samples taken during that epoch and x_t is the amplitude at point t.

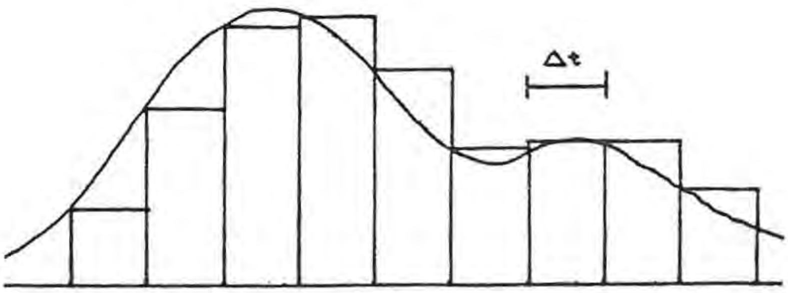
The simplicity of this algorithm is marred firstly by its inherent inaccuracy due to the fact that the points derived from the signal could be excessively discrete and, secondly, should the sampled points be both positive and negative, the total amplitude would be computed as nearly zero for each epoch.

The latter problem can be overcome by computing a measure of squared amplitude thereby eliminating the direction.

A more sophisticated series of algorithms are presented by Shaw (1967) involving, rather, the use of integration of the area within the bounds of the signal, thus approximating the area under the curve.

In the simplest case of signal integration, the points are joined by straight lines parallel with the time axis and the area of each of these rectangles is summed into the total area over the whole epoch. FIGURE 3.3.1.(a) (below) illustrates this process.

FIGURE 3.3.1.(a) Rectangular integration



Mathematically this may be stated as:

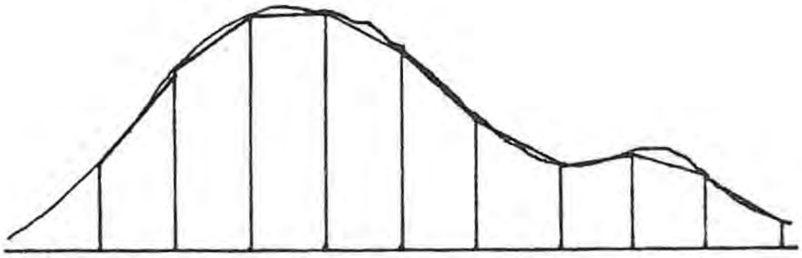
$$A = \sum_{i=1}^{n} a_i \Delta t \qquad \ldots (6)$$

Again, criticism can be levelled at this algorithm since the use of rectangles for integration is, at best, a poor approximation of area.

In an attempt to obtain a better estimate of the area under a signal, Trapezoid integration may be used. FIGURE 3.3.1.(b) illustrates this method and the mathematical formulation is given below.

$$A = \{\frac{1}{2} (a_1 + a_n) + \sum_{i=2}^{n-1} a_i\} \Delta t \qquad \ldots (7)$$

FIGURE 3.3.1.(b) Trapezoid integration



For a greater accuracy of estimated area under the signal that either of the above mentioned methods provide, Shaw proposes the use of a more complex integration method applying Simpson's rule (Shaw, 1967, p.412). This may be called Parabolic Integration as the segments between the samples are assumed to be parabolic.

$$A = \left[(t_1+t_n) + 4(\text{sum of even ordinates}) + 2(\text{sum of odd ordinates})\right]\frac{1}{3}\Delta t \quad \ldots \ (8)$$

The choice of one of these methods is determined by the time available for calculation and the degree of accuracy desired. None of these methods eliminates the problem discussed at the outset of the section on integration. If the signal is composed of both negative and positive excursions about some central line, the integrated result will approximate zero this being overcome by the calculation of the squared amplitude.

3.3.2. Frequency Analysis

In the description of any signal that fluctuates in amplitude over time, the rate of fluctuations is an important data-reduction method.

Before embarking on a discussion of the methods of frequency analysis, further discussion of sampling theory seems appropriate. Having established a method to find the minimum sampling frequency to represent some maximum signal frequency, we find that another relationship exists which relates the resolution of the analysis, the number of points in an epoch and the sampling interval.

$$N \cdot F_r \cdot \Delta t = 1 \qquad \ldots (9)$$

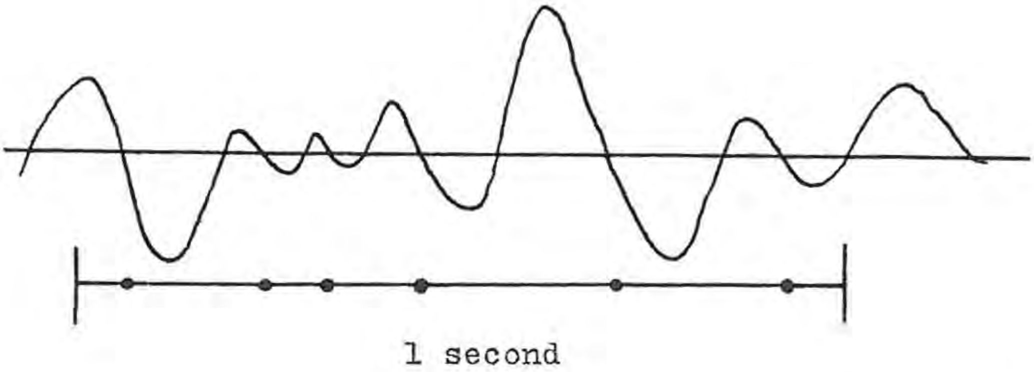
We can define any two of these parameters and have the last one determined for us where N is the number of points in an epoch, F_r is the resolution frequency and Δt is the sampling interval.

In its simplest form, the analysis of frequency consists of merely counting the number of "peaks" in a signal over some time period. This is only of value when dealing with simple sinusoid or non-sinusoid signals.

A slightly more sophisticated algorithm to detect "zero-crossing" can be used to measure frequency, but again the information derived from this formula is but a poor approximation of frequency. The zero-point is calculated over each epoch as a mean of the points present and the number of times the signal crosses the zero-line from a positive to a negative value, is counted and presented as frequency over time.

FIGURE 3.3.2. shows a periodic signal with its "zero-line". The points indicated on the time axis represents the "zero-crossings" leading to the obvious result of 6 Hz. as the frequency of the signal.

FIGURE 3.3.2. Zero-crossing



The major source of inaccuracy in the above mentioned methods of frequency analysis, is that they ignore components that could be present in the signal if it is a compound sinusoid.

3.3.2.1 Fourier Analysis

Any complex wave-form can be resolved into an infinite number of sinusoid components by means of a mathematical formulation called the Fourier Series. A number of different mathematical expressions of this series have been devised, but it may be generally stated as:

$$H_f = \int_{-\infty}^{+\infty} h_t e^{-i\omega t} dt \qquad \ldots (12)$$

Where H_f is the Fourier transformation of some frequency, h_t is a point on a time series, e is the Naperian base and -i is the imaginary coefficient.

Application of the Fourier Transformation have been devised to utilise digital data and these versions of the Transform are generically called Discrete Fourier Transformations and a large number of algorithms exist to perform this calculation. In the general case it may be expressed as:

$$H_j = \frac{1}{n} \sum_{k=0}^{n-1} h_k \; e^{-i2\pi jk/n} \qquad \dots (13)$$

Where j is the limited set of frequencies to be observed (j=0,1,2,...[n-1]) and k is the limited set of points from the time series under investigation (k=0,1,2,...[n-1]). The jth Fourier frequency may be expressed as:

$$\omega_j = 2\pi j/n \text{ or } F_j = j \; (F_n/n) \qquad \dots (13a)$$

Where the resolution may be determined from the Nyquist frequency, the steps being equal from 0 Hz. (D.C.) through to the Nyquist frequency.

For this analysis, the remarks made concerning sampling theory are especially pertinent.

The major problem involved in solving this equation is that it results in complex points (points having a real component and an imaginary component). This can be resolved by restating the equation in such a way as to give rise to the real and imaginary components as discrete values.

$$A_j = \frac{2}{n} \sum_{i=0}^{n-1} t_i \cos 2\pi f_j t$$

$$B_j = \frac{2}{n} \sum_{i=0}^{n-1} t_i \sin 2\pi f_j t \qquad \dots (14)$$

Where A_j is the jth real component and B_j is the jth imaginary component. Having calculated these points, the amplitude of the frequency component can be ascertained by:

$$R_j^2 = A_j^2 + B_j^2 \qquad \dots (15)$$

By plotting a series of these amplitudes against their Fourier frequencies, an amplitude spectrum can be created.

Bloomfield (1976) suggests the following transform to give rise to a "power spectrum" from the amplitude spectrum.

$$I_j = \frac{n}{8\pi} R_j^2 \qquad \dots (16)$$

(Bloomfield, 1976, p.113).

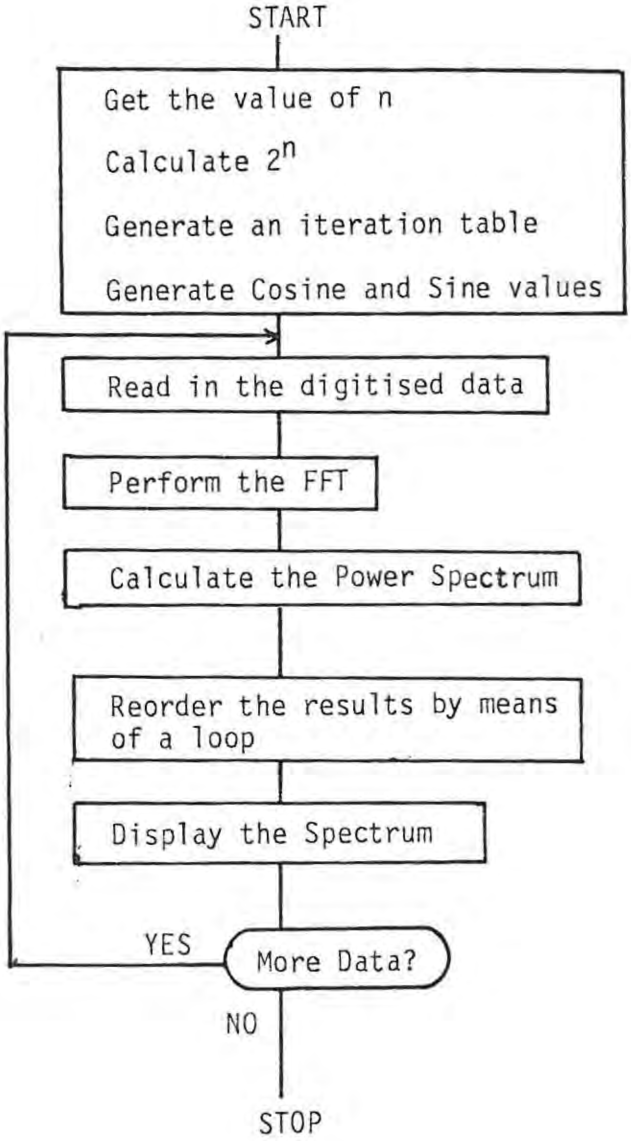
Equation (14) is clearly the equation of choice for the calculation of Fourier transforms, but is a very time consuming calculation. To overcome this difficulty the Fast Fourier Transform (F.F.T.) was devised.

This algorithm is distinct from the above equation in that it performs the transformation of 2^n point resulting in the same number (2^n) of frequencies being represented. The resolution of the spectrum can be calculated by equation (9).

An improvement in the speed of performance of the F.F.T. algorithm was brought about by the revision of the original

Cooley and Tukey algorithm (Cooley and Tukey, 1965) by Bergland (1969). The saved time is mainly due to the calculation of an "iteration table" and the initial calculation of a table of transcendental results which can be applied repeatedly for each successive epoch on condition that the number of points per analysis remains constant.

A possible application of this algorithm is shown below (FIGURE 3.3.2.1.) after Gersbach (1978).



3.4. Conclusion

The inclusion of this section is justified in terms of the complexity of the analysis methods utilised on biological signals. Although the presentation of this material is mathematically simplistic, it gives sufficient information to make the use of the analysis system, that is to be discussed in the ensuing chapters, more understandable to technically orientated researchers.

It may be necessary for the user of the system to refer back to the original texts from which the analysis methods have been extracted for a more complete overview of their applications with special reference to their limitations.

The use of a small computer in the application on the technology that has been discussed thus far necessitates some discussion on computers in general.

The computer may be seen as the central coordinator of the analysis system in that it controls the action of the peripheral devices that it has access to. The components of the system that is to be discussed here are shown diagrammatically below.

4

A SIGNAL PROCESSING SYSTEM

4.1. The 6800 Computer System

The 6800 family of computer products all revolve around the Motorola M6800 integrated micro-processor which is fitted to a "mother-board" (in this case the SWTPC system) which gives the processor access to data lines and control signals from the peripheral devices such as the memory boards, the Input/Output (I/O) ports and the disk controller.

Peripherals connected to the computer system are usually attached via a Peripheral Interface Adaptor (P.I.A.) which serves to "decode" the data from these peripherals making it compatible with the M.P.U..

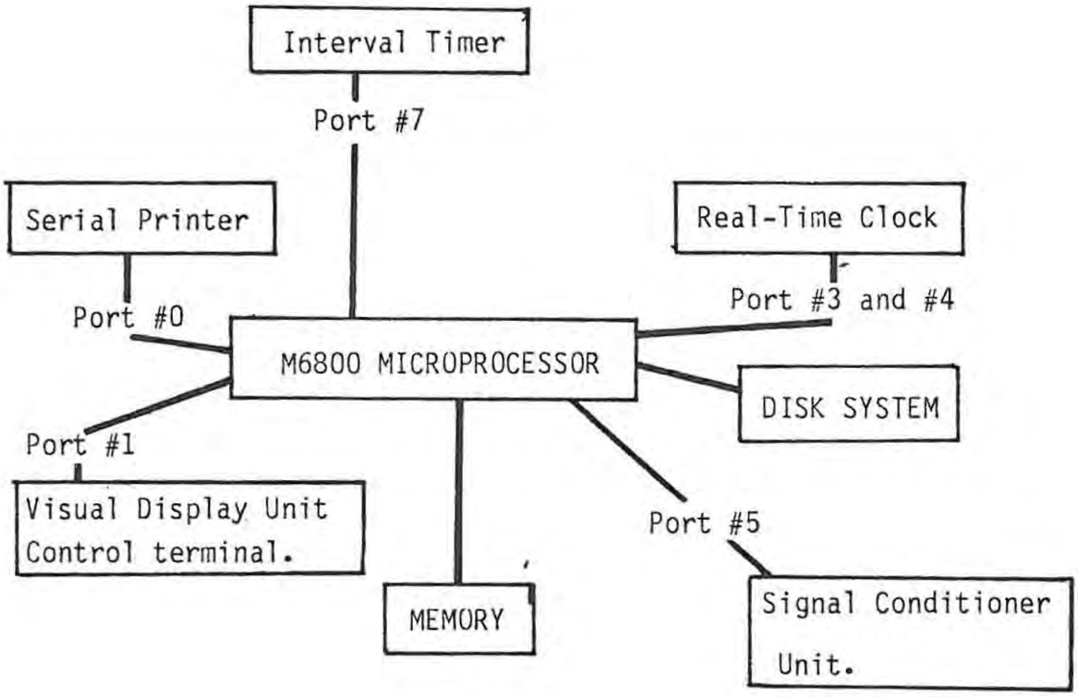
The Control Port (Port #1) is reserved for the Control Terminal which is used for starting up the system and the presentation of general commands to the system. A V.D.U. is connected to this port. A printer is connected to Port #0 to provide hard-copy output used by some programs.

The 6800 "chip" allows for a maximum of 64 Kilobytes of memory although this full complement need not be present for the system to function. The memory in the system may be broadly divided into two types:

a) Random Access Memory (R.A.M.) which is fully programable and may contain either program instructions or data.

b) Read-Only Memory (R.O.M.) which may be

FIGURE 4.1. The DATCAP System



read from but not written to. This is usually reserved for the storage of the operating system.

4.1.1. Peripheral Devices

The use of a disk system with the 6800 computer system is important in determining the way in which the system is used. The speed of data storage and retrieval allows for rapid accessing of program files into memory and also allows programs to create data files in real time.

A digital clock is fitted onto the front panel of the computer system and interfaced into the system allowing programs to access the chronological time during their execution.

4.2. The Signal Processor Unit

The incoming biological signals are conditioned and digitized by means of a custom built signal processor unit which is interfaced into the computer on port #5. Although this unit is capable of performing more than simple Analogue to Digital conversion of a signal, these further capabilities are not made use of here and thus the parts of the conditioner that will be discussed here will not be fully indicative of the capabilities of the system.

The diagram below (FIGURE 4.2.) shows the components of the conditioner unit.

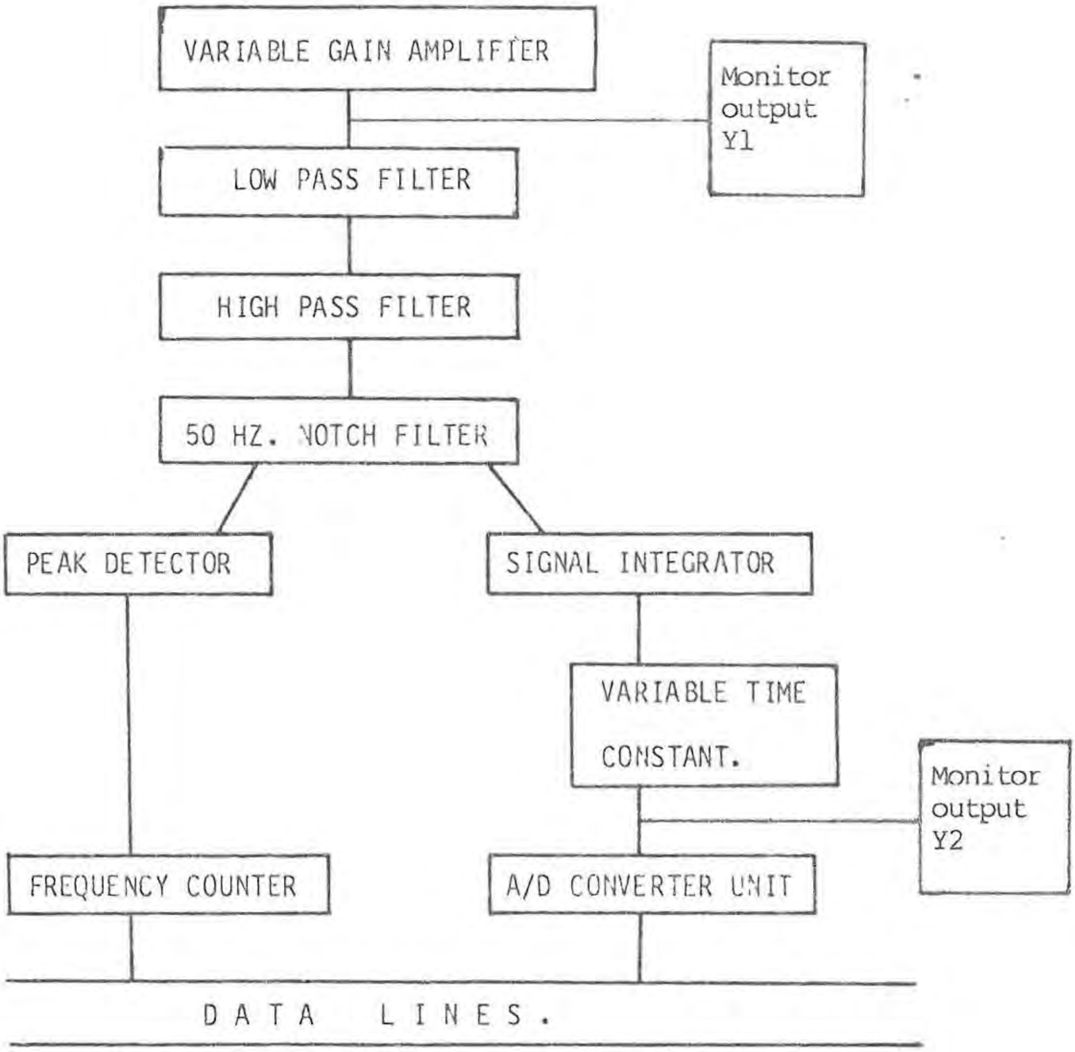


FIGURE 4.2. A Single Channel of the Signal Processor Unit.

Four identical modules are provided each conforming to this scheme.

The signal entering the module is first passed through an AC/DC selector circuit. The variable gain amplifier which it then enters is controlled by, firstly, a step-wise attenuator switch on the front panel of the module and secondly, by a fine amplitude control also on the front panel. In combination these two controls allow for fine selection of amplifier gain factor and the resulting signal can be monitored from the output Y1 on the modules.

A series of filters is provided in each module to allow for the selection of signal band-width and is set by removing the modules and setting the filter switches to the desired positions. Four switch arrays are found on each module and the two left most switches and the two right most switches must be set identically; the left most switches setting the high pass filter and the right most switches setting the low pass filter. The switch selection conforms to the table below. (FIGURE 4.3.)**

A and A1 (High pass)	B and B1 (Low pass)	Frequency (Hz.)
1	1	1
2	2	5
3	3	10
4	4	20
5	5	100
6	6	200
7	7	500
8	8	1000

FIGURE 4.3. Filter Selector Switch Settings.

If the high pass filter is set above the low pass filter, no signal will be passed through the filters and care must be taken

---

**See N2.6

to avoid this.

A switch selectable 50 Hz. filter is provided to reduce mains interference and is activated by switching the control on the modules to the ON position.

The route that the signal is passed through from this point onwards is under the control of the user programs and as the unit is used only in the AMPLITUDE mode on all channels, the INTEGRATOR and FREQUENCY modes will not be discussed in the text (although additional information will be given in the appendix under programming specifications).

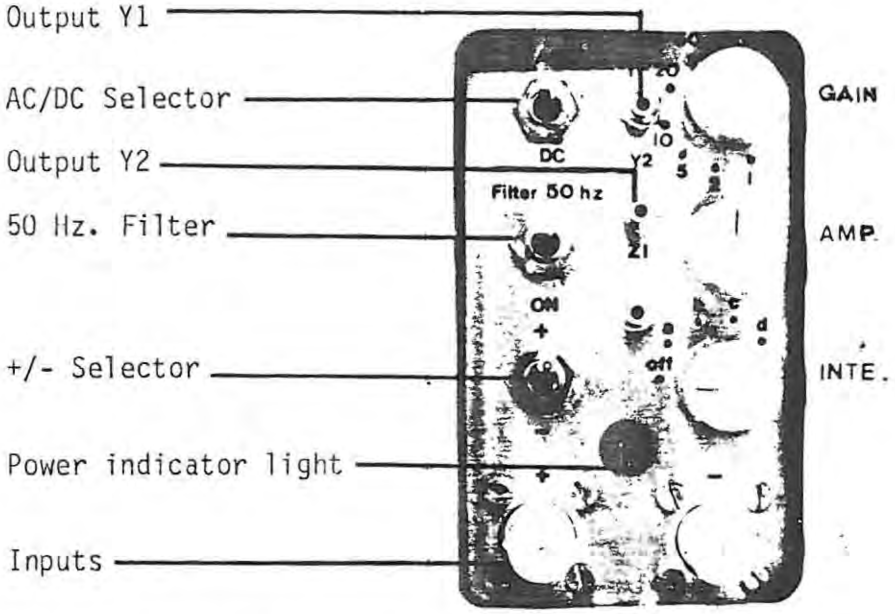
The output, Y2, allows for the monitoring of the signal that is presented to the A/D converter. FIGURE 4.3.1. (below) shows the front panel of a single module from the system.

4.3. The Software Specifications of the System

At the most expansive level of analysis, programs can be divided into two classes: Those that exist in the form of logic circuits designed and constructed to perform specific tasks, and those that are user-written for application on a machine that is able to run temporally stored programs.

Inherent in the above division is the notion that each of these types of programs has a specific versatility over the

FIGURE 4.3.1. Front panel of Conditioner Module



other. The logic circuit type of program is the basis of all computers and has the advantage over temporally stored programs as far as execution speed is concerned. At the same time, it has the disadvantage of being fixed in its operation, thus being limited in what it can do. This type of program is referred to as a hardware or hard-wired program. A modification is made to this type of program allowing for the use of a general hardware to run user programs, which in effect reconstruct the circuits to their own specifications. This reconfiguration of the hardware is either attained by wiring a number of connections together in such a way as to perform the desired function, or by the use of a special instruction set to which parts of the hardware are programmed to respond in a specific way. Apart from the increased ease of programming, a greater flexability can be gained from such a system.

It is clear from this description that the program is a link between that machine and the user providing the machine with directives. The programs are executed from machine language instruction codes that are stored in the computer memory and this type of program is termed software.

Two main types of software are used in the present system. The first consists of large system programs which form a direct link between the user and the system, allowing the selection of certain options in the use of the peripheral devices such as the printer. The second type of program is in the form of Assembly Programs which are written in Assembly Language and easily translated into machine code. These programs form the routines used by the system for utility operations such as getting the time and collecting that data from the signal processor.

4.3.1. The System Programs

Two systems programs are provided each with a specific function.

a) DATCAP (DATa CAPture)
This is an interactive program which performs the capture of data from the processor or from disk file and performs a number of user selectable analysis routines on this data.

b) OLDCAP (Off-Line Data CAPture)

> Also an interactive program, OLDCAP collects data from the signal processor and writes it to a disk file which can later be used as data for DATCAP.

An interactive program indicates that the program communicates with the user by means of a series of questions and answers. The application of this type of system is justified in that it makes the system easy to operate by users with minimal computer experience.

For those users wishing to know more about the programs, Appendix B contains detailed operation instructions along with program source listings and flow diagrams.

4.3.2. Assembly Language Subroutines

The Assembly routines are listed as separate programs by virtue of their being loaded into memory as discrete blocks. There are three such routines.

> BANNER is the routine which prints the header of the DATCAP system to the selected output device. The advantage of this routine being written in Assembly Language is that it can be changed without the recompilation of the large systems program.

TIMER is the routine that interfaces the front panel clock into the system enabling the time to be printed during the execution of programs. It consists of two parts, the first being executed during the start-up of the system which initially sets the clock to display the time in Hour/Minute mode. The second part (found as part of the systems command files) is executed during the running of the systems programs and displays the time to the current output device. The output format of this routine is in hours, minutes and seconds (twelve hour format) with either AM or PM following this.

FETCH interfaces the signal processor into the system and selects the operation mode of each channel of the processor. Two forms of this program have been written although only the second, FETCH2, is used in this application of the processor. Whereas FETCH allows the selection of other output modes from the signal processor (i.e. INTEGRATION and FREQUENCY), FETCH2 does not support these modes and selects only the AMPLITUDE mode. If FETCH is used six parameters must be supplied:

```
CALL FETCH (INTE,CH1,CH2,CH3,CH4,N)
```

Where INTE is the interval between samples, CH1 to CH4 are the codes of operation with 1 requesting AMPLITUDE, 2 requesting INTEGRATION and 3 requesting FREQUENCY. N is the number of points to be sampled in a second. The use of FETCH2 obviates the need for these parameters.

4.4. The Operation of the Data Capture System

The System Programs, DATCAP and OLDCAP, are constructed in similar ways both beginning with the execution of a series of questions which collect the information that the system needs to select options that are available. This section of the programs is called SYSINF (SYStem INFormation). When the system has selected the options on the grounds of the answers that the user provides to the questions, it displays a READY message. To proceed from this point, the user must depress the RETURN key on the control terminal after which the next section of the program, DATCAP, is executed. The DATCAP routine of program DATCAP reads the data from either a disk file or directly from the digitizer and analyses it as opposed to the same section of OLDCAP which writes the data to a disk file.

The first part of SYSINF in the DATCAP program selects the analysis routine that is to be used on the data. The routines are derived from the information presented in Chapter 3 and in this application they are all software analysis programs incorporated into the DATCAP program as a series of subprograms.

4.4.1. Subprogram FOURIER

The application of the Bergland algorithm used in the DATCAP system is after Gersbach (1978) and performs a Fast Fourier Transform (F.F.T.) on 128 points resulting in a maximum of 64 spectral estimates. As the sample is over a single second, the resolution of the spectrum is fixed at 1 Hz. resulting in a analysed range of 64 Hz. (from the D.C. band). As the use of the 50 Hz. filter is suggested to eliminate mains interference, the frequencies up to and including 50 Hz. are displayed.

Two modes of output are provided by this routine:

a) Frequency by frequency display from D.C. through to 50 Hz.

b) Power in the customary frequency bands used in the analysis of the E.E.G. (See Chapter 1).

The selection of the output mode is made during the execution of the SYSINF section of the DATCAP program. Specimen output from the two output modes is given below. The phenomenon of aliasing (discussed in Chapter 3) is clearly illustrated in the frequency by frequency display of the analysis of a test signal of 10 Hz. A clear peak is discernable at 10 Hz. and smaller peaks at the harmonics (20 Hz., 30 Hz. etc.).[**]
It is often useful to transform the spectral estimates to either emphasise the peaks or generally lower the magnitude of the peaks

---

[**] See N2.7

FIGURE 4.4.1.(a) Fourier output (Banded)

```
CHANNEL # 1
FOURIER ANALYSIS
DC= 11.45390625
DELTA       THETA        ALPHA-       ALPHA+       BETA-        BETA+        GAMMA
   2.101        0.804        0.699       48.049        5.256       14.938       21.841
```

FIGURE 4.4.1.(b) Fourier output (Unbanded)

```
 08:37:02 AM EPOCH # 0

 CHANNEL # 1
 FOURIER ANALYSIS


  1.0       0.013       17.0        0.145      33.0       0.356
  2.0       0.456       18.0        0.121      34.0       0.323
  3.0       0.653       19.0        0.058      35.0       0.226
  4.0       0.566       20.0       53.862      36.0       0.166
  5.0       0.279       21.0        1.221      37.0       0.411
  6.0       0.102       22.0        0.441      38.0       0.813
  7.0       0.044       23.0        0.208      39.0       1.217
  8.0       0.352       24.0        0.271      40.0       2.624
  9.0       2.970       25.0        0.280      41.0       0.238
 10.0     233.135       26.0        0.387      42.0       0.267
 11.0       0.379       27.0        0.534      43.0       0.397
 12.0       0.006       28.0        0.302      44.0       0.245
 13.0       0.135       29.0        0.057      45.0       0.161
 14.0       0.114       30.0        3.032      46.0       0.223
 15.0       0.128       31.0        0.422      47.0       0.221
 16.0       0.218       32.0        0.304      48.0       0.103
                                               49.0       0.789
                                               50.0       1.304

 D.C. BAND  =   4.981875
```

in a systematic way. Two transformations are provided by this subprogram and, again, these are selected during the execution of

SYSINF.

a) The SQUARE ROOT TRANSFORM allows the user to lower the range of the peaks that the spectrum shows, thereby making the graph of the spectrum easier to plot on the one hand, but less indicative of the true power in any frequency.

b) The LOGARITHM TRANSFORM can be used to emphasise the peaks by causing those frequencies with low power to be displayed as negative. The same disadvantage which was encountered with the Square root transform applies here, with a loss of the true magnitude of the peaks.**

The specimen output below illustrates the effects of these transforms on the same data used for the last illustration.

FIGURE 4.4.1.(c) Fourier output (SQR transform)

```
CHANNEL # 1
FOURIER ANALYSIS
SQARE-ROOT TRANSFORM APPLIED


  1.0        0.607      17.0        0.360      33.0       0.375
  2.0        0.174      18.0        0.576      34.0       0.192
  3.0        0.376      19.0        0.711      35.0       0.173
  4.0        0.206      20.0        7.001      36.0       0.248
  5.0        0.204      21.0        0.324      37.0       0.242
  6.0        0.305      22.0        0.226      38.0       0.726
  7.0        0.225      23.0        0.231      39.0       0.253
  8.0        0.295      24.0        0.246      40.0       1.704
  9.0        0.358      25.0        0.155      41.0       0.050
 10.0       15.677      26.0        0.270      42.0       0.255
 11.0        0.576      27.0        0.455      43.0       0.161
 12.0        0.433      28.0        0.327      44.0       0.206
 13.0        0.336      29.0        0.513      45.0       0.211
 14.0        0.353      30.0        1.283      46.0       0.334
 15.0        0.262      31.0        0.276      47.0       0.295
 16.0        0.337      32.0        0.137      48.0       0.202
                                               49.0       0.548
                                               50.0       1.337

D.C. BAND  =   5.0353125
```

** See N2.8

FIGURE 4.4.1.(d) Fourier output (LOG transform)

```
 08:34:20 AM EPOCH # 0

CHANNEL # 1
FOURIER ANALYSIS
LOG TRANSFORMATION APPLIED


 1.0      -0.662     17.0      -2.485     33.0      -2.696
 2.0      -1.940     18.0      -1.564     34.0      -2.302
 3.0      -1.055     19.0      -1.464     35.0      -1.775
 4.0      -1.873     20.0       3.782     36.0      -1.337
 5.0      -1.027     21.0      -0.093     37.0      -0.964
 6.0      -0.953     22.0      -1.509     38.0      -1.992
 7.0      -0.737     23.0      -0.592     39.0      -0.500
 8.0      -0.969     24.0      -0.830     40.0       0.956
 9.0       0.515     25.0      -0.684     41.0      -1.321
10.0       5.512     26.0      -1.231     42.0      -1.527
11.0      -1.125     27.0      -1.208     43.0      -1.428
12.0      -1.426     28.0      -1.163     44.0      -1.331
13.0      -2.381     29.0      -0.343     45.0      -1.660
14.0      -2.120     30.0      -0.233     46.0      -2.174
15.0      -1.672     31.0      -2.726     47.0      -2.883
16.0      -4.382     32.0      -2.933     48.0      -1.583
                                          49.0      -3.802
                                          50.0      -0.883

D.C. BAND  =   4.99359375
```

4.4.2. Subprogram CARDIO

The cardiotachometer analysis routine calculates the mean reading of the output of the cardiotachometer over 128 points and computes heart rate over the epoch from this on the grounds of the Calibration signal which is requested during the execution of SYSINF.

The mean and standard deviation of the calculated heart-rate is displayed as is shown in the specimen output shown below.

FIGURE 4.4.2. CARDIO output

```
 12:42:24 PM EPOCH # 0

CHANNEL # 3
CARDIO-TACHOMETER
MEAN =  60.5376            DEVIATION = 6.43778
```

4.4.3. Subprogram INTEGRATOR

The application of the integration routine applying Simpson's rule (After Shaw, 1967) rapidly integrates 128 data points and the result is output as an ACTIVITY COEFFICIENT as is shown in the specimen below.

FIGURE 4.4.3. INTEGRATOR output

```
12:46:44 PM EPOCH # 1


CHANNEL # 4
INTEGRATION
ACTIVITY COEFFECIENT =  14.553208
```

4.4.4. Output from Program OLDCAP

A hard-copy record of the epochs run to disk by OLDCAP can be selected and this output includes the name of the file, the channel options and the factors calculated during the calibration routines. The time at which an epoch is taken and the number of the epoch is also printed. The output included below illustrates the output from this program.

FIGURE 4.4.4. OLDCAP output

```
RECORD OF DATA RUN TO FILE BY OLDCAP.01
DISK FILE NAME : 1:TEST.DAT
CHANNEL # 1       FOURIER ANALYSIS
CHANNEL # 2       UNUSED
CHANNEL # 3       UNUSED
CHANNEL # 4       UNUSED

UNITARY FACTOR :  .03
CARDIOTACHOMETER FACTOR :  .6055664062

 08:43:28 AM     # 1

 08:43:37 AM     # 2

 08:43:44 AM     # 3
```

4.5. The Assessment of Change in Arousal state

To analyse the efficacy of the DATCAP system, a short research project was undertaken involving subjects sitting in a darkened room for two 15 minute periods, one before and one after lunch, on the same day.

It was tentatively hypothesised that there would be a more gradual trend towards lowered arousal in the morning session (9:30 a.m.- 9:45 a.m.) when the subjects were more alert, than in the afternoon session (2:15 p.m.- 2:30 p.m.) when the subjects were supposedly experiencing the "after-lunch dip" in arousal.

By virtue of the discussion of measures of arousal presented in Chapter 3, it was decided to use the E.E.G. as the indicator of arousal in this demonstration.

Method

Subjects:

Two male first year psychology students were used for this research. They were asked to participate in a short research project and were not told the nature of the research. A date was set when each of them would be available for half an hour in the morning and half an hour directly after lunch.

Procedure:

When the subjects arrived they were escorted into an office and seated in a comfortable chair and told that electrodes were going to be affixed to their heads. The electrodes were Silver-Silver Chloride cup electrodes and were affixed to the T4 and 02 positions (10-20 system) on the dominant side of the head by means of Collodion. An earth electrode was placed on the neck just behind the ear on the same side of the head as the Recording electrodes were placed. The earth electrode to recording electrode resistance was checked and an attempt was made to obtain a reading of less that 10 Kilo-ohms for each of the two paths. After the electrodes were successfully fitted, the subject was taken to the laboratory where he was asked to rate his alertness on the Stanford Sleepiness Scale (S.S.S.) (See Appendix C). He was then taken through into the recording room and the electrodes were plugged into the recording system.

The gain of the amplifiers was set with the subject sitting relaxed with his eyes closed. The subject was told that the room was going to be darkened (almost totally) and he was to keep as still as possible. He was to keep his eyes open for as much of the time as he could.

The room was darkened and the SYSINF section of the DATCAP program was executed. One minute after the room was darkened, the recording started and continued for approximately 15 minutes.

At the termination of the session, the subject was disconnected from the recording apparatus and brought into the laboratory where he was, again, asked to fill in the S.S.S.. The two values obtained from the S.S.S. (i.e. the before and after) were indicated on a graph with a time axis and the subject was asked to draw a series of lines to indicate his experienced state of alertness over the 15 minutes using the S.S.S. criteria as a guideline.

Results

The tables given below show the results of the linear regression analysis run on the data using the Statistical Package for the Social Sciences (SPSS). The B coefficient is the slope of the least-squares regression line and its Standard Error is shown. The Beta coefficient is the slope calculated when the data has been standardised to a Standard Deviation of 1. The F statistic can be used to test the Null Hypothesis:

B (Slope) = 0

The Bands in which significant change is observed on the grounds of this F value are marked "*".

Subject 1

The collection of the data for Subject 1 was performed with the DATCAP system presenting a Banded output of power every 24 seconds for 30 epochs.

The table below (TABLE 4.5.1) shows the results of the regression analysis run on the data derived from the morning session.

Band	Pearson r	B (Slope)	Beta	Standard Error of B	F
DELTA	-0.335	1.316	0.035	9.454	0.019
THETA	-0.235	-2.680	-0.205	4.062	0.435
ALPHA-	-0.208	-2.922	-0.120	7.089	0.170
ALPHA+	-0.332	-0.503	-0.038	3.539	0.020
BETA-	-0.637	-4.615	-0.652	1.245	13.749*
BETA+	-0.086	-1.226	-0.047	4.818	0.065
GAMMA	0.100	4.983	0.129	7.507	0.441

* d.f. = 1 and 28, $p<0.05$.

TABLE 4.5.1. Subject 1 Morning Session

With the exception of the Gamma and Delta bands of the E.E.G., a general decrease in amplitude of the bands was observed, although this was only significant in the case of the lower part of the Beta band.

The analysis of the data derived from the afternoon session is shown below (TABLE 4.5.2.).

Band	Pearson r	B (Slope)	Beta	Standard Error of B	F
DELTA	-0.136	2.166	0.066	8.941	0.059
THETA	0.249	4.396	0.191	4.286	1.052
ALPHA-	0.168	1.521	0.033	10.315	0.022
ALPHA+	-0.042	1.698	0.090	5.060	0.113
BETA-	-0.275	-1.210	-0.149	1.840	0.432
BETA+	-0.169	4.965	0.220	5.780	0.733
GAMMA	-0.492	-26.065	-0.604	11.222	5.395*

* d.f. = 1 and 28, $p<0.05$.

TABLE 4.5.2. Subject 1 Afternoon session

Here we observe a change from the trends noted in the morning session in that the most significant decrease is in the Gamma band and a slight increase is observed in the lower frequency bands, notably the Theta and Alpha bands.

Subject 2

The data collected from Subject 2 was also presented by DATCAP in the Banded mode but a logarithmic transform was applied to the data to demonstrate the use of this option. This resulted in a slightly longer analysis time (31 seconds).

TABLE 4.5.3., presented below shows the regression analysis on the data from the morning session.

Band	Pearson r	B (Slope)	Beta	Standard Error of B	F
DELTA	-0.425	-41.719	-0.443	21.917	3.623
THETA	-0.138	-14.408	-0.118	22.859	0.397
ALPHA-	0.053	-5.337	-0.061	25.384	0.044
ALPHA+	-0.179	-31.763	-0.407	23.289	1.860
BETA-	0.013	23.156	0.442	15.556	2.216
BETA+	0.016	-0.316	-0.007	11.924	0.001
GAMMA	0.261	26.748	0.547	11.908	5.045*

* d.f. = 1 and 28, $p<0.05$.

TABLE 4.5.3. Subject 2 Morning Session

A significant decrease in the Delta band is countered by a significant increase in the Gamma band and a slight increase in the lower Beta band (shown on TABLE 4.5.3)

A similar analysis for the afternoon session is shown in TABLE 4.5.4..

Band	Pearson r	B (Slope)	Beta	Standard Error of B	F
DELTA	-0.246	39.039	0.354	33.692	1.343
THETA	-0.022	34.571	0.268	25.857	1.788
ALPHA-	-0.399	-101.279	-0.764	37.371	7.345*
ALPHA+	-0.269	-47.910	-0.542	29.104	2.710
BETA-	-0.167	11.469	0.147	18.474	0.385
BETA+	-0.143	4.689	0.111	12.777	0.135
GAMMA	0.170	14.199	0.320	8.581	2.738

* d.f. = 1 and 28, $p<0.05$.

TABLE 4.5.4. Subject 2 Afternoon Session

A strong negative trend is observed in the Alpha bands and this appears to be offset by a slight increase in the Gamma and Delta bands. Although there is a change in the nature of the trend found for the morning session, it is in the form of a shift of maximum decrease from the Gamma band to the Alpha bands.

Discussion

The results indicate there is some change in the way the E.E.G. spectrum changes before and after lunch even though this change is not explicit because of the small number of subjects used.

Subject 1 reported himself to be in an "alert" state at the start of the morning session and experienced only a slight decrease in alertness over the session. The spectral analysis of the E.E.G. trace reveals fairly distributed power over the bands with the peak power being in the lower Beta band which decreases steadily over the course of the session with the other bands remaining fairly constant. At the start of the afternoon session he reported that he was "not at full alertness" and that, although he only went up one point on the S.S.S., there is considerable variation within the 15 minutes of the session. Spectral analysis reveals that, again, the power is initially centered in the lower Beta band but this time the decrease in the lower Beta band is not as distinct although there is a consistent decrease in Gamma. A slight increase in Theta and Alpha marks what could be the beginning of a lowering in arousal and perhaps a longer session would have revealed this trend more significantly.

Subject 2 reported a score of 3 on the S.S.S. at the begining of the morning session and a consistent trend to an ultimate score of 4. The E.E.G. analysis for this session shows an increase in the Gamma band from an initial centering of power in the upper Alpha and lower Beta bands. This centering is consistent over the session. The subject reported no change in arousal over the afternoon session, rating himself as 3 on the S.S.S. at both the beginning and the end of recording. The only significant change in the frequency spectra over this session is a decrease in the lower Alpha band, the maximum power remaining in the upper Alpha and Beta bands.

Two points emerge from these findings:

a) The second subject seems to have resisted drowsiness better than the first and this seems to be indicated in their respective degree of change of the nature of the E.E.G..

b) Although there is consistency within the E.E.G. of a single subject, there seems to be little in the way of a consistent trend between the subjects.

The intention of this piece of research is not to indicate that the system functions to illustrate a lowering of arousal in the two individuals used. It should, rather, be seen as an example of the type of research methodology that the DATCAP system has been designed to handle.

The trends that have been exposed in the results are far from clear indications of a decrease in the higher frequencies of the E.E.G. with a corresponding increase in the lower frequencies which one would expect after the discussion presented in Chapter 3. Rather, they illustrate a fundamental principle in the exposure of multi-factorial responses such as arousal: If the phenomenon is not well-defined, the concomitant bodily changes will be equally ill-defined. This principle is applied here in that the experimental methodology used is not a sure way of eliciting lowered arousal states.

Even in the face of this observation, the E.E.G. analysis is indicative of the the "Awake - Alert state" of these subjects indicating that the system is analysing the E.E.G. correctly.

4.6. General Conclusions

It is only at the completion of this work that it is possible to assert alternative ways of approaching the development of an analysis method for Psychophysiological data. The limitations of the present system can all be summarised in a single word: Time.

In the first place, the 6800 system cannot run at a higher execution speed than 1 micro-second per operation by virtue of its memory speed capabilities. The only conceivable ways of improving the execution speed of analysis programs are either to create algorithms that are considerably more efficient than those used in this work (notably the Fourier Analysis) or to design units external to the computer system that perform these functions at a higher clock-rates and then place the results into the computer memory for display.

Secondly, the time allocated for the development and design of a system of this nature has, in this case, been insufficient to carry the development to an adequate point. This is mainly in terms of the large amount of technical information that has to be understood by a researcher who is not necessarily well equipped to easily understand it.

The single most important part of the system would appear to be the Fourier System and thus it is suggested that this be the first priority in the development of a Mk. 2 package. A hard-ware Fourier Analysis system has been developed in the R.U. Physics department for use with their Antartic research programme. This is designed to sample at 1024 Hz. and perform a Cooley-Tukey F.F.T. on 1024 points in about 25 milli-seconds. The spectral resolution can be adjusted by manipulating the sampling interval in terms of equation 9 given in Chapter 3. It would appear that it will be less costly to rewrite DATCAP to cope with 1024 points than to have the Analyser redesigned to perform a smaller number of analyses. Alternatively, this system could be minimally modified to perform different numbers of analyses less than 1024, the remaining hard-ware within the Analyser remaining the same.

The DATCAP Mk. 1 system must not be seen as a satisfactory end product of this work although it illustrates the versatility of a small computer system in this type of work. Instead of being static in nature, it gives the system a great deal of flexibility unavailable from an exclusively hard-ware orientated system. An example of this versatility can be found in the proposed development of a Stimulus control unit which can be interfaced into the 6800 and facilitate the use of Evoked Potentials in the assessment of changes in arousal.

The ground is prepared for a highly sophisticated research tool to be established with the ability to accurately assess changes within the human body that are not readily discerned by superficial observation. The manner in which such a system used is largely dependent on the nature of the questions which are being asked.

I am confident that DATCAP will be the sire of a long line of reliable indicators of changes to the "internal millieu".

REFERENCES

Bloomfield, P. *Fourier Analysis of Time Series - An Introduction*. New York: John Wiley & Son, 1976.

Brenner, J. Heart Rate. In P.H. Venables and I. Martin (Eds.), *A Manual of Psychophysiological Methods*. Amsterdam: North-Holland Publishing Company, 1967. Pp.103-131.

Brown, C.C. Instruments in Psychophysiology. In N.S. Greenfield and R.A. Sternbach (Eds.), *Handbook of Psychophysiology*. New York: Holt, Rinehart and Winston, Inc., 1972. Pp.159-193.

Darrow, C.W., Pathman, J. and Kronenberg, D. Levels of Autonomic Activity and the Electroencephalogram. *Journal of Experimental Psychology*, 1946, *36*, 355-365.

Dolice, G. and Waldeier, H. Spectral and Multivariate Analysis of E.E.G. changes during Mental Activity in Man. *Electroencephalography and Clinical Neurophysiology*, 1974, *36*, 577-583.

Dowling, F.H., Fitch, P. and Wilson, R.G.A. A Special Purpose Digital Computer in the Analysis of the Human E.M.G., *Electroencephalography and Clinical Neurophysiology*, 1968, *25*, 570-574.

Dubin, D. *Rapid Interpretation of Electrocardiograms*. Florida:

Cover Publishing Company, 1974.

Duffy, E. The Concept of Energy Mobilisation. Psychological Review, 1951, 58, 30-40.

Duffy, E. The Psychological Significance of the Concept of "Arousal" and "Activation". Psychological Review, 1957, 64, 265-275.

Duffy, E. Activation. In N.S. Greenfield and R.A. Sternbach (Eds.), Handbook of Psychophysiology. New York: Holt, Rinehart and Winston, Inc., 1972. Pp.577-622.

Frusfield, R.D. Analysis of E.M.G. signals by Measurement of Wave Duration. Electroencephalography and Clinical Neurophysiology, 1971, 30, 337-341.

Geddes, L.A. The Measurement of Psychological Phenomena. In C.C. Brown (Editor), Methods in Psychophysiology. Baltimore: Williams and Wilkins & Co., 1967. Pp.369-458.

Gersbach, F.F. Vinnige Fourier Transformasie (FFT). Instituut vir Rekenaarstelsels, Universiteit Van Suid-Afrika, UNIREK 8343, 1978.

Goff, W.R. Human Average Evoked Potentials: Procedures for Stimulating and Recording. In R.F. Thompson and M.M.

Patterson (Eds.), Bioelectric Recording Techniques. New York: Academic Press, 1974. (PART C). Pp.101-156.

Goldstein, I.B. Electromyography. In N.S. Greenfield and R.A. Sternbach (Eds.), Handbook of Psychophysiology. New York: Holt, Rinehart and Winston, Inc., 1972. Pp.329-365.

Gunn, C.G., Wolf, S., Block, R.T. and Person, R.J. Psychophysiology of the Cardiovascular System. In N.S. Greenfield and R.A. Sternbach (Eds.), Handbook of Psychophysiology. New York: Holt, Rinehart and Winston, Inc., 1972. Pp.457-483.

Hahn, W.W. Attention and Heart Rate - A Critical Appraisal of the Hypothesis of Lacey and Lacey. Psychological Bulletin, 1973, 79, 59-70.

Hassett, J. A Primer in Psychophysiology. San Fransisco: W.H. Freeman & Co., 1978.

Hawkes, C.H. and Presscott, P.J. E.E.G. Variation in Healthy Subjects. Electroencephalography and Clinical Neurophysiology, 1973, 34, 197-203.

Kennedy, J.L. and Travis, R.C. Prediction of Speed of Performance by Muscle Action Potentials. Science, 1947, 105, 410-411.

Kennedy, J.L. and Travis, R.C. Prediction and Automatic Control of Alertness. Journal of Comparative and Physiological Psychology, 1947, 40, 457-461.

Kennedy, J.L. and Travis, R.C., Prediction and Automatic Control of Alertness: (II) Continuous Tracking. Journal of Comparative and Physiological Psychology, 1948, 41, 203-210.

Kiloh, L.G., Mc Comas, A.J. and Osselton, J.W. Clinical Electroencephalography. London: Butterworth & Co. (Publishers) Ltd., (3rd edition), 1972.

Lindsay, D.B. and Wicke, J.D. The Electroencephalogram: Autonomous Electrical Activity in Man and Animals. In R.F. Thompson and M.M. Patterson (Eds.), Bioelectric Recording Techniques. New York: Academic Press, 1974. (PART B).

Lippold, O.C.J. Electromyography. In P.H. Venables and I. Martin (Eds.), A Manual of Psychophysiological Methods. Amsterdam: North-Holland Publishing Company, 1967. Pp.247-297.

Mc Adam, D.W. The Contingent Negative Variation. In R.F. Thompson and M.M. Patterson (Eds.), Bioelectric Recording Techniques. New York: Academic Press, 1974. (PART C). Pp.245-257.

Malmo, R.B. Activation: A Neuropsychological Dimension.

Psychological Review, 1959, 66, 368-386.

Margerison, J.H., St.John-Loe, P. and Binnie, C.D. Electroencephalography. In P.H. Venables and I. Martin (Eds.), A Manual of Psychophysiological Methods. Amsterdam: North-Holland Publishing Company, 1967. Pp.353-399.

Oswald, I. Sleep. Harmondsworth: Penguin Books Ltd., 1966.

Roth, B. The Clinical and Theoretical Importance of E.E.G. Rhythms corresponding to States of Lowered Vigilance. Electroencephalography and Clinical Neurophysiology, 1961, 13, 395-399.

Ryle, G. The Concept of Mind. Harmondsworth: Penguin Books Ltd., 1963.

Schneiderman, N., Dauth, G.W. and Van Dercar, D.H. Electrocardiogram: Techniques and Analysis. In R.F. Thompson and M.M. Patterson (Eds.), Bioelectric Recording Techniques. New York: Academic Press, 1974. (PART C).

Shagass, C. Electrical Activity of the Brain. In N.S. Greenfield and R.A. Sternbach (Eds.), Handbook of Psychophysiology. New York: Holt, Rinehart and Winston, Inc., 1972. Pp.263-328.

Shaw, J.C. Quantification of Biological Signals using Integration Techniques. In P.H. Venables and I. Martin (Eds.), A Manual of Psychophysiological Methods. Amsterdam: North-Holland Publishing Company, 1967. Pp.405-463.

Smith, J. and Schade, J.P. Computer Programming for Parameter Analysis of the Electroencephalograph. In J.P. Schade and J. Smith (Eds.), Computers and Brains. Amsterdam: Elsevier Publishing Company, 1970. Pp.193-201.

Surwillo, W.W. Psychological Factors in Muscle Action Potentials: The E.M.G. Gradient. Journal of Experimental Psychology, 1956, 52, 263-272.

Taylor, S.P. and Epstein, S. The Measurement of Autonomic Arousal. Psychosomatic Medicine, 1967, 29, 514-525.

Travis, R.C. and Kennedy, J.L. Prediction and Control of Alertness (III) Calibration of the Alertness Indicator and Further Results. Journal of Comparative and Physiological Psychology, 1949, 42, 45-57.

Walter, D.O., Rhodes, D.M. and Adey, W.R. Discriminating Among States of Consciousness by E.E.G. Measurement. Electroencephalography and Clinical Neurophysiology, 1967, 22, 22-29.

Welch, A.J. and Richardson, P.C. Computer Sleep Stage

Classification Using Heart Rate Data. *Electroencephalography and Clinical Neurophysiology*, 1973, *34*, 145-148.

Young, J.Z. *The Life of Mammals*. Oxford: Oxford University Press, 1962.

BIBLIOGRAPHY

Chandor, A., Graham, J. and Williamson, R. The Penguin Dictonary of Computers. Harmondsworth: Penguin Books Ltd., 1977.

M6800 Programming Reference Manual. Motorola, Inc., M68PRM(D), November, 1976.

Nie, N.H., Hadlai Hull, C., Jemkins, J.G., Steinbrenner, K. and Bent, D.H. Statistical Package for the Social Sciences. New York: Mc Graw-Hill Book Company, 1975.

SSB Disk System Reference Manual, Smoke Signal Broadcasting, 1979.

6800 BASIC Compiler V1.3, Software Dynamics, 1977.

SWTBUG 6800 ROM Monitor, Version 1.0, Users Guide. Southwest Technical Products Corporation, 1977.

APPENDICES

APPENDIX A

Techniques in Electrophysiological Recording

A.1. Care of Electrodes

Three types of electrodes are used in this work.

a) CARDIAC ELECTRODES

Metal plate electrodes are usually used for cardiac recordings and are attached to the wrists and ankles of the subject by means of elastic straps. These electrodes must be kept free of corrosion, and scouring lightly is the best method of maintaining their condition.

b) E.E.G. ELECTRODES

Chlorided silver cup electrodes are best used in the recording of the E.E.G. in research situations. The electrodes must be maintained in a condition where the chloride layer appears uniform and no bare silver is exposed. To maintain this condition the electrodes must be regularly chlorided. See Kiloh et al (1972, p.35) for the technique used. After use they must be washed in soapy water and dried well. They may be stored in 5% saline for an hour after use and then either placed in deionised water or stored dry.

c) E.M.G. ELECTRODES

In the recording of the E.M.G. use is made of either the cup electrodes described above, or of shallow sub-cutaneous needle electrodes. The former is preferable and they are maintained as described above.

APPENDIX A - 2

A.2. The Application of Electrodes

a) Preparation of the Electrode Sites

The following steps are suggested to ensure satisfactory recordings.

i) Clean the site with 70% ethanol to remove sebum from the skin.

ii) In the case of cardiac electrodes, apply the electrode jelly to the site and rub it in lightly making use of the slightly abrasive texture of the electrolyte to abrade the skin slightly.

b) Application of the Electrodes

i) Cardiac electrodes are affixed to the site by means of a perforated rubber strap which is is fitted over the spike on the back of the electrode such that the electrode is held in place sufficiently tightly to prevent movement and yet not tightly enough to seriously impede circulation.

ii) Cup electrodes are affixed to the skin by means of Collodion. Hold the cup electrode in place on the site, rim downwards, with a pencil placed through the aperture on the bottom of the cup. Now using the other hand place Collodion around the rim of the cup and on the surrounding skin. By use of either compressed air or a hair dryer (cold setting) dry the collodion. Using a syringe fitted with a BLUNT needle, insert electrode jelly through the aperture in the electrode until jelly can be seen to escape through the aperture about the needle. Use the blunt needle to lightly abrade the skin under the electrode until the desired impedance (less than 5 kilo-ohms) is attained.

To remove the electrode after use, use acetone to dissolve the Collodion and remove the excess from the subject's skin.

FIGURE A.1. Cardiac Electrode Placement

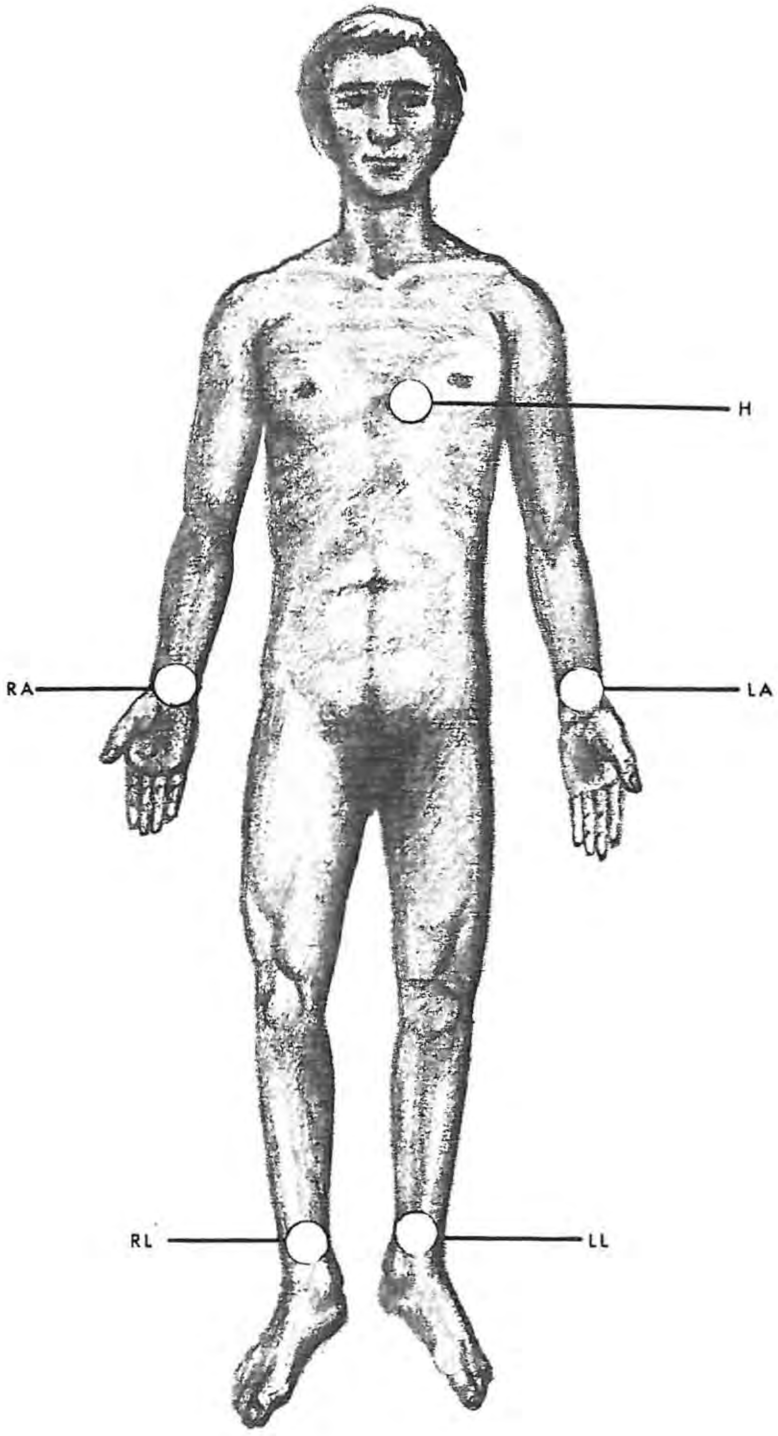


FIGURE A.1.1. The Connection of the Cardiac Electrodes

	R.A. Right arm	L.A. Left arm	R.L. Right leg	L.L. Left leg	H. Heart
I	+	-	Unused	EARTH	Unused
II	+	Unused	EARTH	-	Unused
III	Unused	+	EARTH	-	Unused
AVL	-	+	-	-	Unused
AVR	+	-	-	-	Unused
AVF	-	-	-	+	Unused

See diagram on previous page for lead positions.

FIGURE A.2. Standard E.M.G. Neck Electrodes

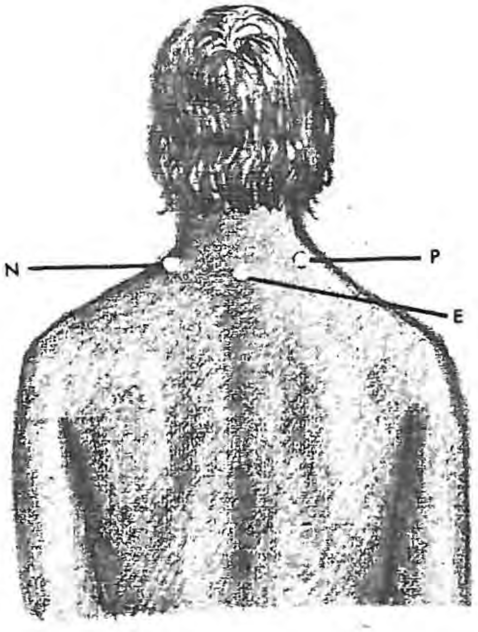
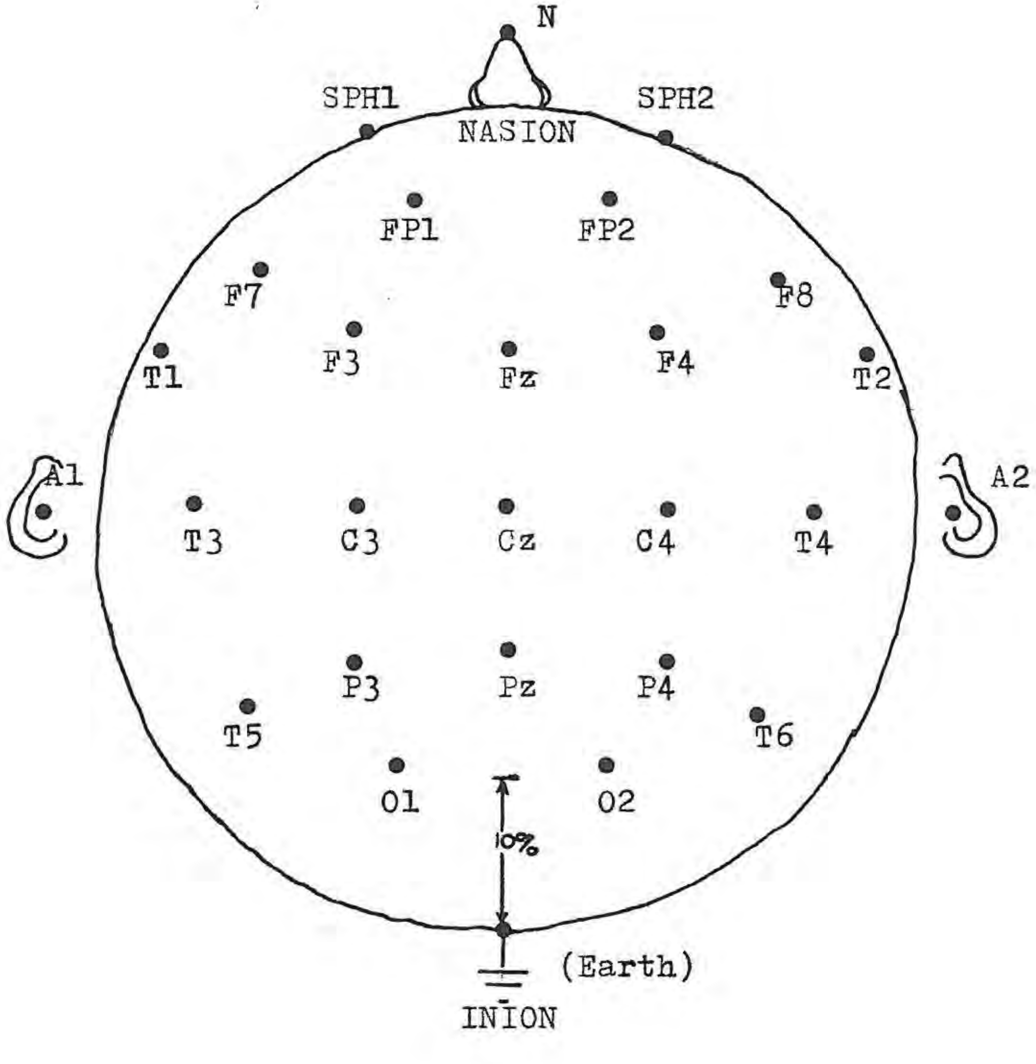


FIGURE A.3. The "10-20" System of E.E.G. Electrode Placement



A.3. The Optimal Scalp Locations for the Recording of the Various Bands of E.E.G. Activity

Alpha: Kiloh et al (1972) report that recent work suggests the existence of more than one source of the Alpha rhythm in the brain, but the optimal area of the scalp to record it from appears to be the occipital area and the nearby parietal and temporal areas.

Beta: This activity is found from a variety of locations on the scalp but is seen most frequently in the precentral regions. (Kiloh et al, 1972) In the posterior areas of the scalp, the Beta rhythm may be masked by the Alpha rhythm although Kiloh et al indicate that it behaves independently of the Alpha.

Theta: This activity is found either in the temporo-occipital areas or about the vertex. Kiloh et al report that the centrally recorded Theta activity is "unlikely to be influenced by eyes open an enhanced during drowsiness" (p.54).

Delta: This activity is recorded from the posterior of the scalp in between 7% and 10% of alert subjects and becomes more prevalent during lowered alertness.

(After Kiloh et al, 1972)

APPENDIX B

B.1. Operating the System

A small section of the operating system of the computer is built into the hard-ware of the system and responds with a $ when the system is powered up. To load the disk-operating system, the following procedure is followed.

1. Switch on the units in the following order:
    a) Preamplifier rack and Signal processor.
    b) Oscilloscope.
    c) Control terminal and Printer unit.
    d) Computer system and disk-drives.

    ENSURE THAT THE DISK-DRIVES ARE EMPTY AND OPEN DURING THE POWER UP OPERATION.

2. Place the DATCAP system disk in the left-hand drive (Drive 0) with the white tag on the bottom edge and the label on the left hand side of the disk if you are facing the drives.

3. Close the drive doors and press the RESET button on the computer.

4. The system should respond with a $, after which type J 8020. (On the control terminal)

The computer system should respond with the disk-drives starting up and the DOS 68 banner being displayed to the control terminal. After execution of the START.UP file, the TIMER routine is initialised and the front panel clock, which displayed in seconds mode after the computer was switched on, will switch to Hours and Minutes mode.

B.1.1. Communication with the System

The character set of the computer is defined during start-up and provides only upper case letters and numerals. The use of the SHIFT key is thus minimised and is needed only for the special characters.

SPECIAL KEYS.

RETURN <OD>	This character is used by the system as the end of line indicator and must terminate all lines of input.
CONTROL	The control key gives rise to a set of characters used by the computer for special functions. When the control key is depressed similtaneously with: A - the input buffer is displayed D - the input buffer is executed H - a single back-space is executed X - the current input line is cancelled.
ESCAPE	This key is set up as the break character and causes the suspension of program execution and a possible return to the DOS system.

B.1.2. The System Disks

The system is contained on three disks, the most important being the control system disk. This disk must contain the following files.

DOS68.50	The DOS68 Version 5 Disk operating system.
DFM680.352 DFM680.353	The disk file management routines.
START.UP	Contains the start-up parameters.
BANNER	Contains the DATCAP system banner.

COMMANDS

TSTART	Timer initialisation command.
SET	Command to set system parameters.
EXEC	Command which executes the start-up.
DC01	DATCAP command file.
OC01	OLDCAP command file.

This disk is used to start up the system and must therefore be LINKed. (See Smokesignal broadcasting DOS 68 VERSION 5 manual for information on creating new disks.)

B.2. The Software Specifications

B.2.1. Program DATCAP

DESCRIPTION:

DATCAP is a general analysis program for use on the SWTPC 6800 computer system operating under DOS68 version 5. During the execution of this program the following segments are used:

SDBASIC RUNTIME PACKAGE
DATCAP MK 1A
SDBASIC RUNTIME I/O PACKAGE.
BANNER
FETCH
TIMER

(For details of the RUNTIME system, see the SDBASIC manual.)

This program, which constitutes the master routine of the on-line analysis package, is housed in memory from \$2800 to \$4DE2. It includes the following segments.

a) SYSINF, a routine which gets the user defined options from the control terminal on port #1.
b) DATCAP, a routine which pulls the data from the Conditioner unit by means of the routine FETCH if the program is set in ONLINE mode, or gets data from a disk-file if in OFFLINE mode.
c) ANALYSIS SUBROUTINES are provided for the following analyses and are selected during the execution of SYSINF.

i) Fast Fourier Transform - Bergland Algorithm.
Performs a F.F.T. transform on 128 points of data which has been read into the array DAT1. The output from this subprogram is either in the form of a frequency by frequency power analysis or the power is displayed in the following frequency bands:

DELTA	1 - 4 HZ.
THETA	5 - 7 HZ.
ALPHA-	8 -10 HZ.
ALPHA+	11-13 HZ.
BETA-	14-20 HZ.
BETA+	21-30 HZ.
GAMMA	31-50 HZ.

The selection of output mode is made during the execution of SYSINF.

The spectral resolution is fixed at 1 Hz.

Transforms of the power spectrum are provided as options defined during SYSINF.

LOG	Logarithm of power
SQR	Square root of power
NO	No transformation.

Two channels at maximum may be used for this analysis and these must be Ch.1 and Ch.2.

ii) Signal Integration applying Simpson's Rule.
Performs an integration of the area under the curve of 128 points giving rise to an ACTIVITY COEFFICIENT. This may only be used on Ch.4 using DAT4.

iii) Cardiotachometer analysis.
This subprogram displays the mean and standard deviation of heart-rate calculated from the output from a hard-ware cardiotachometer. It requires a calibration input which is achieved during the execution of SYSINF.

There is no limit placed on the number of consecutive epochs that may be analysed, although with OFFLINE operation, a limitation is set by the number of epochs that can be written to a single disk. The number of epochs to any run is defined during SYSINF. At the conclusion of a run, a message is displayed to the control terminal and the program may be continued on request.

DETAILED EXECUTION INFORMATION

1. To start execution of the program, type DC01 <0D>. The disk drives will start up and after some time, the system banner will be displayed to the screen.

2. The SYSINF questions are summarised below. All these questions require an answer.

CLIENT'S NAME - The subject's name is read in for output to the printer if Hard - Copy is requested.

CHANNEL CODES - The system uses the information gathered here to decide how to use the information coming in on each of the channels. These codes are as follows.

CODE NUMBER	ANALYSIS	CHANNELS ON WHICH IT MAY BE USED.
1	Fourier	1 and 2
2	Integration	4
3	Tachometer	3
4	CHANNEL	FREE

NOTE: If an incorrect choice is made on input, an error is reported and reinput requested.

CALIBRATION (YES/NO) - The calibration routine allows the user to check if the Signal Processor is satisfactorally set. It also allows for the setting of a UNITY FACTOR which must be done during both OFFLINE and ONLINE operation.
In the former mode, the calibration routine can be omitted by answering NO as the unity factor will still be requested.
If YES is selected, the system will respond:
CALIBRATE :
Pressing RETURN at this point causes the calibration routine to execute afterwhich it will request:
OK? (Y/N/F)
Answering Y causes the exit

from the CALIBRATE routine.
N causes the recalibration of system and F causes the UNITY FACTOR to be requested.
A suggested value for this constant is somewhere between 0.1 and 0.5.
After the factor is set, the CALIBRATE routine is exited.

ONLINE OR OFFLINE (ON/OFF)
This informs the system whether the data is to be obtained from the signal processor or from a disk-file.

HARD COPY (YES/NO)
The response to this question decides whether the output is to be rerouted to the printer unit.

At this point, if Fourier was selected, the following information will be requested.
FOURIER OUTPUT BANDED (YES/NO)
FOURIER SPECTROGRAMME TRANSFORMED (NO/LOG/SQR).

If the Cardiotachometer routine is to be used, the following will be requested.
CARDIOTACHOMETER CALIBRATION AT 60 B.P.M.
CALIBRATE :

Pressing RETURN causes the routine to read in the input from the tachometer which it assumes to be the constant for 60 b.p.m. which can be presented by keeping the CAL button on this unit depressed.

NUMBER OF EPOCHS : This sets the number of epochs to be run consecutively.

READY >
This message indicates that the system is ready to run with SYSINF complete.
Should something not be satisfactory, NO can be typed, returning the control to the beginning of SYSINF. Otherwise, press RETURN.

At the termination of the run, an END message is sent to the current output device and the output is diverted to the control port. The message:
GOING ON? (YES/NO)
is output and the answer determines whether the program is halted at this point. If it

is answered YES, then the arrays are zeroed and the terminal displays:
REENTRY MODE (R=RESTART,C=CONTINUE)
If R is selected, then a return is made to the beginning of SYSINF. If C is selected in the event of ONLINE operation, the READY signal is displayed. If the C re-entry is attempted during OFFLINE operation, the system reports an error and the re-entry is made to the beginning of SYSINF.
NOTE: THE RETURN TO SYSTEM IS READY RESETS

THE EPOCH COUNTER TO 0.

B.2.2. Program OLDCAP

Similar in structure and operation to DATCAP, this program creates the disk files that DATCAP uses for its OFFLINE mode.

With the exception of routine BANNER, the same subprograms are called by this program as are used by DATCAP.

The operation of the program is modeled on the operation of DATCAP.

1. To start the program, type OC01 <OD>.

2. The Control terminal will respond with "OLDCAP MK 1A" after a few seconds.

3. A request is made for a FILE-NAME. A File-Error check is performed and if the file is found to exist o the specified disk, the system requests whether it is to delete this file.
DELETE OLD DATAFILE <file name> (YES/NO) :

4. An options is given to create a hard-copy record of the data being run to the file.

5. The Channel options are requested in the same manner that is used in DATCAP.

```
REM
REM    **************************************************
REM    *                                                *
REM    *   D A T C A P         M K .  1 B               *
REM    *                                                *
REM    *   PSYCHOLOGY DEPARTMENT    RHODES UNIVERSITY   *
REM    *                                                *
REM    *   MASTER ROUTINE CALLING PROGRAM FOR THE      *
REM    *   CAPTURE AND ANALYSIS OF PHYSIOLOGICAL        *
REM    *       PHENOMENA.                               *
REM    *                                                *
REM    *   PROGRAMMER: ROB BARNES    NOVEMBER, 1979     *
REM    *                          REVISED JULY, 1980    *
REM    **************************************************
        PROGRAM ORIGIN :2800
        DATA ORIGIN :AC00
        DIM  N$(25),CODE(4),DAT1(128),DAT2(128),DAT3(128),DAT4(128)
     DIM B(70),W1(32),W2(32),V2(64),CHK$(5),A$(3),F$(12)
     DIM L,N,F2,L3,L1,T,L2,G,K1,K2,I,N4,J,P2,T1,N1,N2,I1,M1,M2
     DIM C1,C2,C3,C4,C5,T6,V,S1,S2,A,HC,BAND,BANDS(8),EN,LN
     DIM EMAX,ICHAN,TRAN,INTERVAL,FACT,FACTH
REM
REM
REM ****************** S Y S I N F ********************
REM
REM
REM    SETS UP AN OPERATOR ABORT AT 9903
      ON ERROR GOTO 9903
     CALL BANNER
     L=7
     N=128
     GOSUB 7000
REM
1      PRINT
       FACT=0
       PRINT
     INPUT "CLIENT'S NAME: " N$
     PRINT "CHANNEL CODES"
     FOR I=1 TO 4
4     PRINT "CHANNEL ";I
     INPUT CODE(I)
     IF CODE(I)>4 THEN 2
     IF CODE(I)<1 THEN 2
     IF I<3 THEN IF CODE(I)>1 THEN IF CODE(I)<>4 THEN 2
     IF I=3 THEN IF CODE(I)<3 THEN 2
     IF I=4 THEN IF CODE(I)<>2 THEN IF CODE(I)<>4 THEN 2
     GOTO 3
2     PRINT "** ERROR 3 **"
     GOTO 4
3     NEXT I
     INPUT "ONLINE OR OFFLINE (ON/OFF) :" A$
```

```
     IF A$="ON" THEN LN=1 ELSE LN=2
     IF LN=1 THEN 5
     ON ERROR GOTO 9001
9002 INPUT "FILE-NAME :" F$
     OPEN 4,F$
     ON ERROR GOTO 9903
5     IF LN=2 THEN GOSUB 8040
      INPUT "CALIBRATION (YES/NO) : " A$
      IF A$="YES" THEN GOSUB 8000
10     F2=128
20     INPUT "HARD-COPY (YES/NO) :" A$
     IF A$="YES" THEN HC=1 ELSE HC=0
     IF HC=0 THEN 693
     POKE :A00B,:00
    PRINT "          D A T C A P   M K . 1 A         R H O D E S   U N I V E R S I
    PRINT
     PRINT
     PRINT "RUN: ";N$
     PRINT
     POKE :A00B,:04
693     TRAN=0
     IF CODE(1)=1 THEN TRAN=TRAN+1
     IF CODE(2)=1 THEN TRAN=TRAN+1
     IF TRAN<1 THEN 77
     INPUT "FOURIER OUTPUT BANDED (YES/NO) :"A$
     IF A$="YES" THEN BAND=1 ELSE BAND =0
     INPUT "SPECTROGRAM TRANSFORMED (NO/LOG/SQR) :"A$
     TRAN=0
     IF A$="LOG" THEN TRAN=1
     IF A$="SQR" THEN TRAN=2
REM     NOTE DEFAULT IS NONE.
77      IF CODE(3)<>3 THEN 78
       PRINT "CARDIOTACHOMETER FACTOR FOR 60 B.P.M."
       IF LN=2 THEN 9920
       INPUT "CALIBRATE : " A$
        FACTH=0
       CALL FETCH(7813,1,1,1,1,128)
       FOR I=1 TO 128
       DAT3(I)=DAT3(I)*FACT
       FACTH=FACTH+DAT3(I)
       NEXT I
       FACTH=FACTH/128
       PRINT "FACTOR : ";FACTH
       GOTO 78
9920   INPUT "FACTOR : " FACTH
78     INPUT "NUMBER OF EPOCHS :" EMAX
7      EN=0
      PRINT
       FOR I=1 TO 4
       IF CODE(I)=1 THEN CHK$="E.E.G."
       IF CODE(I)=2 THEN CHK$="E.M.G."
```

```
        IF CODE(I)=3 THEN CHK$="E.K.G.T."
        IF CODE(I)=4 THEN 813
        PRINT "CHANNEL ";I;TAB(15);CHK$
813     NEXT I
       INPUT "READY   >" A$
REM
REM
REM ******************** D  A  T  C  A  P  ************************
REM
REM
       IF A$="NO" THEN 1
      IF HC=0 THEN 30
      POKE :A00B,:00
30     IF CODE(2)=1 THEN A=1 ELSE A=0
        ON LN GOTO 60,70
60      INTERVAL=1/N
REM
REM  ***** THIS SECTION GETS THE DATA FROM THE DIGITIZER UNIT.
REM
      PRINT
      CALL TIMER
      FOR I=1 TO 128
      DAT1(I)=0
      DAT2(I)=0
      DAT3(I)=0
      DAT4(I)=0
      NEXT I
      CALL FETCH(7813,1,1,1,1,128)
      GOTO 80
REM
REM ***** THIS SECTION GETS THE DATA FROM A DISK FILE
REM
70    PRINT
      FOR I=1 TO N
      IF CODE(1)<4 THEN READ 4,DAT1(I)
      IF CODE(2)<4 THEN READ 4,DAT2(I)
      IF CODE(3)<4 THEN READ 4,DAT3(I)
      IF CODE(4)<4 THEN READ 4,DAT4(I)
        NEXT I
80      PRINT "EPOCH ";EN
      PRINT
REM
REM ***** THE UNITARY FACTOR IS APPLIED
REM
      IF LN=2 THEN 81
      FOR I=1 TO 128
      DAT1(I)=DAT1(I)*FACT
      DAT2(I)=DAT2(I)*FACT
      DAT3(I)=DAT3(I)*FACT
      DAT4(I)=DAT4(I)*FACT
      NEXT I
```

```
81    FOR ICHAN=1 TO 4
REM
REM ***** THE ANALYSIS SUBROUTINES ARE CALLED
REM
          IF ICHAN=2 THEN IF A=1 THEN GOSUB 4000
      IF CODE(ICHAN)=4 THEN 99
      IF CODE(ICHAN)=1 THEN GOSUB 1000GOTO 40
      IF CODE(ICHAN)=2 THEN GOSUB 2000GOTO 40
      IF CODE(ICHAN)=3 THEN GOSUB 3000GOTO 40
      GOTO 40
99      PRINT
40      NEXT ICHAN
      IF EN=EMAX THEN 50
REM
REM ***** ON TERMINATION OF ANALYSIS ...
REM
      EN=EN+1
      GOTO 30
50      POKE :A00B,:04
      IF LN=2 THEN CLOSE 4
      PRINT
      PRINT "END"
      PRINT
      INPUT "GOING ON (YES/NO) :" A$
      IF A$="YES" THEN GOTO 5000
      PRINT "HALTED OK"
      ON ERROR GOTO 0
      PRINT
      PRINT
      STOP
REM
REM ******************** S  U  B  R  O  U  T  I  N  E  S  ******************
REM
REM       ** FOURIER ROUTINE **
REM       ** ADAPTED FROM GERSBACH, F.F. WITH THANKS TO
REM       ** PROF. GRIESEL - UNISA.
REM
1000      PRINT "CHANNEL ";ICHAN
      PRINT "FOURIER ANALYSIS"
      IF TRAN=1 THEN PRINT "LOG TRANSFORMATION APPLIED"
      IF TRAN=2 THEN PRINT "SQARE-ROOT TRANSFORM APPLIED"
      L3=0
      J=0
      N4=32
140       J=J+1
      P2=1
      T=2©(L-J)
      T=T+0.5
      T=INT(T)
      T1=0
      N1=0
```

```
       IF CODE(I)=3 THEN CHK$="E.K.G.T."
       IF CODE(I)=4 THEN 813
       PRINT "CHANNEL ";I;TAB(15);CHK$
813    NEXT I
      INPUT "READY   >" A$
REM
REM
REM ******************** D  A  T  C  A  P  ************************
REM
REM
      IF A$="NO" THEN 1
     IF HC=0 THEN 30
     POKE :A00B,:00
30    IF CODE(2)=1 THEN A=1 ELSE A=0
       ON LN GOTO 60,70
60     INTERVAL=1/N
REM
REM  ***** THIS SECTION GETS THE DATA FROM THE DIGITIZER UNIT.
REM
     PRINT
     CALL TIMER
     FOR I=1 TO 128
     DAT1(I)=0
     DAT2(I)=0
     DAT3(I)=0
     DAT4(I)=0
     NEXT I
     CALL FETCH(7813,1,1,1,1,128)
     GOTO 80
REM
REM ***** THIS SECTION GETS THE DATA FROM A DISK FILE
REM
70   PRINT
     FOR I=1 TO N
     IF CODE(1)<4 THEN READ 4,DAT1(I)
     IF CODE(2)<4 THEN READ 4,DAT2(I)
     IF CODE(3)<4 THEN READ 4,DAT3(I)
     IF CODE(4)<4 THEN READ 4,DAT4(I)
       NEXT I
80     PRINT "EPOCH ";EN
     PRINT
REM
REM ***** THE UNITARY FACTOR IS APPLIED
REM
     IF LN=2 THEN 81
     FOR I=1 TO 128
     DAT1(I)=DAT1(I)*FACT
     DAT2(I)=DAT2(I)*FACT
     DAT3(I)=DAT3(I)*FACT
     DAT4(I)=DAT4(I)*FACT
     NEXT I
```

```
81   FOR ICHAN=1 TO 4
REM
REM ***** THE ANALYSIS SUBROUTINES ARE CALLED
REM
         IF ICHAN=2 THEN IF A=1 THEN GOSUB 4000
     IF CODE(ICHAN)=4 THEN 99
     IF CODE(ICHAN)=1 THEN GOSUB 1000GOTO 40
     IF CODE(ICHAN)=2 THEN GOSUB 2000GOTO 40
     IF CODE(ICHAN)=3 THEN GOSUB 3000GOTO 40
     GOTO 40
99     PRINT
40     NEXT ICHAN
     IF EN=EMAX THEN 50
REM
REM ***** ON TERMINATION OF ANALYSIS ...
REM
     EN=EN+1
     GOTO 30
50     POKE :A00B,:04
     IF LN=2 THEN CLOSE 4
     PRINT
     PRINT "END"
     PRINT
     INPUT "GOING ON (YES/NO) :" A$
     IF A$="YES" THEN GOTO 5000
     PRINT "HALTED OK"
     ON ERROR GOTO 0
     PRINT
     PRINT
     STOP
REM
REM ******************** S  U  B  R  O  U  T  I  N  E  S  ******************
REM
REM     ** FOURIER ROUTINE **
REM     ** ADAPTED FROM GERSBACH, F.F. WITH THANKS TO
REM     ** PROF. GRIESEL - UNISA.
REM
1000     PRINT "CHANNEL ";ICHAN
     PRINT "FOURIER ANALYSIS"
     IF TRAN=1 THEN PRINT "LOG TRANSFORMATION APPLIED"
     IF TRAN=2 THEN PRINT "SQARE-ROOT TRANSFORM APPLIED"
     L3=0
     J=0
     N4=32
140    J=J+1
     P2=1
     T=2©(L-J)
     T=T+0.5
     T=INT(T)
     T1=0
     N1=0
```

```
150        FOR I=1 TO T/2
       N1=N1+1
       T1=T1+1
       N2=N1+T
       I1=I-1
       IF P2=1 THEN 160
       M1=N1+(T/2)
       M2=N2+(T/2)
       C1=DAT1(M1)*W1(P2)+DAT1(M2)*W2(P2)
       C2=DAT1(M2)*W1(P2)-DAT1(M1)*W2(P2)
       C3=DAT1(N1)+C1
       C4=DAT1(N2)+C2
       C5=DAT1(N1)-C1
       DAT1(M2)=DAT1(N2)-C2
       DAT1(M2)=-DAT1(M2)
       DAT1(N1)=C3
       DAT1(N2)=C5
       DAT1(M1)=C4
       GOTO 170
160        M1=N1+(T/2)+0.5
       M1=INT(M1)
       M2=N2+(T/2)
       C3=DAT1(N1)+DAT1(N2)
       C4=DAT1(M1)+DAT1(M2)
       DAT1(N2)=DAT1(N1)-DAT1(N2)
       DAT1(M2)=DAT1(M1)-DAT1(M2)
       DAT1(M2)=-DAT1(M2)
       DAT1(N1)=C3
       DAT1(M1)=C4
170        NEXT I
       IF T1>=N4 THEN 180
       T6=T/2
       N1=N1+T+T6
       P2=P2+1
       GOTO 150
180        IF J>=(L-1) THEN 190
       GOTO 140
190        C1=DAT1(1)+DAT1(2)
       DAT1(2)=DAT1(1)-DAT1(2)
       DAT1(1)=C1
       N2=N/2
       B(1)=DAT1(1)/N2
       J=1
       FOR I=3 TO N STEP 2
       J=J+1
       V=V2(J)+1
       S1=DAT1(I)*DAT1(I)
       S2=DAT1(I+1)*DAT1(I+1)
       B(V)=(S1+S2)
       N2=N/2
       B(V)=B(V)/N2
```

```
     ON ERROR GOTO 888
     IF TRAN=1 THEN B(V)=LOG(B(V))
     IF TRAN=2 THEN B(V)=SQR(B(V))
887     NEXT I
     GOTO 889
888     B(V)=0.0
     PRINT "ILLEGAL TRANSFORM"
     GOTO 887
889   ON ERROR GOTO 9903
      IF BAND=0 THEN 890
     FOR I=2 TO 50
     IF I>1 THEN IF I<5 THEN N1=1
     IF I>=5 THEN IF I<8 THEN N1=2
     IF I>=8 THEN IF I<11 THEN N1=3
     IF I>=11 THEN IF I<14 THEN N1=4
     IF I>=14 THEN IF I<21 THEN N1=5
     IF I>=21 THEN IF I<31 THEN N1=6
     IF I>=31 THEN IF I<=50 THEN N1=7
      BANDS(N1)=BANDS(N1)+B(I)
     NEXT I
     BANDS(8)=B(1)
     PRINT "DC= ";BANDS(8)
   PRINT "DELTA";TAB(12);"THETA";TAB(24);"ALPHA-";TAB(36);"ALPHA+";TAB(48);"BETA-";TAB(60
1021      FORMAT "-##.#   -##.#   -##.#   -##.#   -##.#   -##.#   -##.#"
     PRINT USING 1021, BANDS(1),BANDS(2),BANDS(3),BANDS(4),BANDS(5),BANDS(6),BANDS(7)
     FOR I=1 TO 8
     BANDS(I)=0.0
     NEXT I
     RETURN
890 PRINT
822 FORMAT "#.    -#.#       #.       -#.#      #.    -#.#"
     PRINT
     FOR I=1 TO 16
   PRINT USING 822,I,B(I+1),(I+16),B(I+17),(I+32),B(I+33)
     B(I+1)=0.0
     B(I+17)=0.0
     B(I+33)=0.0
     NEXT I
823 FORMAT "                                                      #.    -#.#"
  PRINT USING 823,I+32,B(50)
  PRINT USING 823,I+33,B(51)
  PRINTPRINT "D.C. BAND  =  ";B(1)
 B(49)=0
 B(50)=0
 B(51)=0
 B(1)=0
     RETURN
REM
REM  ** INTEGRATION APPLYING SIMPSON'S RULE **
REM  ** AFTER SHAW, 1967.
REM
```

```
2000      PRINT "CHANNEL ";ICHAN
     PRINT "INTEGRATION"
     A=0
     C1=0
     C2=0
     A=A+DAT4(1)+DAT4(N)
     K1=1
     M1=2
210     C1=C1+DAT4(K1)
     C2=C2+DAT4(M1)
     M1=M1+2
     K1=K1+2
     IF M1>N THEN 220
     GOTO 210
220     C1=C1*2
     C2=C2*4
     A=A+C1+C2*((1/F2)/3.0)
     A=A*FACT
     PRINT "ACTIVITY COEFFECIENT = ";A
     A=0
     C1=0
     C2=0
     RETURN
REM
REM  ** CARDIOTACHOMETER ANALYSIS **
REM  ** DISPLAYS THE MEAN AND STANDARD DEVIATION OF
REM  ** 128 READINGS IN A SECOND.
REM
3000      PRINT "CHANNEL ";ICHAN
     PRINT "CARDIO-TACHOMETER"
     T6=0.0
     T=0.0
     FOR I=1 TO N
     IF LN=2 THEN 3001
     DAT3(I)=DAT3(I)/FACTH*60
3001 T=T+DAT3(I)
     T6=T6+(DAT3(I)*DAT3(I))
     NEXT I
     M1=T/N
     T=(T*T)/N
     S1=T6-T/N
     S1=SQR(S1)
     PRINT "MEAN = ";M1;"       DEVIATION = ";S1
     RETURN
4000      FOR I=1 TO N
     DAT1(I)=DAT2(I)
     NEXT I
     RETURN
5000      PRINT "REENTRY"
REM
REM  **** THE REENTRY REQUEST IS MADE
```

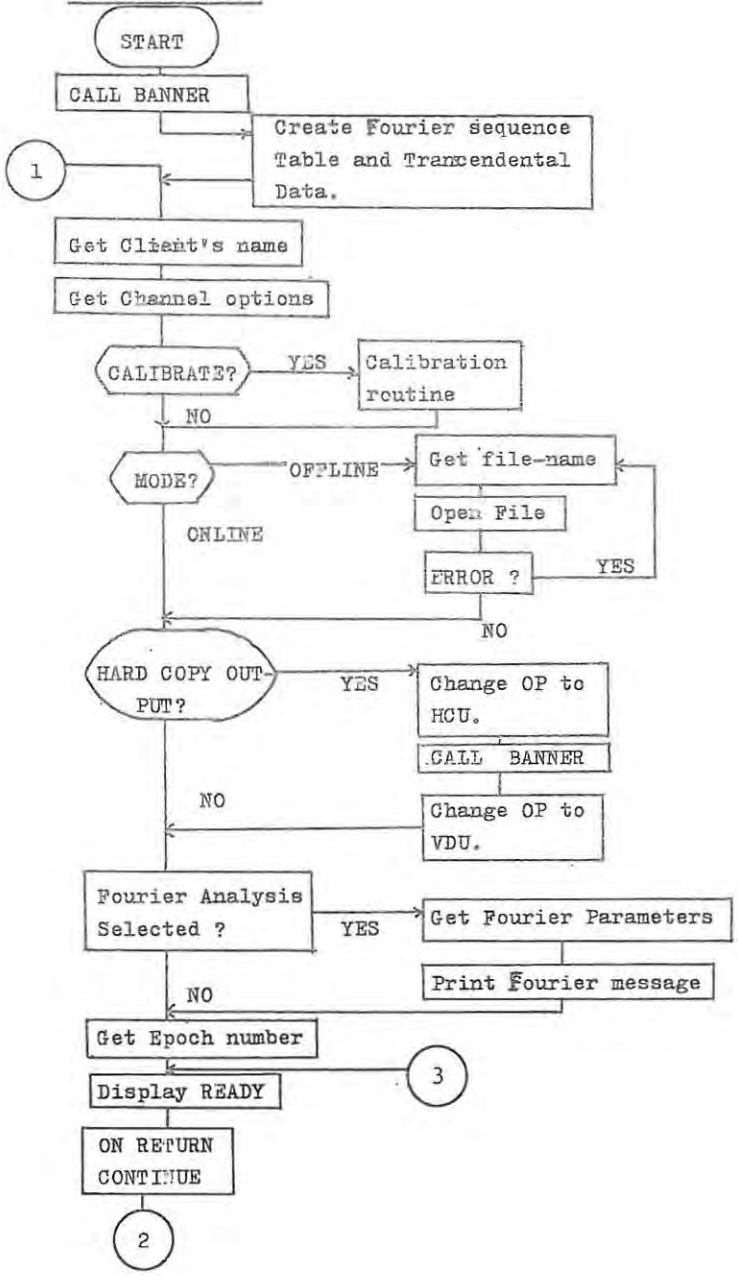
```
REM
     FOR I=1 TO 128
     DAT1(I)=0
     DAT2(I)=0
     DAT3(I)=0
     DAT4(I)=0
     NEXT I
     INPUT "REENTRY MODE (R=RESTART, C=CONTINUE) :" A$
     IF A$="R" THEN 1
     IF A$="C" THEN IF LN=1 THEN 7
     PRINT "** ERROR 2 **"
     GOTO 1
REM
REM
REM  ****** A TABLE OF TRANCENDENTAL DATA AND AN
REM  ****** ITERATION TABLE IS CALCULATED FOR USE
REM  ****** IN THE FFT ROUTINE.
REM
7000      L=7
     N=128
     L3=0
     L1=L-2
     DAT1(1)=0
     DAT1(2)=1
     T=L-1
7010      N1=2↑(L-T)
     N1=N1+0.5
     N1=INT(N1)
     L2=N1-1
     V2(1)=DAT1(1)
     V2(2)=DAT1(2)*2
     G=V2(2)*2
     K1=2
         K2=4
     FOR I=1 TO L2
     V2(K2)=G-DAT1(K1)
     K1=K1+1
     K2=K2+2
     NEXT I
     K1=2
     K2=3
     FOR I=1 TO L2
     V2(K2)=DAT1(K1)
     K1=K1+1
     K2=K2+2
     NEXT I
     L3=L3+1
     IF L3>=L1 THEN 7020
     FOR K2=1 TO (N1*2)
     DAT1(K2)=V2(K2)
     NEXT K2
```

```
     T=T-1
     GOTO 7010
7020     C1=2*3.141592654/N
     J=1
     N4=N/4
     FOR I=1 TO N4
     A=V2(J)
     W1(I)=COS(A*C1)
     W2(I)=SIN(A*C1)
     J=J+2
     NEXT I
     RETURN
REM
REM    ** ROUTINE CALIB MK 2 **
REM
8000     INPUT "CALIBRATE :" A$
     IF A$="NO" THEN 8010
       FOR I=1 TO 128
       DAT1(I)=0.0
       NEXT I
8020     CALL FETCH(7813,1,1,1,1,128)
     FOR I=1 TO 128
     T=T+DAT1(I)
     T1=T1+DAT2(I)
     N1=N1+DAT3(I)
     N2=N2+DAT4(I)
     NEXT I
     T=T/128
     T1=T1/128
     N1=N1/128
     N2=N2/128
     PRINT USING 8030,T,T1,N1,N2
8030     FORMAT "##.#      ##.#      ##.#      ##.#"
     INPUT "OK? (Y/N/F) : " A$
     IF A$="N" THEN 8020
     IF A$="F" THEN 8040
     PRINT "OK"
8010     RETURN
8040     INPUT "UNITY FACTOR : " FACT
         GOTO 8010
9001     PRINT "** ERROR 1 **"
     IF ERR=52 THEN CLOSE 4
     GOTO 9002
REM
REM  MISCELLANEOUS ERROR REPORTING ROUTINE
REM  NOTE:  ERROR 1 INDICATES AN OPPERATOR
REM         ABORT.
REM
9903   POKE :A00B,:04
       PRINTPRINT "OPERATOR ABORT"
       PRINT "** RUNTIME ERROR  ";ERR
```

```
       PRINT "HALTED AB"
       ON ERROR GOTO 0
       STOP
REM         ********* END OF PROGRAM.********
     END
```

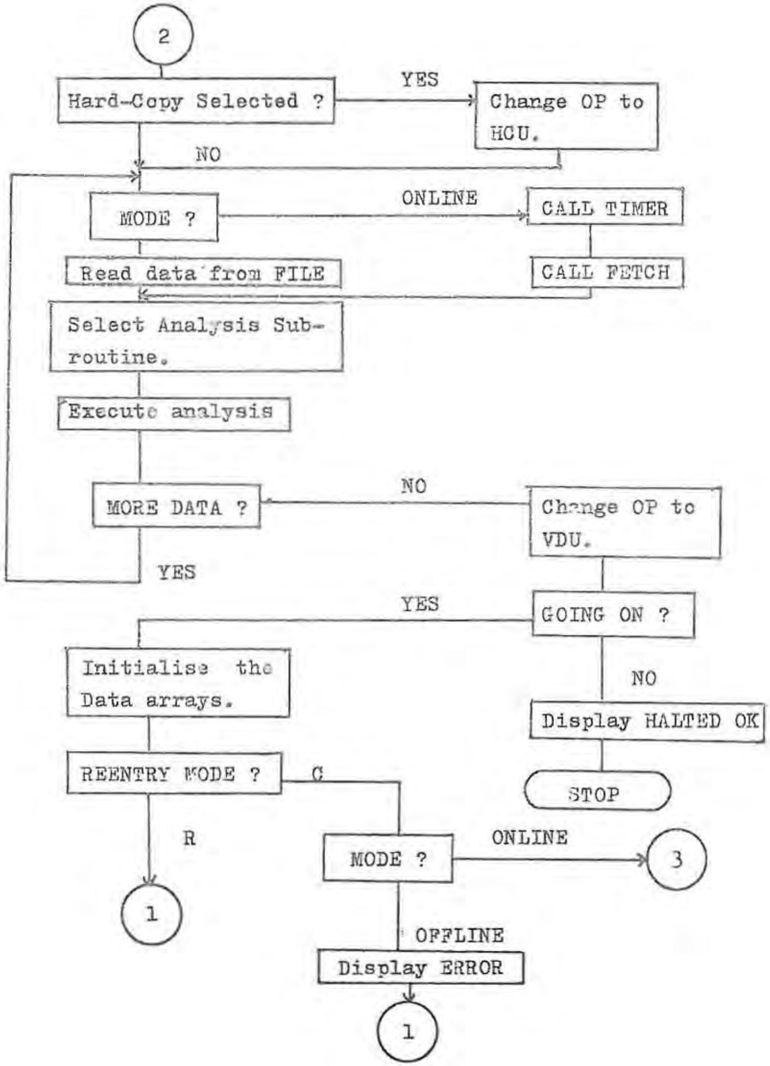
Programme DATCAP

Section: SYSINF



Programme DATCAP

Section: DATCAP



6. The Calibration routine used in DATCAP is executed.

7. The Cardiotachometer calibration routine is executed.

8. A summary of the channel options is output and the READY signal is displayed. On the depressing of the RETURN key execution begins.

9. At the termination of the execution of the number of epochs requested, the re-entry mode message is displayed and the program may be reentered in either the Continue or restart mode or terminated.

10. If the disk to which the data is being written should become full during the execution of the program, A message is output to the control terminal and the re-entry request is displayed.

NOTE: The Execution of this program follows largely from the description of DATCAP above.

B.2.3. Subprogram TIMER

The development of an electronic chronometer for the 6800 system was motivated by the need for an accurate display of the real time during the execution of programs which function in real time.

The routine described below reads the time from the clock module mounted on the front panel of the computer and translates it into ASCII constants which can be displayed to the screen. The display in in the form:

HH:MM:SS XX

Where H is hours, M minutes and S, seconds. The XX is the AM/PM indicator.

```
REM           ****************************************************
REM           *    O L D C A P          M K   1 B        *
REM           *                                          *
REM           *    AN OFFLINE DATA CAPTURE PROGRAM FOR USE    *
REM           *    WITH DATCAP.1B AS A DATA-FILE CREATING      *
REM           *    ROUTINE.    CREATES A BINARY-READ/WRITE     *
REM           *    FILE FOR SDBASIC RUN PROGRAMS.          *
REM           *                                          *
REM           *   PROGRAMMER:  ROB BARNES, PSYCHOLOGY DEPT.    *
REM           *                        RHODES UNIVERSITY.     *
REM           ****************************************************
REM
 PROGRAM ORIGIN :2810
 DATA ORIGIN :AC00
 DIM N$(25),CODE(4),DAT1(128),DAT2(128),DAT3(128),DAT4(128)
 DIM N,I,MAXS,J,A$(10),F$(12),SAMP,INTERVAL,PFLG,CALI(4),CONTFL,FACT,FACTH
1     PRINTPRINT "OLDCAP MK 1B"
      PRINTPRINT       REM  ****** THIS IS THE REENTRY POINT FOR ANOTHER SET
      A$=""             REM  ****** CLEARS THE ANSWER BUFFER
      CONTFL=0
      PRINT  REM  ****** GETS THE CREATE FILE NAME AND CHECKS FOR
                         REM  ****** ERRORS IN CREATING THE FILE.
19       ON ERROR GOTO 10
20    INPUT "FILE-NAME : " F$
21    OPEN 5,F$      REM  ****** SETS THE FILE TO CHANNEL 5
         ON ERROR GOTO 0  REM ***** CLEARS THE ERROR-FIND ENABLE ROUTINE
      GOTO 11          REM **** THE FILE EXISTS - RECOVERY AT 11
REM
REM                            ***** GETS THE CHANNEL OPTIONS
REM
210    IF CONTFL=1 THEN 225
       INPUT "HARD COPY RECORD OF EPOCHS (YES/NO) : " A$
       PFLG=0
       IF A$="NO" THEN 2100
        PFLG=1
       POKE :A00B,:00
       PRINT "RECORD OF DATA RUN TO FILE BY OLDCAP.01"
       PRINT "DISK FILE NAME : ";F$
       POKE :A00B,:04
         IF A$="C" THEN 25 REM **** MISSES THIS ROUTINE IF REENTRY MODE IS
REM                             **** SET TO "CONTINUE"
2100    PRINT "CHANNEL OPTIONS"
           FOR I=1 TO 4
23    PRINT "CHANNEL ";I
      INPUT CODE(I)
REM                            ***** CHECKS FOR ERRORS IN THE CODE CHOICE
         IF CODE(I)<1 THEN 22
         IF CODE(I)>4 THEN 22
         IF I<3 THEN IF CODE(I)>1 THEN IF CODE(I)<>4 THEN 22
         IF I=3 THEN IF CODE(I)<>3 THEN IF CODE(I)<>4 THEN 22
         IF I=4 THEN IF CODE(I)<>2 THEN IF CODE(I)<>4 THEN 22
```

```
     GOTO 24
22   PRINT "** ERROR 3 **    OPTION ERROR - REINPUT"
     GOTO 23
24        NEXT I
25   N=128         REM      ****** SETS THE NUMBER OF POINTS PER EPOCH
     INPUT "NUMBER OF EPOCHS : " MAXS
     PRINT
REM
REM                           ***** DISPLAYS THE CHANNEL OPTION CHOICES
REM
        IF PFLG=1 THEN POKE :A00B,:00
     FOR I=1 TO 4
     IF CODE(I)=1 THEN N$="FOURIER ANALYSIS"
     IF CODE(I)=3 THEN N$="CARDIOTACHOMETER"
     IF CODE(I)=2 THEN N$="CURVE INTEGRATOR"
     IF CODE(I)=4 THEN N$="UNUSED"
         PRINT "CHANNEL ";I;"     ";N$
     NEXT I
       IF PFLG=1 THEN POKE :A00B,:04
REM           **** PROVIDES A CALIBRATION ROUTINE TO CHECK
REM           **** LEVEL OF THE INPUT.
REM
    INPUT "CALIBRATE (YES/NO) : " A$
    IF A$="NO" THEN 8000
8010  CALL FETCH(7813,1,1,1,1,128)
    FOR I=1 TO 4
    CALI(I)=0
    NEXT I
    FOR J=1 TO 128
    CALI(1)=CALI(1)+DAT1(J)
    CALI(2)=CALI(2)+DAT2(J)
    CALI(3)=CALI(3)+DAT3(J)
    CALI(4)=CALI(4)+DAT4(J)
    NEXT J
    FOR I=1 TO 4
    CALI(I)=CALI(I)/128
    NEXT I
8020 FORMAT "##.#      ##.#      ##.#      ##.#"
    PRINT USING 8020,CALI(1),CALI(2),CALI(3),CALI(4)
    INPUT "OK? (Y/N/F) : " A$
    IF A$="N" THEN 8010
    IF A$="F" THEN 8030
    GOTO 8000
8030 INPUT "UNITARY FACTOR : " FACT
8000 PRINT "OK"
REM
REM      CALCULATES A CARDIO FACTOR FOR USE WITH DATCAP
REM
      IF CODE(3)<>3 THEN 225
      PRINT "CARDIOTACHOMETER FACTOR FOR 60 B.P.M."
      INPUT "CALIBRATE : "A$
```

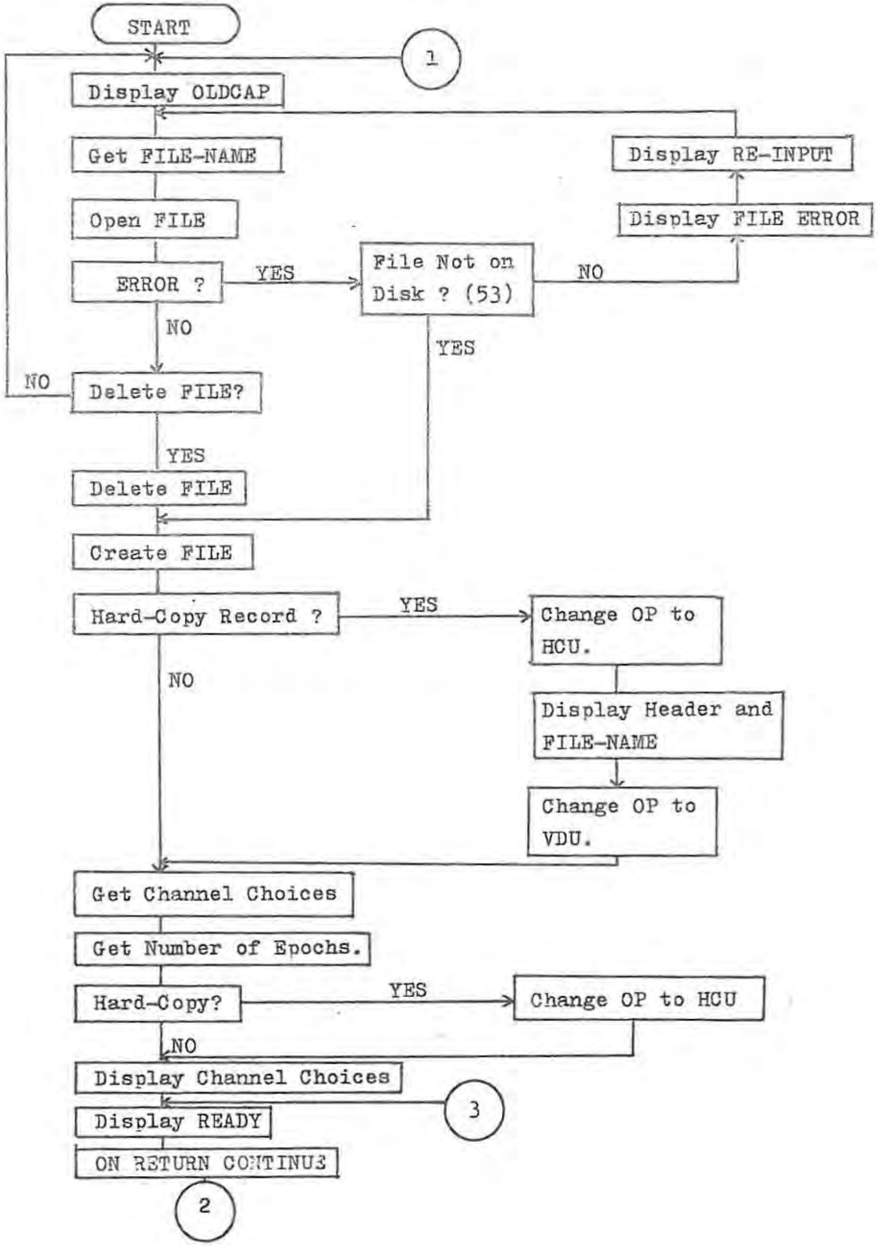
```
       CALL FETCH(7813,1,1,1,1,128)
        FACTH=0
       FOR J=1 TO N
       DAT3(J)=DAT3(J)*FACT
       FACTH=FACTH+DAT3(J)
       NEXT J
       FACTH=FACTH/128
       PRINT "FACTOR = ";FACTH
REM
REM  IF A NEW FILE HAS BEEN CREATED IN A CONTINUATION RUN
REM  THE NEW FILE-NAME IS PRINTED IF H.C. IS REQUESTED.
REM
225   IF CONTFL=1 THEN IF PFLG=1 THEN GOSUB 9000
REM                            ***** DISPLAYS THE SYSTEM READY BANNER
REM
        PRINTINPUT "READY    >" A$
        IF A$="NO" THEN 1
        SAMP=1
        IF PFLG=1 THEN POKE :A00B,:00
REM
REM                            ***** WRITES THE DATA COLLECTED FROM THE
REM                            ***** DATA-CAPTURE INPUT TO DISK.
REM
    PRINTPRINT "UNITARY FACTOR : ";FACT
          PRINT "CARDIOTACHOMETER FACTOR : ";FACTH
      ON ERROR GOTO 60     REM ***** SETS UP DISK FULL ERROR RECOVERY
            FOR I=1 TO MAXS
         INTERVAL=1/N  REM **** INTERVAL IS THE SAMPLING INTERVAL
REM                         **** FOR POINTS OVER ONE SECOND.
     CALL TIMER         REM**** DISPLAYS THE CURRENT TIME.
     CALL FETCH(7813,1,1,1,1,128)
     PRINT "    ";I
              FOR J=1 TO N
                DAT1(J)=DAT1(J)*FACT
                DAT2(J)=DAT2(J)*FACT
                DAT3(J)=DAT3(J)*FACT*FACTH
                DAT4(J)=DAT4(J)*FACT
                IF CODE(1)<4 THEN WRITE 5,DAT1(J)
                IF CODE(2)<4 THEN WRITE 5,DAT2(J)
                IF CODE(3)<4 THEN WRITE 5,DAT3(J)
                IF CODE(4)<4 THEN WRITE 5,DAT4(J)
              NEXT J
REM
REM     ****** N O T E :    SEQUENTIAL RECORDS ARE NOT IN SERIAL ORDER
REM                         OF ANY ONE DATA ARRAY.  THE READ IN ROUTINE
REM                         OF DATCAP 1A IS THE MATCH OF THIS.
REM
            NEXT I
     ON ERROR GOTO 0     REM ***** DISABLES THE ERROR RECOVERY
REM
REM                          ****** REENTRY ROUTINE
```

```
REM
       CLOSE 5       REM   ****** BREAKS THE FILE ASSOCIATION WITH THE CHANNEL
       PRINTPRINT
         POKE :A00B,:04
61     PRINT "GOING ON (YES/NO)"
       INPUT A$
              IF A$="YES" THEN 30
       PRINTPRINTPRINT "HALTED OK"
       STOP            REM   ****** TERMINATION POINT IN THE PROGRAM
REM
REM
30     PRINT "REENTRY"
       PRINT "REENTRY MODE (R=RESTART, C=CONTINUE)"
       INPUT A$
              IF A$="R" THEN 1
       PRINTPRINT "NEW FILE-NAME"
       CONTFL=1
         GOTO 19
REM
REM                             ****** FILE CREATION ERROR RECOVERY ROUTINE
REM
10            IF ERR=53 THEN 1100
       PRINT "** ERROR 1 **    FILE ERROR"
       PRINT "** RUNTIME ERROR  ";ERR
       PRINT "RE-INPUT!"
         GOTO 20
11     PRINT "DELETE OLD DATA FILE: ";F$;" (YES/NO)"
       CLOSE 5
       INPUT A$
              I  A$="YES" THEN DELETE F$ ELSE GOTO 12
         GOTO 1100
12     PRINT "OK"
         GOTO 1
REM
REM                             ****** DISK FULL RECOVERY ROUTINE
60     POKE :A00B,:04    REM *** ENSURES THAT COMMUNICATION IS WITH
REM                          *** THE CONTROL TERMINAL.
       PRINT "WRITE DISK IS FULL"
    ON ERROR GOTO 0
       PRINT I;" EPOCHS WRITTEN TO ";F$
       CLOSE 5
       GOTO 61          REM ****** GOES TO REENTRY ROUTINE
REM
REM    THE FILE CREATING ROUTINE
REM
1100       CREATE 5,F$
                GOTO 210
REM
REM  PRINTS NEW FILE NAME
REM
9000    POKE :A00B,:00
```

```
       PRINTPRINT "NEW FILE-NAME : ";F$
       POKE :A00B,:04
       RETURN
REM
REM                              ****** END OF PROGRAM
    END
```

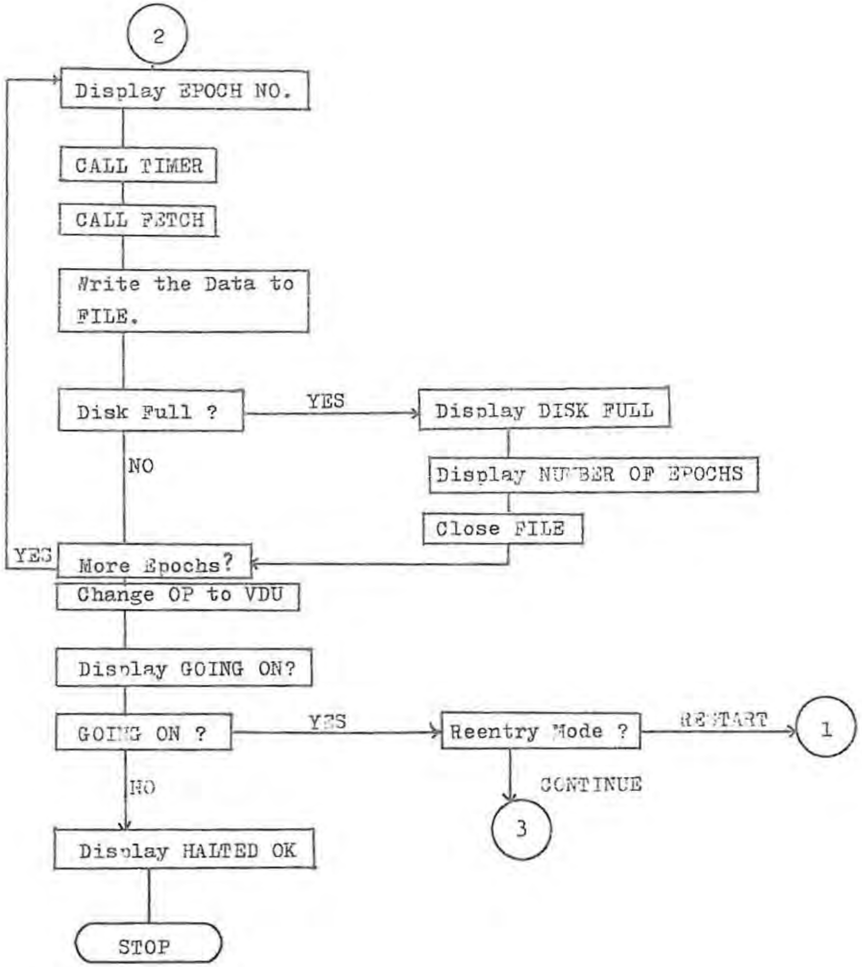
Programme: OLDCAP

Section: SYSINF



Programme: OLDCAP

Section: OLDCAP



The routine may be called from a program by executing a jump to memory location $A17C and treating this routine like a subroutine.

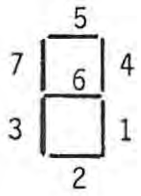
This subprogram is primarilly involved in the interfacing of hardware into the system and therefore the hardware requires description.

a) The Clock board:

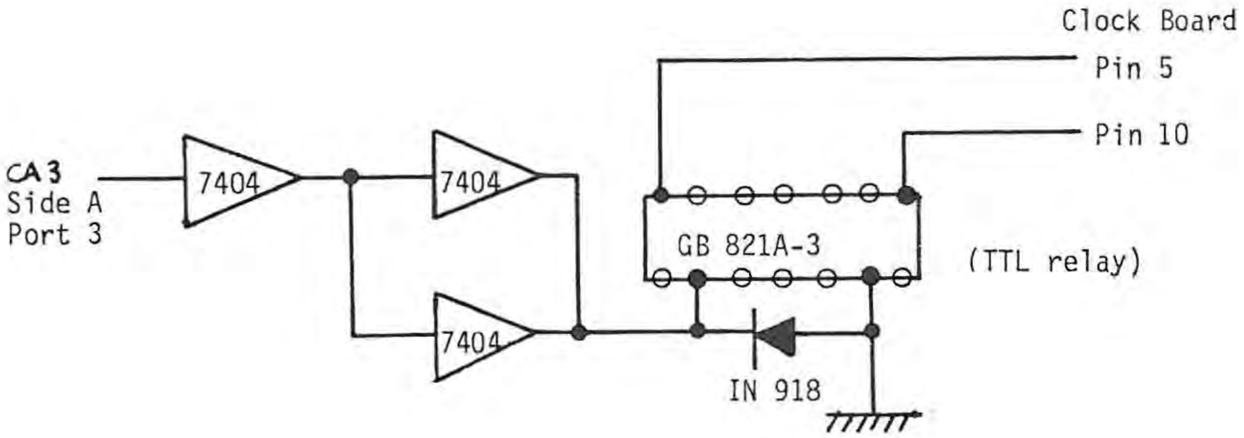
A small digital alarm clock chip was used and wired as per manufacturer's instructions. The display unit is driven by aproximately 22 V.D.C. and as it was to be directly interfaced into a P.I.A., it was necessary to divide the voltage to ground to result in the required 5V logic 1. The lines from the display segments of the clock were thus run to the input ports via two 6821 P.I.A. boards.

PIN	SEGMENT	PIN	SEGMENT
1	-	19	1 Hours units
2	-	20	2 "
3	1 Min/Sec Units	21	3 "
4	2 "	22	4 "
5	3 "	23	5 "
6	4 "	24	6 "
7	5 "	25	7 "
8	6 "	26	4&1 Hours tens
9	7 "	27	4&1 Hours tens
10	1 Min/Sec Tens	28	-
11	3 "	29	-
12	5&2 "	30	-
13	4 "	31	P.M. indicator
14	5&2 "	32	Colon
15	6 "	33	P.M. indicator
16	7 "	34	A.M. indicator
17	Colon		
18	Colon		

The table (above) refers to the pins on the edge of the clock board and the segment numbering conforms to the diagramme below.



Because the clock operates in two modes (Hour/Min. and Min./Sec.), in order to display the time in Hour/Min./Sec. mode, it is necessary to switch from one mode to the other during the execution of the clock programme. To achieve this the control line CA2 on the B side of port 3 is used to drive a TTL relay which grounds the clock line for the duration of the reading of



the seconds.

The Inverters (7404) are used in this circuit to provide sufficient current to drive the relay. The 5V supply for these chips is taken to the clock board via the Indexing pin on the PIA which is jumpered to the 5V line on the PIA board.

b) The interface connections:

Two double sided PIA boards are used to interface the clock logic into the 6800. These are configured for INPUT and connected to ports 3 and 4 in the following manner.

PORT 3	Side A	P.M. indicator	BIT 0
		Hours Tens	BIT 1
	Side B	Segments 1 to 7 to bits 0 - 6 in order. Hours Tens.	
PORT 4	Side A	Segments 1,3,5 and 2,4,6,7 to bits 0 - 5 in that order. Minutes/Seconds tens.	
	Side B	Segments 1 to 7 to bits 0 - 6 in that order. Minutes/Seconds units.	

c) Software:

The addresses associated with each of these input ports are given below.

PORT	SIDE	PERIPHERAL REGISTER	CONTROL REGISTER
3	A	$800C	$800D
3	B	$800E	$800F
4	A	$8010	$8011
4	B	$8012	$8013

The memories set aside for data storage are shown below.

$A102	Hours Tens and AM/PM indicator
$A103	Hours units
$A104	Minutes/Seconds Tens
$A105	Minutes/Seconds Units

The translation of the data is achieved by means of the table below.

NUMBER	TENS		UNITS		HOURS TENS		
	Hex	Dec	Hex	Dec	Hex	Dec	
1	01	1	09	9	01	1	(A.M.)
					03	3	(P.M.)
2	1E	30	3E	62			
3	1D	29	3B	59			
4	31	49	69	105			
5	3D	61	73	115			
6			77	119			
7			19	25			
8			7F	127			
9			7B	123			
0	2F	47	5F	95	00	0	(A.M.)
					02	2	(P.M.)

NOTE: DURING THE EXECUTION OF THE PROGRAMME AS A SUBROUTINE, THE PROGRAMME MAY RESPOND WITH "?" IN A COLUMN. THIS IS INDICATIVE OF A READ ERROR WHICH IS PROBABLY DUE TO A HARDWARE FAULT ON THE CLOCK BOARD.

IN THE EVENT OF THIS HAPPENING TECHNICAL ASSISTANCE SHOULD BE CALLED IN.

B.3.4. Subprogram FETCH2

(NOTE: Although reference has been made to Subprogram FETCH, it is not discussed here.)

This subprogram constitutes the link between the signal conditioner unit and the computer whereby the computer is able to

```

                 * * * * * * * * * * * * * *
                 * TIMEPAK.1A - TIME DISPLAY
                 * TO THE OUTPUT FROM THE
                 * FRONT-PANNEL CLOCK ON THE
                 * 6800.
                 ***************************
 A120             ORG $A120
                 *
                 * THE PORTS ARE INITIALISED FOR INPUT
                 *
A120 B68011      START LDA A $8011
A123 84FB         AND A #$FB
A125 B78011       STA A $8011
A128 8600         LDA A #$00
A12A B78010       STA A $8010
A12D B68011       LDA A $8011
A130 8A04         ORA A #$04
A132 B78011       STA A $8011
A135 B68013       LDA A $8013
A138 84FB         AND A #$FB
A13A B78013       STA A $8013
A13D 8600         LDA A #$00
A13F B78012       STA A $8012
A142 B68013       LDA A $8013
A145 8A04         ORA A #$04
A147 B78013       STA A $8013
A14A B6800F       LDA A $800F
A14D 84FB         AND A #$FB
A14F B7800F       STA A $800F
A152 8600         LDA A #$00
A154 B7800E       STA A $800E
A157 B6800F       LDA A $800F
A15A 8A04         ORA A #$04
A15C B7800F       STA A $800F
A15F B6800D       LDA A $800D
A162 84FB         AND A #$FB
A164 B7800D       STA A $800D
A167 8600         LDA A #$00
A169 B7800C       STA A $800C
A16C B6800D       LDA A $800D
A16F 8A04         ORA A #$04
A171 B7800D       STA A $800D
                 *
                 * THE CLOCK IS SWITCHED TO HRS/MIN. MODE.
                 *
A174 8634        SWIT1 LDA A #$34
A176 B7800D       STA A $800D
                 *
                 * RETURNS TO DOS AFTER THE START UP HERE.
                 *
A179 7E7283       JMP $7283
                 *
                 *
                 * READS THE PORTS ON EACH CALL TO THE CLOCK
```

```
                 * AND STORRES THE DATA IN SET LOCATIONS.
                 * (SEE DOCUMENTATION)
                 *
A17C CE0000      READ1 LDX #$0000
A17F FFA11A       STX $A11A
A182 CEA110       LDX #$A110
A185 FFA11C       STX $A11C
A188 B68010       LDA A $8010
A18B B7A105       STA A $A105    MINUTES UNITS
A18E B68012       LDA A $8012
A191 B7A104       STA A $A104   MINUTES TENS
A194 B6800E       LDA A $800E
A197 B7A103       STA A $A103   HOURS UNITS
A19A B6800C       LDA A $800C
A19D B7A102       STA A $A102   HOURS TENS AND AM IND.
                 *
                 *
                 * CALLS THE SWITCHING ROUTINE TO SECONDS MODE.
                 *
A1A0 863C        SWI2 LDA A #$3C
A1A2 B7800D       STA A $800D
                 *
                 * PERFORMS A SORT ON THE DATA IN THESE MEMORIES.
                 *
A1A5 CEA102       LDX #$A102
A1A8 5F           CLR B
A1A9 8601        SORT1 LDA A #$01
A1AB A100         CMP A 0,X
A1AD 2778         BEQ OUT1
A1AF 8603         LDA A #$03
A1B1 A100         CMP A 0,X
A1B3 2772         BEQ OUT1
A1B5 8609         LDA A #$09
A1B7 A100         CMP A 0,X
A1B9 276C         BEQ OUT1
A1BB 867E         LDA A #$7E
A1BD A100         CMP A 0,X
A1BF 276A         BEQ OUT2
A1C1 8600         LDA A #$00
A1C3 A100         CMP A 0,X
A1C5 275C         BEQ OUT0
A1C7 8602         LDA A #$02
A1C9 A100         CMP A 0,X
A1CB 2756         BEQ OUT0
A1CD 861E         LDA A #$1E
A1CF A100         CMP A 0,X
A1D1 2758         BEQ OUT2
A1D3 863E         LDA A #$3E
A1D5 A100         CMP A 0,X
A1D7 2752         BEQ OUT2
A1D9 861D         LDA A #$1D
A1DB A100         CMP A 0,X
A1DD 2750         BEQ OUT3
A1DF 863B         LDA A #$3B
A1E1 A100         CMP A 0,X
```

```
A1E3 274A         BEQ OUT3
A1E5 8631         LDA A #$31
A1E7 A100         CMP A 0,X
A1E9 2748         BEQ OUT4
A1EB 8669         LDA A #$69
A1ED A100         CMP A 0,X
A1EF 2742         BEQ OUT4
A1F1 863D         LDA A #$3D
A1F3 A100         CMP A 0,X
A1F5 2740         BEQ OUT5
A1F7 8673         LDA A #$73
A1F9 A100         CMP A 0,X
A1FB 273A         BEQ OUT5
A1FD 8677         LDA A #$77
A1FF A100         CMP A 0,X
A201 2738         BEQ OUT6
A203 8619         LDA A #$19
A205 A100         CMP A 0,X
A207 2736         BEQ OUT7
A209 867F         LDA A #$7F
A20B A100         CMP A 0,X
A20D 2734         BEQ OUT8
A20F 867B         LDA A #$7B
A211 A100         CMP A 0,X
A213 2732         BEQ OUT9
A215 862F         LDA A #$2F
A217 A100         CMP A 0,X
A219 2708         BEQ OUT0
A21B 865F         LDA A #$5F
A21D A100         CMP A 0,X
A21F 2702         BEQ OUT0
A221 2028         BRA ERROR
                 *
                 * ASSIGNS NUMBERS AND CALLS THE OUTPUT.
                 *
A223 8630        OUT0 LDA A #$30
A225 2028         BRA OUTPUT
A227 8631        OUT1 LDA A #$31
A229 2024         BRA OUTPUT
A22B 8632        OUT2 LDA A #$32
A22D 2020         BRA OUTPUT
A22F 8633        OUT3 LDA A #$33
A231 201C         BRA OUTPUT
A233 8634        OUT4 LDA A #$34
A235 2018         BRA OUTPUT
A237 8635        OUT5 LDA A #$35
A239 2014         BRA OUTPUT
A23B 8636        OUT6 LDA A #$36
A23D 2010         BRA OUTPUT
A23F 8637        OUT7 LDA A #$37
A241 200C         BRA OUTPUT
A243 8638        OUT8 LDA A #$38
A245 2008         BRA OUTPUT
A247 8639        OUT9 LDA A #$39
A249 2004         BRA OUTPUT
```

```
A24B 863F        ERROR LDA A #$3F
A24D 2000         BRA OUTPUT
                 *
                 *
                 * OUTPUT ROUTINE FOR THE TIME
                 *
A24F FFA11A      OUTPUT STX $A11A
A252 FEA11C       LDX $A11C
A255 A700         STA A 0,X
A257 08           INX
A258 FFA11C       STX $A11C
A25B FEA11A       LDX $A11A
A25E 08           INX
A25F 8CA106       CPX #$A106
A262 2703         BEQ SELECT
A264 7EA1A9       JMP SORT1
                 *
                 *  SELECTS WHETHER THIS IS THE SECOND TIME THROUGH OR NO
                 *
A267 C101        SELECT CMP B #$01
A269 271F         BEQ AMCHK
A26B C601         LDA B #$01
                 *
                 * READS THE SECONDS AFTER SELECTING A SHORT PAUSE.
                 *
A26D CEA000       LDX #$A000
A270 BDE2C5       JSR DELAY1
A273 B68010       LDA A $8010
A276 B7A105       STA A $A105
A279 B68012       LDA A $8012
A27C B7A104       STA A $A104
A27F CEA104       LDX #$A104
A282 8634         LDA A #$34
A284 B7800D       STA A $800D
A287 7EA1A9       JMP SORT1
                 *
                 * CHECKS IF AM OR PM.
                 *
A28A 8600        AMCHK LDA A #$00
A28C B1A102       CMP A $A102
A28F 270E         BEQ AMDIS
A291 8601         LDA A #$01
A293 B1A102       CMP A $A102
A296 2707         BEQ AMDIS
A298 8650        PMDIS LDA A #$50
A29A B7A116       STA A $A116
A29D 2007         BRA DISPLY
A29F 8641        AMDIS LDA A #$41
A2A1 B7A116       STA A $A116
A2A4 2000         BRA DISPLY
                 *
                 *  DISPLAY TIME TO OUTPUT PORT.
                 *
A2A6 CEA100      DISPLY LDX #$A100
A2A9 860D         LDA A #$0D
```

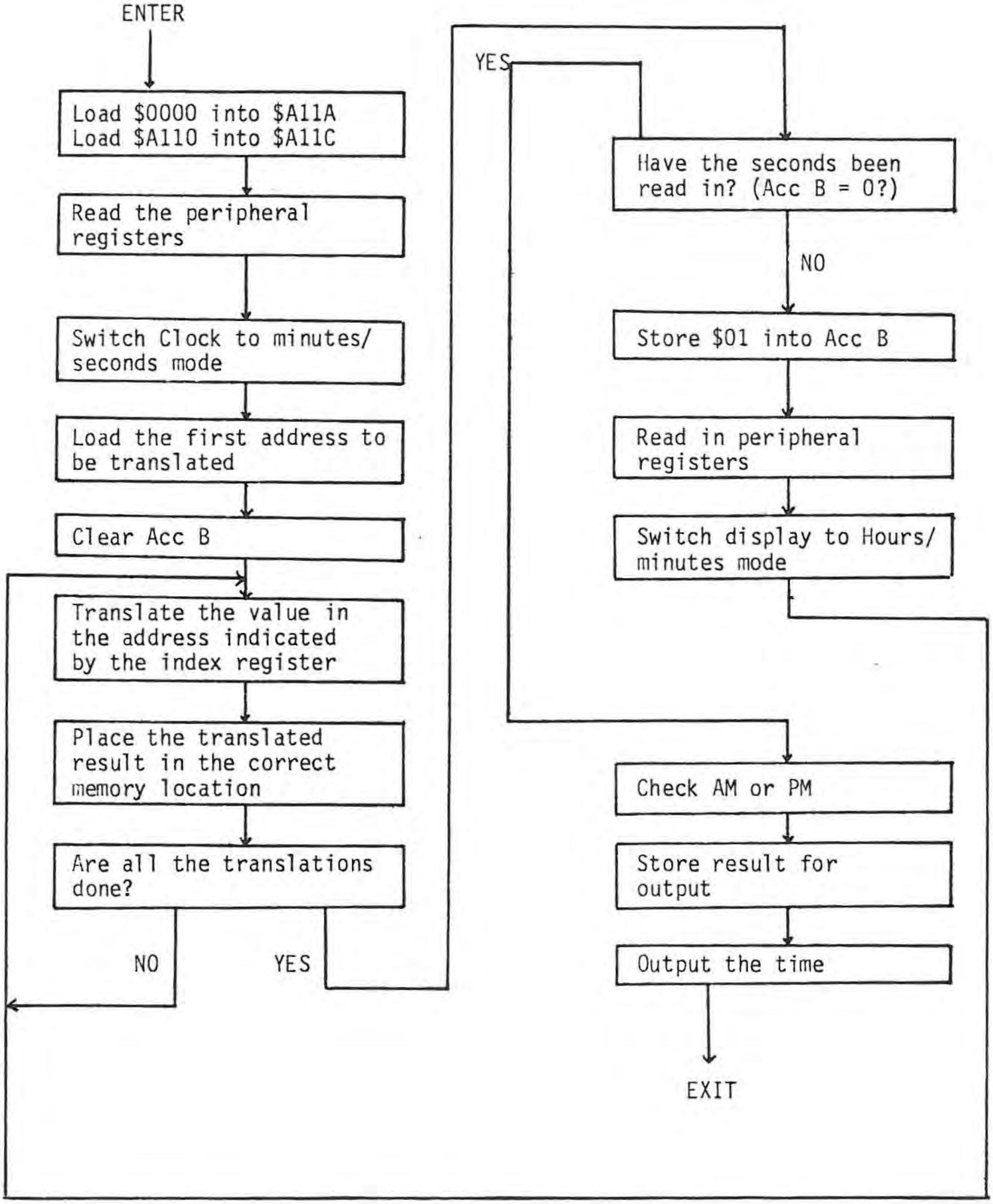
```
MAL/6800 1.2: A2AD
DATE TIME; Page 5; Form 1

A2AB A700       221:  STA A 0,X
A2AD 08         222:  INX
A2AE 860A       223:  LDA A #$0A
A2B0 A700       224:  STA A 0,X
A2B2 08         225:  INX
A2B3 8620       226:   LDA A #$20
A2B5 A700       227:  STA A 0,X
A2B7 08         228:  INX
A2B8 B6A110     229:  LDA A $A110
A2BB A700       230:  STA A 0,X
A2DD 08         231:  INX
A2BE B6A111     232:  LDA A $A111
A2C1 A700       233:  STA A 0,X
A2C3 08         234:  INX
A2C4 863A       235:  LDA A #$3A
A2C6 A700       236:  STA A 0,X
A2C8 08         237:  INX
A2C9 B6A112     238:  LDA A $A112
A2CC A700       239:  STA A 0,X
A2CE 08         240:  INX
A2CF B6A113     241:  LDA A $A113
A2D2 A700       242:  STA A 0,X
A2D4 08         243:  INX
A2D5 863A       244:  LDA A #$3A
A2D7 A700       245:  STA A 0,X
A2D9 08         246:  INX
A2DA B6A114     247:  LDA A $A114
A2DD A700       248:  STA A 0,X
A2DF 08         249:  INX
A2E0 B6A115     250:  LDA A $A115
A2E3 A700       251:  STA A 0,X
A2E5 08         252:  INX
A2E6 8620       253:  LDA A #$20
A2E8 A700       254:  STA A 0,X
A2EA 08         255:  INX
A2EB B6A116     256:  LDA A $A116
A2EE A700       257:  STA A 0,X
A2F0 08         258:  INX
A2F1 864D       259:  LDA A #$4D
A2F3 A700       260:  STA A 0,X
A2F5 08         261:  INX
A2F6 8620       262:  LDA A #$20
A2F8 A700       263:  STA A 0,X
A2FA 08         264:  INX
A2FB 8604       265:  LDA A #$04
A2FD A700       266:  STA A 0,X
A2FF CEA100     267:  LDX #$A100
A302 BDE07E     268:  JSR PDATA1
                269: *
                270: * RETURNS TO THE CALLER ROUTINE
                271: *
A305 39         272: RETURN RTS
                273: *
                274: *
  E07E          275: PDATA1 EQU $E07E
```

```
MAL/6800 1.2: A306
DATE TIME; Page 6; Form 1

 E2C5           276: DELAY1 EQU $E2C5
                277: *
                278: *
                279:  END
```

SUBPROGRAM TIMER Assembly Routine Flow diagram



select the mode of operation of the conditioner and then read the data from the digitizer circuits.

As this application of the processor uses it only in AMPLITUDE mode, only this mode will be dealt with.

The processor is interfaced via a PIA configured on port 5 with the A side configured for input of the data and the B side configured for output of the control characters. Associated with this interface is a digital counter/timer interfaced in port 7 and used to time the interval between samples taken from the signals presented to all four input channels.

i) Interface and Control. The control characters that are sent to the digitizer determine the mode of output and are determined for AMPLITUDE mode by the table shown below.

CHANNEL NO.	NAME	AMPLITUDE MODE OPERATION CODE.
1	Berger	$01
2	Caton	$06
3	Pavlov	$08
4	Freud	$0B

NOTE: The channel names are of no significance further than identifying the channels.

The mode of operation of the system is to send the control character to the processor via the control character address (port 5, Side B data register: $8016) and then, some small time period later, read the data presented to the data address (port 5, A side data register: $8014). This data is the hexidecimal value of the output of the A/D converter in the particular channel requested.

ii) Timing the sample interval. The counter/timer chip is initialised and switched to the count mode in which a pulse is output on the termination of the count. To start the counter, the value of the count is loaded in a user specified manner into the chip. On the presentation of the second bit of count value data, counting is immediately initiated.

The pulse at the termination of the count is run into the Signal conditioner unit via a control line connected to C1 on the A side of the PIA on port 5. This pulse is used as the start of conversion pulse for the A/D converters on all four channels, and, although it is not possible to read the data from all these channels similtaneously, the data stored in each of them, was sampled at the same instant.

NOTE: For further details on the counter operation, see documentation on the 8253 counter/timer integrated circuit.

iii) Data placement. The data captured from the signal processor is written directly into the memory locations set up for the data arrays in the master control programs DATCAP and OLDCAP. The data array initial positions are given on the table below.

CHANNEL	ARRAY NAME.	START LOCATION.
1	DAT1	$AC4A
2	DAT2	$AF53
3	DAT3	$B25B
4	DAT4	$B563

The data locations each require 6 memories and the organisation of these memories for integers is shown below.

0	X	X	X	Most Signif.	Least Signif.
	UNUSED			INTEGER	

```
                   1:  NAM FETCH2
  A320             2:  ORG $A320
                   3: *
                   4: * THIS SECTION GIVES A HANDY EQUATE TABLE.
                   5: * SEE DOCUMENTATION FOR DETAILS OF PROGRAM.
                   6: *
A320 0002          7: DELY1 RMB 2
  E1D1             8: OUTEEE EQU $E1D1
  E07E             9: PDATA1 EQU $E07E
  E2C5            10: DELAY1 EQU $E2C5
  0001            11: CH1 EQU $01 AMPLITUDE CODE FOR CHAN 1
  0006            12: CH2 EQU $06 AMPLITUDE CODE FOR CHAN 2
  0008            13: CH3 EQU $08 AMPLITUDE CODE FOR CHAN 3
  000B            14: CH4 EQU $0B AMPLITUDE CODE FOR CHAN 4
                  15: *
                  16: * NOTE:  THESE CODES MAY EITHER BE CHANGED
                  17: *        HERE OR AN INPUT ROUTINE APPENDED
                  18: *        TO GET THEM FROM THE CALLER ROUTINE
                  19: *        WHICH IS THE CASE WITH FETCH.
                  20: *
  1E85            21: INTEV EQU $1E85 SET FOR 128 POINTS/SEC
  0005            22: MINC EQU 5 MISS 5 MEMORIES EACH TIME FOR SDBASIC
                  23: *
                  24: *
                  25: *  THE BASES OF THE DATA ARRAYS IN MAIN
                  26: *  PROGRAMS ARE SET.
                  27: *
A322 0002         28: DATB1 RMB 2    SET AT  $AC4A
A324 0002         29: DATB2 RMB 2    SET AT  $AF53
A326 0002         30: DATB3 RMB 2    SET AT  $B25B
A328 0002         31: DATB4 RMB 2    SET AT  $B563
  8016            32: CTLO EQU $8016 SET OUTPUT LOCATION (CODES)
  8014            33: DATI EQU $8014 SET INPUT LOCATION (DATA)
A32A 0002         34: COUNT RMB 2
  7283            35: ENTRYD EQU $7283
                  36: *
                  37: * ASSIGN VALUES TO THE ARRAY BASE VARIABLES.
                  38: *
  A350            39:  ORG $A350
A350 CEAC4A       40: LOADB LDX #$AC4A
A353 FFA322       41:  STX DATB1
A356 CEAF52       42:  LDX #$AF52
A359 FFA324       43:  STX DATB2
A35C CEB25A       44:  LDX #$B25A
A35F FFA326       45:  STX DATB3
A362 CEB562       46:  LDX #$B562
A365 FFA328       47:  STX DATB4
A368 CE8180       48:  LDX #$8180 LOAD A DELAY VALUE
A36B FFA320       49:  STX DELY1 STORE IT
                  50: *
                  51: *
                  52: *
                  53: * INITIALISES THE INPUT AND OUTPUT
                  54: * LOCATIONS TO PORT
                  55: * 5 OF THE SYSTEM.
```

```
                  56: *
A36E B68015       57: INITRA LDA A $8015
A371 84FB         58:  AND A #$FB
A373 B78015       59:  STA A $8015
A376 8600         60:  LDA A #$00
A378 B78014       61:  STA A $8014
A37B B68015       62:  LDA A $8015
A37E 8A04         63:  ORA A #$04
A380 B78015       64:  STA A $8015
A383 B68017       65: INITRB LDA A $8017
A386 84FB         66:  AND A #$FB
A388 B78017       67:  STA A $8017
A38B 860F         68:  LDA A #$0F
A38D B78016       69:  STA A $8016
A390 B68017       70:  LDA A $8017
A393 8A04         71:  ORA A #$04
A395 B78017       72:  STA A $8017
                  73: *
                  74: *
                  75: * THE SYSTEM IS READY:
                  76: * A) THE INTERVAL TIMER IS STARTED
                  77: * B) VARIABLE "COUNT" IS USED TO CHECK THE
                  78: *    NUMBER OF SAMPLES TAKEN
                  79: *
                  80: *
A398 CE0080       81: SAMPR LDX #$0080 SET UP TO 128
A39B FFA32A       82:  STX COUNT STORE AS COUNT
A39E BDA44A       83:  JSR TIMEST GO START TIMER
A3A1 7EA3B9       84:  JMP EXECO GO SAMPLE
A3A4 FEA32A       85: TCHECK LDX COUNT CHECK TIME
A3A7 8C0002       86:  CPX #$0002 IS IT TERMINAL?
A3AA 270A         87:  BEQ EX1 IF YES - EXIT
A3AC BDA45A       88:  JSR TIMEUP IF NO - UPDATE
A3AF 09           89:  DEX DECR COUNT
A3B0 FFA32A       90:  STX COUNT
A3B3 7EA3B9       91:  JMP EXECO DO SAMPLE
A3B6 7EA447       92: EX1 JMP EXITR GO EXIT ROUTINE
                  93: *
                  94: *
                  95: *  THE SAMPLE IS TAKEN AND PLACED IN THE
                  96: *  CORRECT DATA LOCATION.
                  97: *
A3B9 FEA320       98: EXECO LDX DELY1
A3BC BDE2C5       99:  JSR DELAY1 GO DELAY
A3BF 8601        100:  LDA A #CH1 GET CHAN 1 CODE
A3C1 BDA3D6      101:  JSR READ1 GO READ CH 1
A3C4 8606        102:  LDA A #CH2 GET CHAN 2 CODE
A3C6 BDA3EC      103:  JSR READ2 GO READ CH 2
A3C9 8608        104:  LDA A #CH3 GET CHAN 3 CODE
A3CB BDA402      105:  JSR READ3 GO READ CH 3
A3CE 860B        106:  LDA A #CH4 GET CHAN 4 CODE
A3D0 BDA418      107:  JSR READ4 GO READ CH 4
A3D3 7EA3A4      108:  JMP TCHECK GO CHECK TIME
                 109: *
                 110: * POPS DATA INTO ARRAYS
```

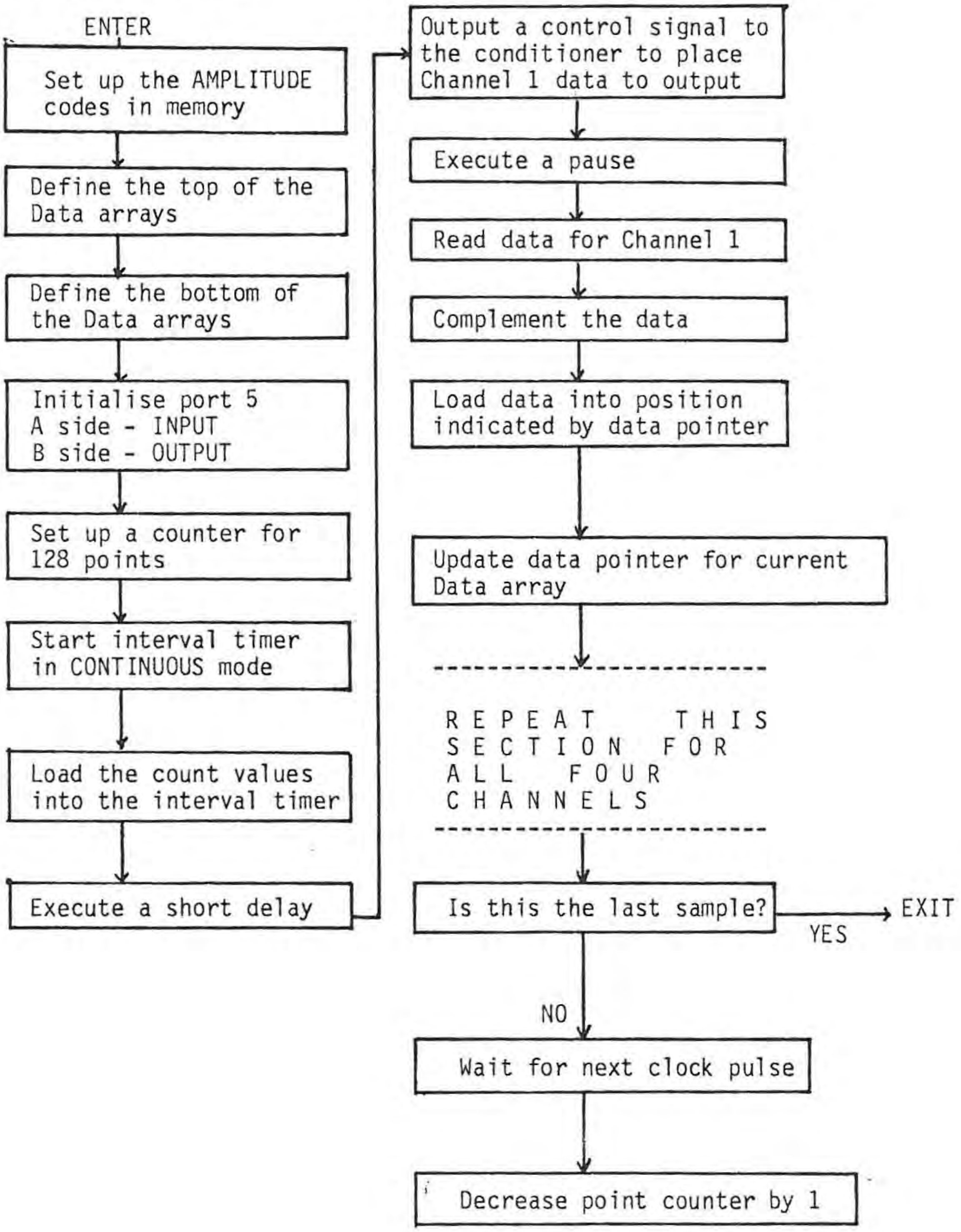
```
MAL/6800 1.2: A3D6   FETCH2
DATE TIME; Page 3; Form 1

                 *
A3D6 B78016      READ1 STA A CTLO OUTPUT CODE
A3D9 BDA430       JSR PAUSE
A3DC B68014       LDA A BATI GET DATA
A3DF 43           COM A COMPLEMENT DATA
A3E0 FEA322       LDX DATB1 STORE DATA
A3E3 A700         STA A 0,X
A3E5 BDA439       JSR INCRX UPDATE ARRAY POSITION
A3E8 FFA322       STX DATB1
A3EB 39           RTS
                 *
                 * THE SAME STEPS HAPPEN FOR EACH CHANNEL ...
                 *
A3EC B78016      READ2 STA A CTLO
A3EF BDA430       JSR PAUSE
A3F2 B68014       LDA A DATI
A3F5 43           COM A
A3F6 FEA324       LDX DATB2
A3F9 A700         STA A 0,X
A3FB BDA439       JSR INCRX
A3FE FFA324       STX DATB2
A401 39           RTS
A402 B78016      READ3 STA A CTLO
A405 BDA430       JSR PAUSE
A408 B68014       LDA A DATI
A40B 43           COM A
A40C FEA326       LDX DATB3
A40F A700         STA A 0,X
A411 BDA439       JSR INCRX
A414 FFA326       STX DATB3
A417 39           RTS
A418 B78016      READ4 STA A CTLO
A41B BDA430       JSR PAUSE
A41E B68014       LDA A DATI
A421 43           COM A
A422 FEA328       LDX DATB4
A425 A700         STA A 0,X
A427 BDA439       JSR INCRX
A42A FFA328       STX DATB4
A42D 7EA3A4       JMP TCHECK GO CHECK THE TIME
A430 01          PAUSE NOP
A431 01           NOP
A432 01           NOP
A433 01           NOP
A434 01           NOP
A435 01           NOP
A436 01           NOP
A437 01           NOP
A438 39           RTS
A439 8605        INCRX LDA A #MINC LOADS ARRAY OFFSET
A43B 08           INX
A43C 6F00        INC CLR 0,X ADD NUMBER TO POINTER
A43E 08           INX
A43F 4A           DEC A
A440 8100         CMP A #$00
```

```
MAL/6800 1.2: A444   FETCH2
DATE TIME; Page 4; Form 1

A442 2702         BEQ RINC
A444 20F6         BRA INC
A446 39          RINC RTS GO BACK TO READ ROUTINE
A447 4F          EXITR CLR A
A448 5F           CLR B
A449 39           RTS RETURN TO MAIN CALLER PROGRAM
                 *
                 *
                 *  INTERVAL TIMER ROUTINES
                 *
                 *
A44A 8636        TIMEST LDA A #$36
                 *   THIS SETS THE INTERVAL TIMER TO "CONTINUOUS" MODE.
A44C B7801F       STA A $801F
A44F 8685        RESTT LDA A #$85 GET L.S.B. OF TIME
A451 B7801C       STA A $801C
A454 861E         LDA A #$1E GET M.S.B. OF TIME
A456 B7801C       STA A $801C
A459 39           RTS RETURN TO CALLER
A45A B68015      TIMEUP LDA A $8015 CHECK FOR PULSE
A45D 2BF0         BMI RESTT YES? THEN RESET
A45F 20F9         BRA TIMEUP NO? TRY AGAIN
A461 39          REENTR RTS
                 *
                 *
                  END
```

SUBPROGRAM FETCH2 Assembly Routine Flow Diagram

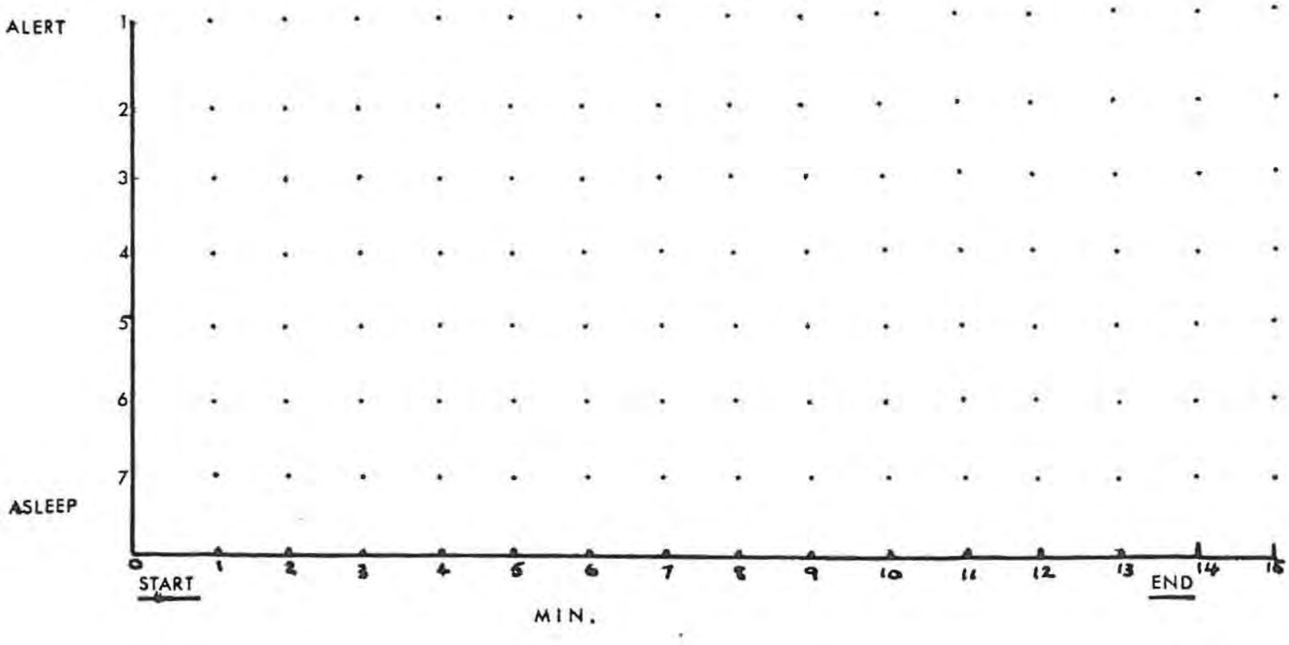


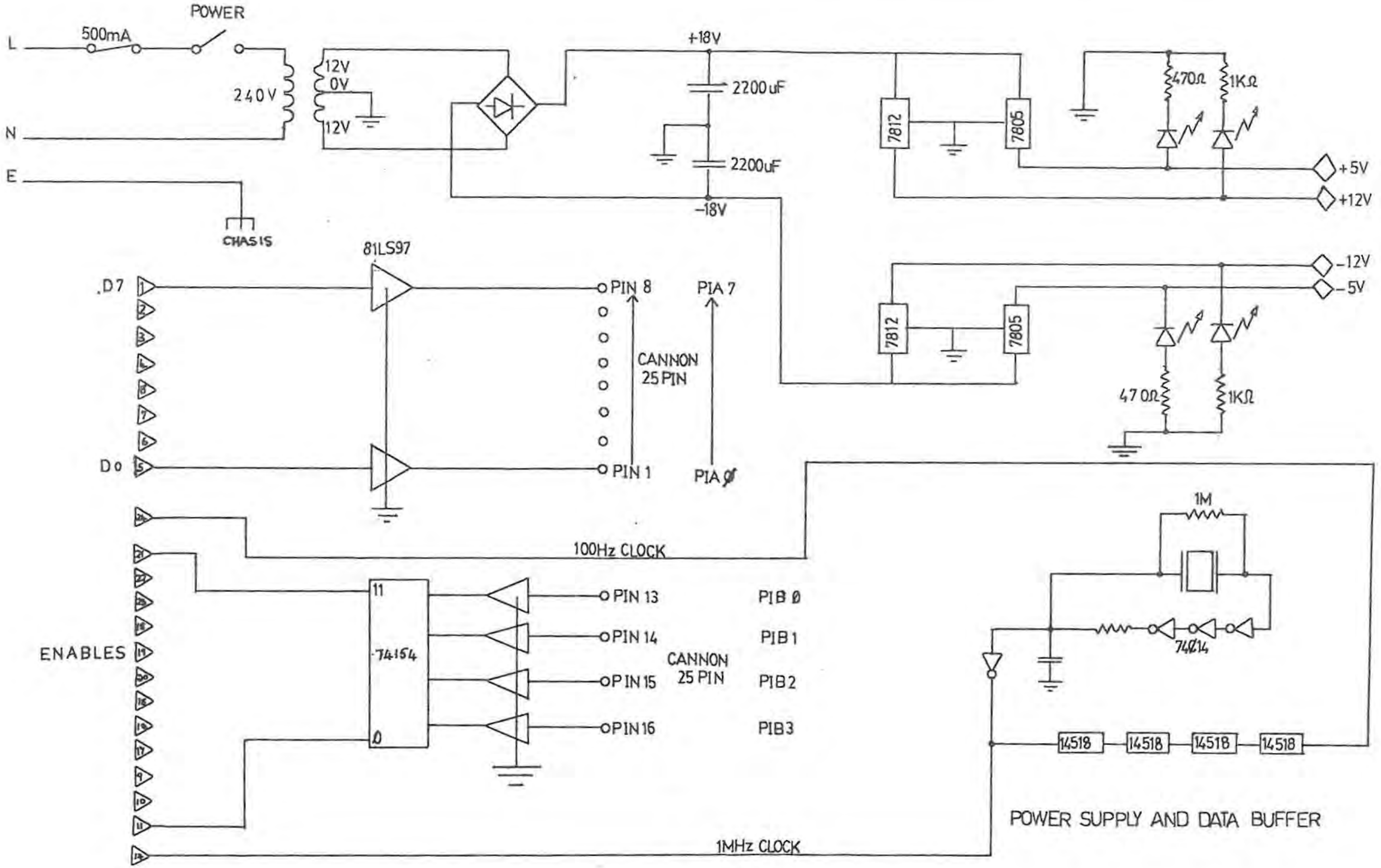
MODIFIED STANFORD SLEEPINESS SCALE : RHODES UNIVERSITY

WHICH ONE OF THE FOLLOWING STATEMENTS BEST DESCRIBES YOUR STATE OF AROUSAL OR SLEEPINESS AT THE MOMENT :

(MARK THE APPROPRIATE BLOCK)

7	AS DROWSY AS I CAN BE; WILL FALL ASLEEP SOON; HAVE LOST STRUGGLE TO REMAIN AWAKE; THINKING IS DREAMLIKE	
6	SLEEPY; WOULD LIKE TO LIE DOWN; FIGHTING SLEEP; THINKING IS BLURRED AND WOOLLY	
5	FOGGINESS; BEGINNING TO LOSE INTEREST IN REMAINING AWAKE; FEEL SLOWED DOWN	
4	A LITTLE FOGGY; NOT AT MY PEAK; BELOW PAR	
3	RELAXED; AWAKE; NOT AT FULL ALERTNESS; RESPONSIVE	
2	FUNCTIONING AT A HIGH LEVEL BUT NOT AT PEAK; ABLE TO CONCENTRATE	
1	FEELING ACTIVE AND ALIVE: ALERT: WIDE AWAKE; ALERT AS I CAN BE	





POWER SUPPLY AND DATA BUFFER

1

MAIN POWER SUPPLY BOARD. (Top) Module with Four LEDs on front.

DATA BUFFER BOARD. (Bottom) Plug-in card with control line input which convert the four line control to 12 enable lines.

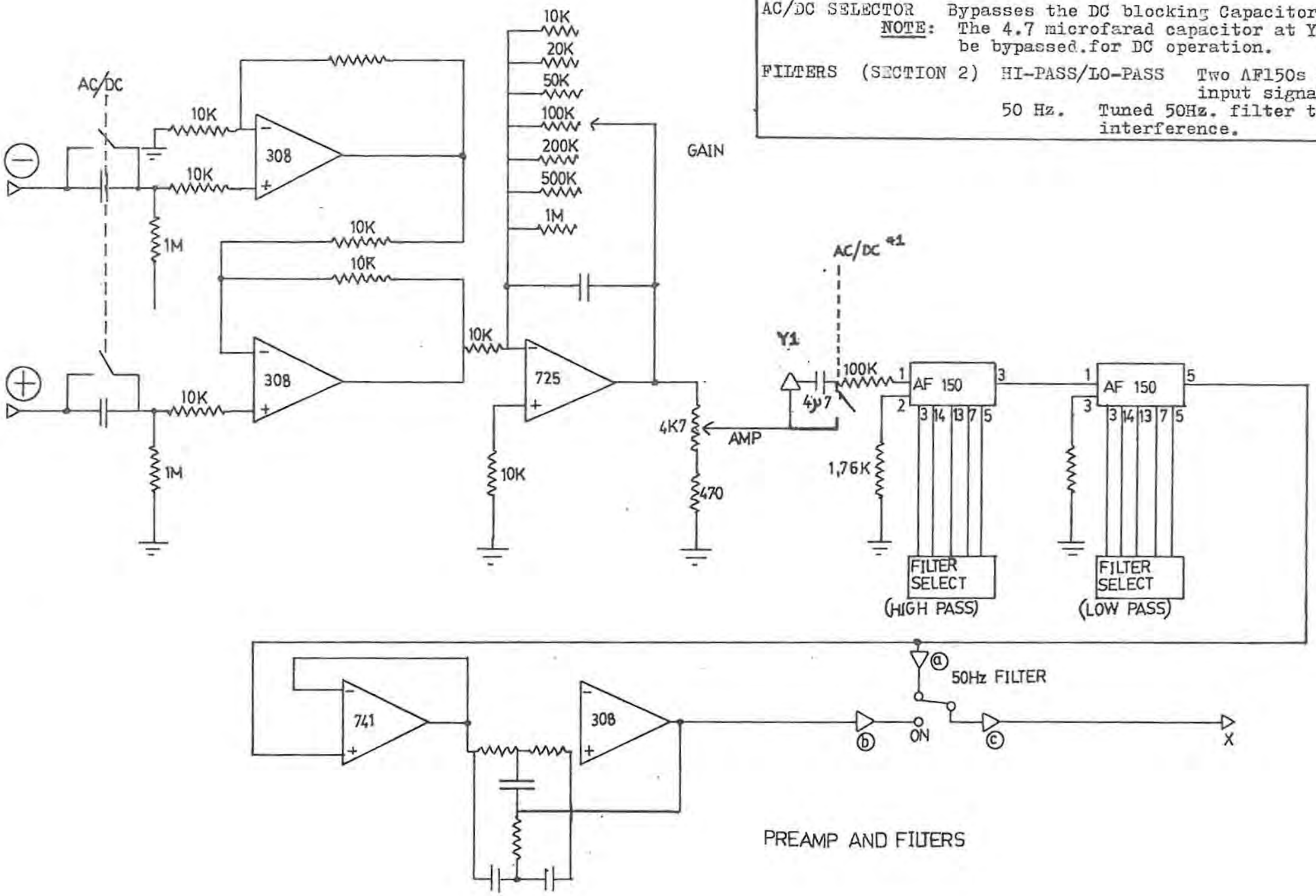
2

PREAMPLIFIER. (Section 1) Switch selectable gain factor by means of a 725 and bypass resistors. Fine amplitude adjustment by means of a potentiometer to ground.

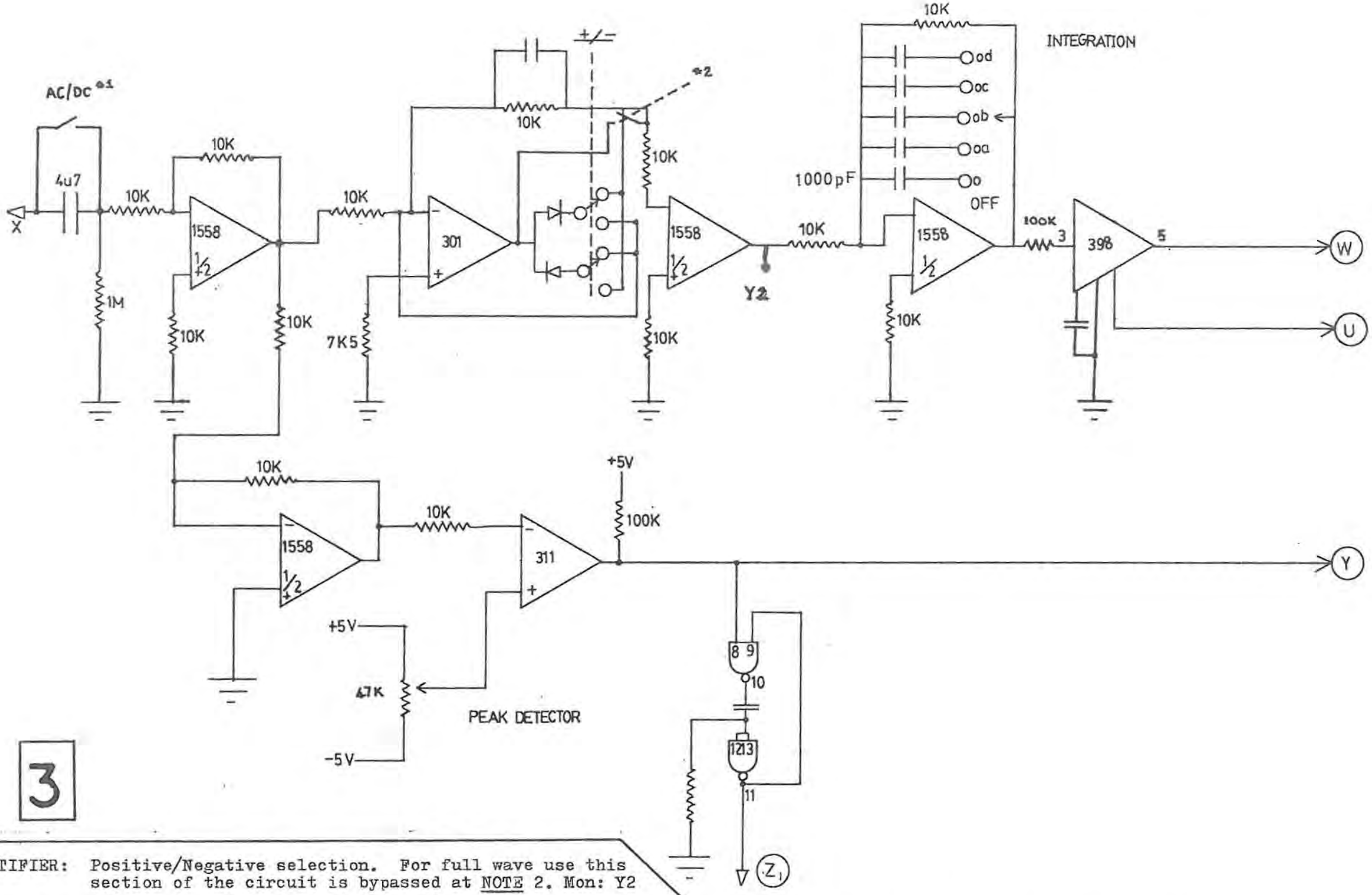
AC/DC SELECTOR Bypasses the DC blocking Capacitor. NOTE: The 4.7 microfarad capacitor at Y1 must also be bypassed.for DC operation.

FILTERS (SECTION 2) HI-PASS/LO-PASS Two AF150s are used to filter input signal.

50 Hz. Tuned 50Hz. filter to attenuate mains interference.



PREAMP AND FILTERS



RECTIFIER: Positive/Negative selection. For full wave use this section of the circuit is bypassed at NOTE 2. Mon: Y2

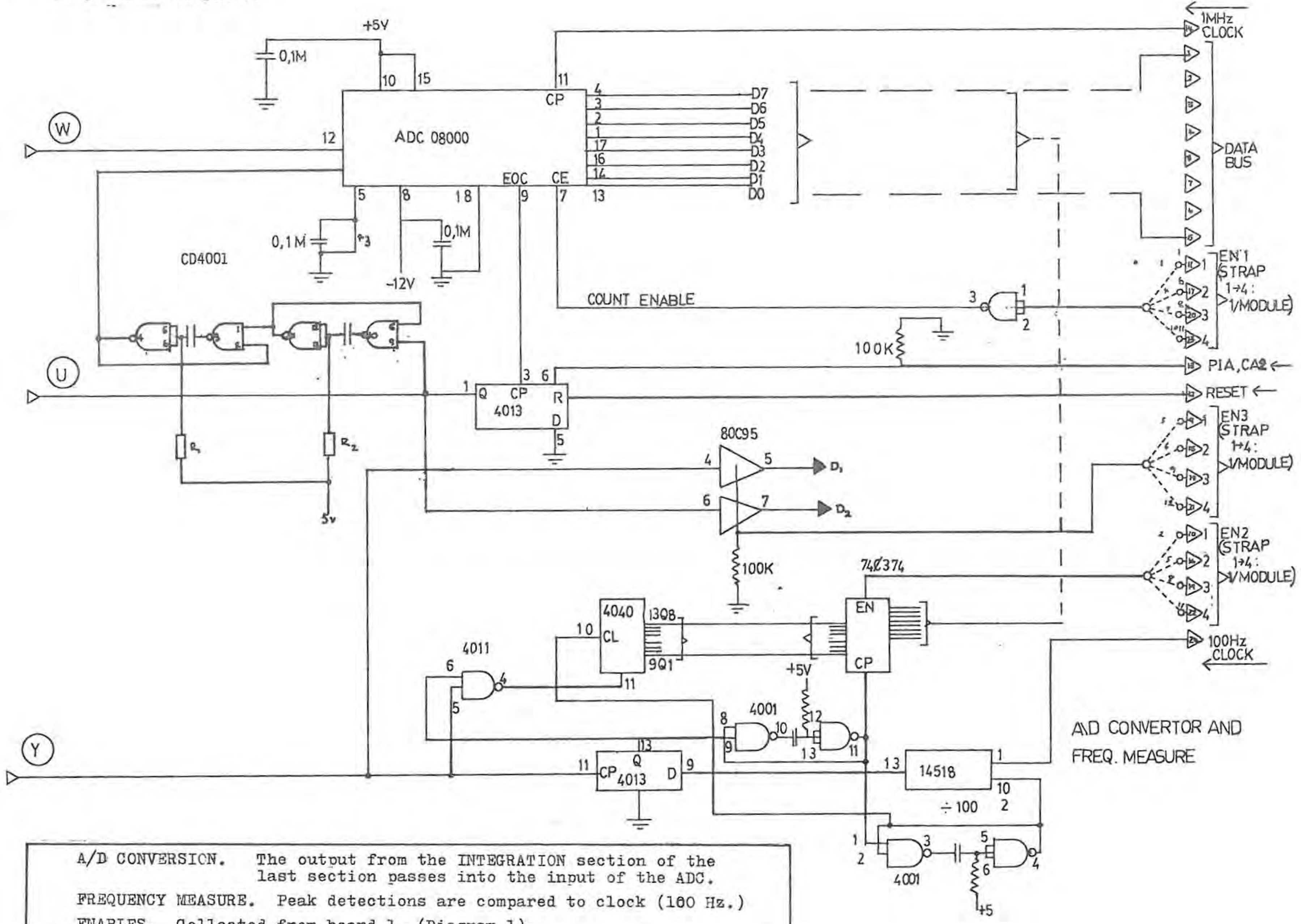
INTEGRATOR. Variable time integration of signal.

PEAK DETECTOR. Variable amplitude peak detection - Monitor output at Z1.

NOTE: For DC application, the capacitor NOTE 1 must be bypassed.

INTEGRATOR, RECTIFIER AND PEAK DETECTOR

NOTE: For full wave operation the ADC must
be grounded on pin 5.



A\D CONVERTOR AND
FREQ. MEASURE

A/D CONVERSION. The output from the INTEGRATION section of the last section passes into the input of the ADC.

FREQUENCY MEASURE. Peak detections are compared to clock (100 Hz.)

ENABLES. Collected from board 1. (Diagram 1)

4

NOTES

1. Rather than causing a decrease in heart-rate, the vagus nerve facilitates a decrease by means of the release of Acetyl Choline (ACH) at the heart muscle.

2. Although muscle activity is more correctly electrochemical in nature, this activity can both be caused by electrical currents and also observed by means of the electrical events which naturally accompany muscle contractions.

3. The FM tape deck in this diagram is incorrectly placed and should occur before the A/D converter. A digital tape deck could be used to record digital data and thus be used in the indicated position on this diagram erroneously occupied by the FM deck.

4. The word 'corresponding' in this sentence should more correctly be 'proportional'. It should be noted that the amplitude again should be linear over the frequency range being amplified. This amplifier characteristic is important in the elimination of artefacts especially where frequency analysis is to be performed.

5. This does not imply the discarding of analog display as this is very important in the calibration of the system with respect to amplitude and filter setting. The use of an oscilloscope in this type of work to provide a visual display of the amplified signal cannot be underestimated.

6. For further details on filter characteristics, see documentation on the AF 150 filter IC as used in the circuitry diagrammed in Appendix D.

7. It must be made clear that the identification of peaks at the harmonic in the analysis of the 10Hz. test signal, is not necessarily due to aliasing but could be due to true harmonic activity as the sampling of the signal is well within the limits proposed by Bloomfield (1976).

8. In an attempt to obtain a more accurate power spectrum from EEG data, an extention of fourier analysis has been proposed by Sciarretta and Erculiani (1975) which purports to be able to detect short bursts of high frequency activity if it is present in the epoch. They call this the Bursts Encephalographic Recognising Gate (BERG) transform. It is based on the rationale that the higher the frequency component you are trying to detect, the shorter the epoch needed to detect it.
This was not incorporated into the system in terms of the amount of memory that would be necessary to store all the data from the relatively long epochs required.