File

INTERNAL DOCUMENT 62

I.O.S.

INDUSTRIAL TRAINING REPORT

D.H.N. BRANSON

AT IOS (WORMLEY), JAN-SEPT 1979

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(042-879-4141)

(Director: Dr. A. S. Laughton)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051-652-2396)
(Assistant Director: Dr. D. E. Cartwright)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823-86211)
(Assistant Director: M.J. Tucker)

INDUSTRIAL TRAINING REPORT

D.H.N. BRANSON

AT IOS (WORMLEY), JAN-SEPT 1979

INDUSTRIAL TRAINING REPORT OF D.H.N. BRANSON ON PLACEMENT AT THE INSTITUTE OF OCEANOGRAPHIC SCIENCES AT WORMLEY, SURREY

INTRODUCTION

My year of placement has been an interesting and most profitable one. The year's work intended for me with Seismograph Services Limited was cut short after illness at sea and within two months a substitute job for the remaining time found - my thanks to Dr John Acton for arranging this.

Because of the changeover between two very different employers, a valuable aspect I have come to appreciate has been the dynamic contrast between on the one hand commercial, and on the other academic, research work. I think that what I gained in the short time that I was at sea with S.S.L. was a facility in performing straightforward tasks under (at the time) the worst conditions conceivable - an often physically and mentally exhausting process. At I.O.S., for the major part of my placement, the emphasis has been on providing near enough ideal working conditions for stimulating productivity and creativity.

I feel that, since I have gained, in my mind, a significantly more fruitful and productive experience in this latter period, I should devote my report exclusively to it.

THE INSTITUTE OF OCEANOGRAPHIC SCIENCES

Sited approximately twenty miles from the south coast in Surrey, I.O.S. (Wormley) is one of four I.O.S. establishments, the others being at Barry, Bidston (Wirral) and Taunton. On the site are two main blocks with 3 satellite single-storey outbuildings. Plans have been drawn up to fit out buildings on a site a few miles away known as 'Hambledon Homes', to be ready for the expansion made necessary by the recently signed nuclear waste disposal contract.

All the institutes are under the direction of NERC, the Natural Environment Research Council, itself a subdivision of the Science Research Council.

The research work undertaken at Wormley may be conveniently categorised by the departmental descriptions: Marine Biology, Geophysics, Marine Physics, and Marine Chemistry. Of necessity there are additional support groups to help in the design and fabrication of equipment. These are the Physics, Acoustics, Instrument and Photographic Laboratories; the Workshop and the Data Processing Group - linked to the main I.O.S. computer at Bidston. There is an extensive library at Wormley, serving the other institutes, in the same building as the I.O.S. Administration departments.

My time at Wormley was spent mainly in the Acoustics Laboratory and I was involved to some extent with almost all the current projects being undertaken there. Rather than occupy myself exclusively with a single project, by the nature of my unpredicted move to I.O.S., I have gathered practical experience in a wide spectrum of pursuits.

COMPUTER PROGRAMMING ON THE NOVA II

My stay at I.O.S. began with my gaining an understanding of the Data General Nova II minicomputer, as used by J. Langford in his research work. At first it was hoped that after a few weeks' practice I would be able to help Jack in making his SRP (Seismic Reflecting Profiling) data processing programme run faster to make real-time analysis a possibility.

The nature of SRP demands an acoustic signal, often referred to as a gunshot, at fixed distance intervals along a desired line on the sea bed. The time lapse between shots is generally less than 15 seconds, the speed of the ship being above a minimum in order to keep the cruise timetable straight. Real-time data processing has a great deal to commend it - in a cruise situation with a flexible brief, areas of seismic promise may possibly be surveyed more thoroughly and the need for future trips to them eliminated, or at least put in a different light. This is where oil-company surveyors such as S.S.L. lose on flexibility - their data processing is far too involved to be carried out on board ship to the extent of justifying where to site rigs. Another reason for real-time processing is of course that less time need be devoted at the end of the cruise, back at Wormley, to sort through raw data, of which there can be a large amount. I am sure that many vacation students have had their employment devotely entirely to this.

At the time of my arrival, Jack's programme involving Fast Fourier Transforms and deconvolution was running at over 20 seconds per shot-point. The majority of the programming was in Assembler; a low-level language in which the most efficient computer use could be made. While Jack continued pruning superfluous instructions and taking short cuts, the best first step for me was to familiarise myself with the substantial system operation manuals supplied by the computer manufacturers.

The Nova II computing unit hardware occupies a roughly 1 m × 1 m × 2 m high cabinet of robust construction. (As an aside, when Jack informed

Data General of the conditions of its use on board ship, when asked during a routine service, the service engineer was convinced he had material for an advertisement for Nova ruggedness).

For its use in an SRP data processing role, the Nova has as peripherals a Silent 700 (Texas) keyboard/printer and reel-to-reel back up for the floppy-disk store integral to the main hardware unit. Also used are a basic X-Y/T plotter and a C.R.O. interfaced with a module of Jack's construction. When displaying processed SRP data, a Jet-Pen recorder, as developed at Cambridge University is used. With its high speed and resolution capability this output device produces a very instructive indication of the results of different processing techniques on raw data - examples of these traces are on display in the Acoustics Laboratory.

There is no substitute for first-hand experience in working with computers. Unfortunately for me, for a considerable proportion of my seven weeks spent with Jack, I could only work with the Data General manuals, since Jack was occupying the 'hot seat'. However, when able to sit down at the console, I was surprised (after a few hours' groping around in the dark for a foothold) how quickly the apparently unrelated instructions I had been sifting through fitted together as a logical operating scheme.

The Nova II has the options of Basic or Fortran for high-level language use and may readily also be accessed at the Assembler and Binary Machine-Code levels, these latter two being useful when the user wishes to have programs or parts of programs running as fast as possible. These languages are, generally speaking, common to a wide variety of computer systems. Unique to the Nova II and its closest relatives in the Data General family is the system operating language.

Simply put, this is the list of instructions input by the user via the console to the main processing unit specifying the users requirement of, say, the floppy disk store and a file within it, a transfer of the file into the text editor to modify it and return it to the disk store. The operating system linked to the languages available for programming makes the computer an intelligent tool with a variety of uses limited only by the operator's imagination. This concept of a complete intelligent system under the control of one person is one of the most important ideas I have grasped in my computing work at I.O.S.

The concrete results of my computing period are manifest in work I did on random number based, digital noise producing programs. When it was realized that the entire computer was to go to sea at the end of March, for use on a cruise in the Indian Ocean, Jack thought, rather than get involved in learning Assembler, that I should write these programs to simulate background noise - to be superimposed upon test data.

The Nova II manuals made mention of a random number function 'RAND' - which I understand is now a commonly used call on other computer systems. However, the documentation given was somewhat lacking except for a reference (D.E. Knuth - The Art of Computer Programming, Vol. II). This was consulted in the extensive library on the Wormley site and yielded an algorithm for the writing of a suitable program. Theory, argument and discussion over several dozen pages yielded the basis for a suitable program. The random numbers produced are members of a sequence:

$$\chi_n = (a\chi_{n-1} + c) \bmod m, \ \chi_o \text{ specified.}$$

Conditions for the parameters are:

(i) m is large; ideally equal to the computer word size - here $m = 2^{16}$.

(ii) for $m = 2^n$, pick a: a mod 8 = 5.

(iii) choose a: $m - \sqrt{m} > a > \{ {m/100 \atop \sqrt{m}}$.

(iv) choose c to be odd.

(v) choose c/m: $c/m \simeq \frac{1}{2} - \frac{1}{6}\sqrt{3}$.

(vi) note that the 'randomness' of any digit increases towards the most significant.

These conditions satisfied (χ_o may be set to zero or some arbitrary number such as a permutation of the date or time of day etc.) values of χ_n are produced between 0 and m with no repetitions before m numbers have been calculated i.e. the sequence has period m.

In order that the program could be of use to Jack, the 'noise' needed to resemble that occurring naturally in the measuring system. Thus the uniform distribution of values was shifted so as to be symmetrical about a zero origin and then a Gaussian subset produced by the rejection of specific samples as described elsewhere in the reference chapter on Random Number Systems. At an intermediate stage the absolute values of the distributed numbers were normalized to fall between -1 and +1. In this form, any user wishing to simulate noise need only specify the first member of the sequence and suitable scaling factors for the distribution limits and its members' absolute values. The graph (see Fig. 1) shows the distribution obtained from a sample of the sequence specified by the final program with $\chi_o = 0$.

Unfortunately, at the time of writing, further documentation, kept with the computer has not yet returned to Wormley from the Seychelles. To my knowledge the Assembler routines have not yet been speeded up to real-time capability (Jack has been without the Nova at Wormley since it left for foreign parts), but it is hoped that the noise generation program will be of use in later program development work.

The leaving of the Nova concluded the longest single period of specific work I undertook at I.O.S. For the rest of my stay, my time has been taken up in a wide variety of interesting jobs which I shall do my best to accommodate in the remainder of this report.

I.O.S. TRACKING FLOAT SYSTEM

For the analysis of water currents at different depths, adjustable buoyancy floats represent the most widely used method at present. Research in this field on the hardware is being undertaken by N.W. Millard and my first electronics project was to help him in this work.

In simple terms, the scheme used at I.O.S. is for 10 floats to be released at once. Each has a self-contained power source, receiver, transmitter and additional circuitry. On board the ship is a 'mother unit' transmitter/receiver, logic circuitry and data-plotting/storage hardware/software. In operation the mother unit transmits a 30 ms pulse at a predetermined frequency of 5 kHz followed by a 'quiet' period of 8 secs. This is repeated for the duration of measurement. During the quiet period, each float should 'echo' the transmit pulse and this will be received - each float responding with a different frequency - after a time interval related to the distance the float is away from the ship.

My part in this was to build and modify if necessary two component circuits of the on-ship logic electronics. After the transmit pulse has interrogated the floats, for the next 8 secs the towed 'fish' transducer is in the listening mode and its received output passed through a series of filters to pick out the individual float responses. The transmit pulse is at 5.1 kHz and the floats, each transmitting at 100W for 100 ms, range in frequency from 5.7 kHz to 6.7 kHz. This part of the system already existed on my arrival. It was now desired to pass the received signals within each of the ten filtered frequency bands through a unit which could latch up, resettably, when a particular channel signal strength exceeded a preset threshold. In logic terms, for each channel, the signal was passed through a dual op-amp configuration, the output of which went to clock a COSMOS D-type flip-flop. The flip-flop state was then taken out to a 20-way plug, also to a red l.e.d. buffered by a COSMOS 4050 I.C. The entire unit was fitted into a standard Vero Electronics instrument case. In operation, ancillary circuits scanned through the flip-flop outputs and whenever one was detected at a logic 'high', the fact noted (and in fact timed) and the reset to that flip-flop pulsed high in preparation for the next interrogation pulse.

The second circuit I built required an amount of juggling with the logic before the desired performance was achieved. This was to be the scanning device and its circuit diagram is shown (Fig. 2).

In operation, the outputs from the circuit described above were fed to one side of a bilateral switch - four of these are contained on each of the 4016 devices. The 4013 and 4017 I.C.s provided the scanning function: when there was no transmit pulse, i.e. in the listening mode, the 4017 decade counter was clock enabled so that when a clock pulse from the CPU (central processing unit of the tracking float system) entered the 4013 flip-flop there was a repetitive selection of a bilateral switch corresponding to the decade count reached alternating with a dummy 'earth' channel. The earth channel in between the decade counts was necessary so as to reset the monostable chip, 4047, in case the previous channel switched had been 'high'. In addition to the wiring shown, reset lines have been taken from the 4017 to the other circuit, resetting a channel at the clock count before it was selected. In this way the return 'answering' pulse from each float only triggered the monostable once; thus during any 'listening' period, the monostable would trigger 10 times, the CPU correlating its clock pulse each time to determine which float had replied. In use the system has tracked floats at up to 70 km, recovery later being accomplished with the aid of pyro-releases activated by a signal from the ship.

BATTERY CHARGER/MAINS OUTLET TIMER

For the digital circuitry used in the majority of Acoustics projects, the technique of wire-wrapping between soldered pins is the most used for connecting on-board components. However, the recent introduction of battery operated wire-wrap guns - the tools used for making the 'wrap' movement, has meant that a lot of time is spent supervising the charging up of run-down nickel-cadmium cells. To cope with this need, a colleague suggested that I built a charger which would switch itself off after the recommended charging time.

Using readily available COSMOS I.C.s, a time period of 12 hours was achieved by dividing down the frequency of a '555' oscillator by two 14-bit ripple-carry binary counters in series. Calculations showed that for an oscillation at 3107 Hz, the output of the last gate of the second counter would have an oscillation of period 24 hours, and so if initially reset to low could drive a relay turning off the supply after 12 hours, suitably buffered. A power supply to provide +12V was built and a standard constant-current charger circuit from a magazine employed for that section.

By the nature of the binary counter, it was a simple matter to offer users of the unit options of 12 h, 6 h, 3 h, 1½ h and ¾ h operating time by switching the last 5 divided outputs to the relay drive circuitry. Additional flexibility was also achieved by having a constant-current of switched magnitude providing outputs for 4 different 'nicad' cell sizes, the upper limit being determined by the transformer used in the power supply as size C (200 mA). The mains relay was also paralleled to a mains outlet at the relay rating of 2A so that other units might be switched. To complete the job a set of leads from the charger was made up terminating in a 3.5 mm jack plug and one of the wire-wrap guns suitably modified to take a socket in parallel with the batteries in its handle. Thus a purpose-built battery holder was provided at no extra cost. Care was taken to diode-protect the leads at the other end from the plug to prevent accidentally discharging the batteries when plugged in.

<u>'PUBS' TAPE-RECORDER PRINTED CIRCUIT WORK</u>

P.U.B.S. stands for Pop Up Bottom Seismometer and is one of the several methods employed by I.O.S. for ocean floor mapping and investigation. A PUBS unit comprises a sphere, 1 m in diameter of protective pressure-tight armouring. Inside is a power pack, a bottom-mounted hydrophone, control and signal logic electronics and a tape-deck for recording results. Inside the latest breed of spheres being constructed by Jack Langford, Bob Kirk and assistants, are also geophones to give a 3-D response to seismic vibrations.

In the simplest case a PUBS sphere is released into the ocean and falls to the ocean floor landing with its hydrophone facing downwards. A signal from the ship continuing along a chosen line, operates a circuit to activate the tape-deck which starts recording. From the ship there is now a series of acoustic impulses - transducers and airguns up to 15 km, explosives when up to 50 km away from the sphere. Signals are then picked up by the sphere following the water path and the indirect route through ocean-floor rock layers. Through data processing, a picture may be constructed of velocity layers along the section of floor the ship has steamed above.

My part in this operation was to lay out the printed-circuit master for the unit used to activate the tape-deck, make up the boards with components and mount one in each of the six PUBS spheres used. The completed layout is shown (Fig. 3) with the positions of major components. Briefly the circuit operates by firing a solenoid, on a given input signal, to release the brake on the tape-recorder reels. If the first attempt is unsuccessful, a microswitch on the brake will stay open sending a high to a gate of the 4081. This is an 'and' gate and after a 3 sec delay a high signal to the other input sent. This retriggers the firing circuit, as often as is necessary to release the brake.

This is one of several printed circuits I produced; a double-sided board with gold-plated edge connector requiring the most care and patience - the drill for the P.C.B. holes rotates at 80,000 r.p.m. and 400 holes on one board with attention paid to the brittleness of the bit can be somewhat taxing.

12 BIT D-A CONVERTER

At one end of the Acoustics Lab. with a bench all to itself is a Commodore PET minicomputer. This is one of the new generation of 'personal computers' that have come onto the scene in the last two years offering remarkable value for money compared to say the Nova system. By providing a VDU output for information, the PET gains on clarity at the expense of being able to produce hard-copy material. For this reason, since an ITT 'Creed' teleprinter was on hand, the building of a printout interface was an obvious way of overcoming the problem. Output ports on the PET itself made this a relatively straightforward task. The 'Creed' could not be used, however, to produce X-Y plots, and if data analysis was to be performed, this would be a highly desirable facility.

Construction of this interface required three circuit modules: an I.E.E.E. interface which had already been built for the 'Creed' output; a 'handshake' accepter logic circuit to allow communication between the PET and the modules; a 12 bit Digital to Analog converter to change the output words from the PET into analogue voltages to supply an X-Y plotter or oscilloscope.

The D-A converter circuit is shown (Fig. 4) and while made out of readily available components at a hardware cost of a few tens of pounds, can compete on level terms with commercial products at around £1000, at least for the application here.

Three dual-in-line pattern breadboards were used for mounting the components, these having 32-way end-connectors designed for wire-wrapping between pins. The boards were mounted in an aluminium box made just for this job, fitted with self-adhesive sliders to keep the boards firmly in place. For testing purposes, logic circuitry was appended to one board - an oscillator/ripple counter device that simulated when linked to the control gates of the bilateral switches, digital inputs from a single L.S.B. to a full complement of 'on' bits. When observed on a C.R.O. the output was seen to be a perfect ramp. Unfortunately time was not available for me to see this project through to completion.

WHALE-HEAD ACOUSTICS

My one venture into 'frontiers of science' research work took me into the world of marine biology and, although somewhat disappointing in results, proved very stimulating throughout.

Experiments carried out in America on porpoises have led experts to suggest that navigation and food gathering is performed using an echosounder transducer made up of layers of tissue in the front upper region of the head. Analysis of this tissue revealed variations in refractive index which it is thought might channel ultrasound from a transducer to focus on specific targets in the vicinity of the animal and again concentrate the reflected signal back to the same area for interpretation of the waveform.

Dr Bob Morris of the Chemistry Department had managed to obtain the heads of two whales washed up on the Eastern American Seaboard and had them flown back, frozen, to be stored in one of the cold-room outhouses at Wormley. Through the agency of Mike Somers, assistant head of the Applied Physics Department, I was asked to make up three transducers suitable for insertion into passageways in a whale-head, given suitable ceramic piezo-crystals; then to set up and if necessary build circuitry suitable for use with the transducers in investigating the whale-head acoustic properties.

Since the intention was to have the whale-head immersed in water while performing the experiment, complete waterproofing of the transducers was imperative. Their final mode of construction was for the piezo-crystal to be inserted at one end into a machined brass collar, this mating with a length of 20 cm of steel spring to support the wire soldered to the electrodes of the crystal. Crystals of this size, approx. 1 cm × 0.5 cm cylinder, posed difficulties in contact silver cleaning to enable a good soldered connection to be made. Watertightness was ensured by encasing the brass collar and crystal in 'Sylastic' rubber compound. This cured within 12 hours to a resilient, protective, smooth finish, a good acoustic contact between crystal and rubber being ensured so as to maximise power transfer to the outside medium.

There is a standard set up of apparatus for use in transducer measurements. A variable-frequency oscillator drives a purpose-built unit which can output a pulse of 1-100 cycles at that frequency with a user varied repeat rate. Simultaneously a trigger pulse is sent to a C.R.O. at the beginning of each pulse, so if a power amplifier is fed from the unit, a transducer attached to it will transmit the desired type of signal. It is a simple matter then to take the output of a receiving transducer through a pre-amplifier for comparison on the C.R.O. with the transmitted signal, as measured across the first transducer. This is the way that transducers are calibrated at I.O.S. and it seemed a suitable method for investigating a whale-head's properties.

It was decided to undertake two sets of measurements: a local survey of the intensity of signals found at the surface of the head, and a 'far field' set using a transducer for receiving on the end of a rotatable beam coupled to a calibrated servo-driven arc sweeper - a piece of equipment normally used for directional sensitivity measurements on transducers.

On the day agreed, one of the whales' heads was brought out of a constant temperature bath where it had been defrosting over the weekend before. Through eight layers of polythene bags the smell was unbearable and quickly filled the entire floor where it had been kept. The nature of whale tissue is that rotting occurs spontaneously after death, giving rise to a similar odour to that of aged milk. The head was taken down to the ground floor where all submersed testing takes place, a 50 cubic metre tank being available along with a cubicle in which to set up equipment.

After several hours of patient endurance of the smelly mass which had been placed in a 1 metre dia. plastic tank, and after consultation with Mike Somers, measurements were abandoned when it was realized that not enough power was available to drive the transducer used so as to overcome the attenuation caused by passage through the whale-head tissue. Furthermore, due to the smallness of the transducers, there was a marked directional characteristic at the frequency of 40 kHz used. Measurements would also have been hampered by reflections from the container sides - experimental difficulties would have been faced if the head had been immersed in the large tank, contamination of the water being another consideration.

The lessons learnt from this project were that for work involving miniature hydrophones, a large amount of attention must be paid to the directional characteristics at the frequency under consideration, and to the power amplification stage - the B & K power amplifier normally used could deliver up to 100V but this was not sufficient for our purposes. Mike Somers made an estimate of 1000V before satisfactory results might be obtained. On the constructive side, much was learnt from the dissection undertaken after the acoustic tests. The specimen, a rare pygmy whale, showed substantial evolutionary modification towards echosounding with what resembled an acoustic baffle formed from lipids found in the head.

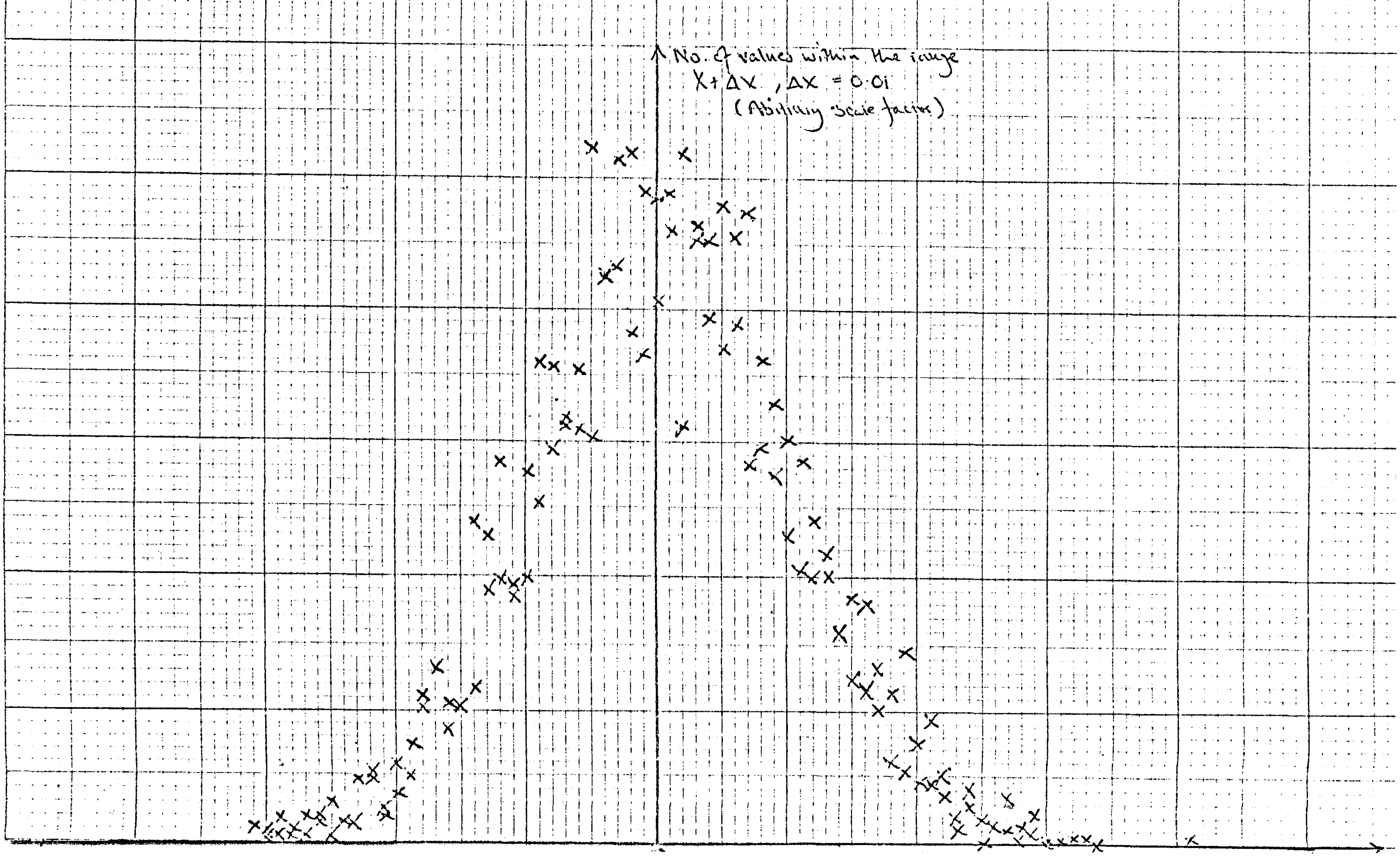
CONCLUSION

Above are described a selection of the tasks undertaken by me while on placement. In addition to those mentioned, I was involved in work in which I gained experience in metalwork, coil-winding, printed-circuit board gold-plating and numerous other useful techniques. I think that I have achieved at least a working knowledge of currently used circuit

building techniques and would like to thank all those in the Acoustics Lab. and the head of department, Dr Brian McCartney, for keeping me busy during the eight months I spent with them.

PSEUDO-GAUSSIAN DISTRIBUTION PRODUCED BY COMBINING TWO RANDOM SEQUENCES

(AFTER D.E. KNUTH – ART OF COMPUTER PROGRAMMING, VOL II)



THRESHOLD BOX CHANNEL MONITORING UNIT

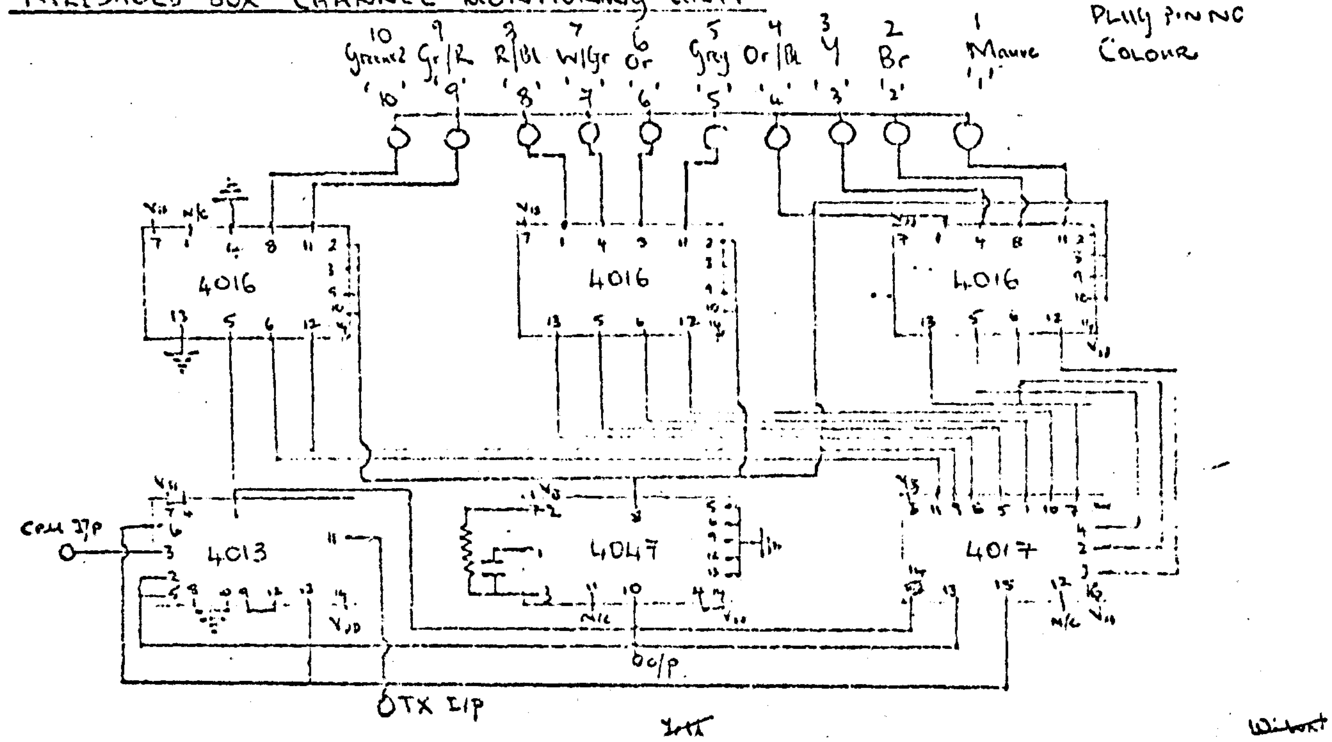


FIG 3

PUBS TAPE RECORDER P.C. MASTER

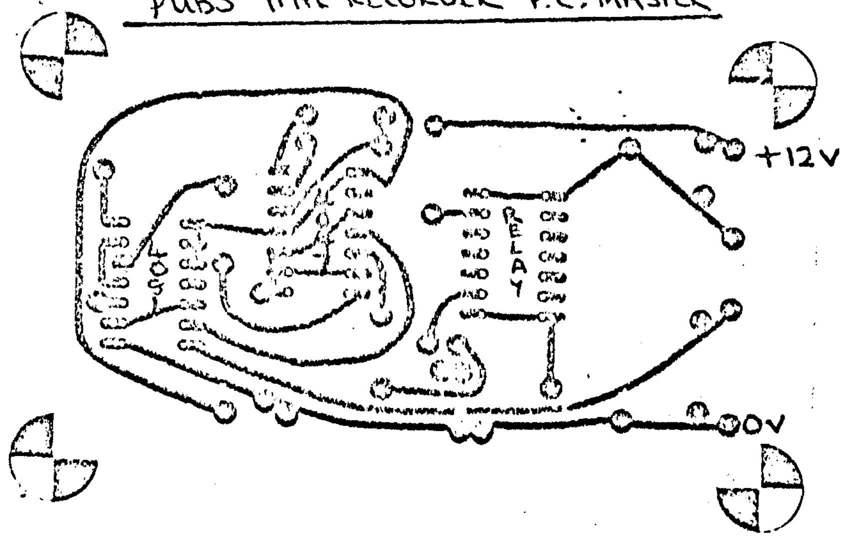


FIG 4

12-BIT D-A CONVERTER