



MICROPROCESSOR BASED SPECTRUM ANALYSER

by KEVIN J ROGERS B E (Honours)

being submitted as a thesis for the  
degree of MASTER OF ENGINEERING SCIENCE  
at the University of Adelaide, October 1979.

This thesis embodies the results of  
supervised project work making up  
two-thirds of the work for the degree.

## SUMMARY

The purpose of this project is to make a low frequency spectrum analyser which has good resolution and dynamic range but is not too expensive. This is achieved by digitizing the analogue input signal and calculating the spectrum using an 8 bit INTELL 8080A micro-processor.

The method for digitally calculating the spectrum of signals has been exploited considerably since Cooley and Tukey introduced the Fast Fourier Transform in the 1960's and the fourier theory used in this project has already been well developed over the past twenty years. The uniqueness of this project lies in the fact that an 8-bit microprocessor is used for a complex "number crunching" application formerly reserved for larger and more powerful computers or minicomputers. Thus a flexible instrument with considerable potential has been built for a capital cost of approximately \$1 000 which is much less than commercial units currently available. However the disadvantage of using a microprocessor is the programming time required to generate efficient software.

The hardware for the spectrum analyser consists of the micro-processor system, power supply, analogue to digital and digital to analogue circuitry and input filters. It was also found necessary to build a digital hardware multiplier to keep calculation time to a reasonable level. The analyser is used in conjunction with a Cathode Ray Oscilloscope or a paper recorder to provide a medium for observing results.

The software was written in INTELL 8080 assembly language. The reason for choosing assembly language rather than a high level language such as PLM was to minimise required memory capacity and execution time.

The spectrum analyser was built with a view to analysing mechanical vibrations at Torrens Island Power Station. The use for which the instrument was built determined the specification and hence the design approach but the application method is not the subject of this thesis.

### DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university and to the best of the author's knowledge and belief contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

### ACKNOWLEDGEMENTS

Thanks are due to my supervisors Dr B Davis and Dr D Pucknell from the University of Adelaide and to a technical officer at the Torrens Island Power Station, R Vear, for his assistance in construction and debugging.

## CONTENTS

	<u>SUMMARY</u>	Page
1.	INTRODUCTION	
1.1	Alternative Approaches to Spectrum Analysis.	1
1.2	The Application.	3
1.3	Specifications for the Spectrum Analyser.	4
2.	FOURIER THEORY	
2.1	The Fourier Transform.	6
2.2	Properties of the Fourier Transform.	6
2.3	Practical Limitations.	6
2.4	Numerical Evaluation of the Fourier Transform.	11
2.5	Power Spectral Density.	12
3.	HARDWARE	
3.1	The Central Processor Unit.	15
3.2	Read Only Memory.	17
3.3	Random Access Memory.	19
3.4	Teletype Communications Board.	21
3.5	Hardware Multiplier Board.	23
3.6	Sample Rate Generator.	25
3.7	Input Amplifier.	27
3.8	Input Filters.	29
3.9	Analogue to Digital Conversion.	32
3.10	Digital to Analogue Conversion.	34
3.11	Frequency Display and Cursor Control.	36
3.12	Power Supply.	38

	Page
4. SOFTWARE	
4.1 Debugging Technique.	39
4.2 Programming of EPROM's.	40
4.3 Allocation of Random Access Memory.	41
4.4 Number Representation.	43
4.5 The Main Program.	44
4.6 Input Routine.	47
4.7 Presmultiplication of Input Data by a Window Function.	50
4.8 Calculation of Fourier Coefficients.	53
4.9 Amplitude Correction due to Windowing and Accumulation of Power Spectral Density.	57
4.10 Calculation of Logarithm of Power Spectral Density.	59
4.11 Calculation of Square Root of Power Spectral Density.	61
4.12 Display of Spectrum on a Cathode Ray Oscilloscope.	63
4.13 Display of Spectrum on a Paper Recorder.	65
5. RESULTS	68
6. CONCLUSION	86
APPENDIX 1: Detailed Circuit Diagrams.	88
APPENDIX 2: Listing of Assembly and Machine Code.	102
APPENDIX 3: The DFT of a Step Function.	143