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AN ECHO INTEGRATOR USING DIGITAL PROCESSING

by

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Introduction

The technique of Echo Integration is at present the most accurate acoustic method of pelagic fish stock assessment. It requires a good quality echo sounder with an accurate 20 log R TVG and a simple easy to operate Integrator. In the Marine Laboratory Aberdeen we have tended to rely on a Simrad EK Scientific Sounder, although any sounder with stable gain characteristics can be used.

We have produced our own Integrator the distinctive features of which are:-
Digital processing for absolute stability coupled with large dynamic range.
Numerical output displays providing clear and accurate output of all information.
An improved sea-bed reference system which is independent of the sounder repetition rate or stability.
An extremely simple set of operator controls coupled with high stability circuitry permits reliable long term operation by scientific staff unskilled in electronics.
A series of electronic outputs which are available for more complicated analysis.
A Numerical depth display.

This integrator divides conveniently into four sections (Fig 1), a) signal processing, b) channel control and sea-bed following, c) store and d) ancillary counters and interface circuits. For the purpose of the present description this method of subdivision will be used.

a. Signal Processing

The analog input in the form of an AM signal in the range 30kHz to 150 kHz is fed via a high impedance FET input stage to a halfwave detector. After the detection the signal is sampled once every metre by a Sample and Hold Module, and then converted to a seven bit binary number by an Analog to Digital converter (ADC).

Echo Integration is the summation of returned acoustic intensity. The output of the ADC, however, is directly proportional to acoustic pressure. To obtain a signal proportional to acoustic intensity the output of the ADC must be squared. This has been achieved by using Binary Rate Multipliers to generate a train of pulses, the number of which in each one metre sample interval is proportional to the square of the ADC output. The adoption of digital squaring makes it possible to utilise a very large dynamic range (40 dB) with low cost components. Accuracy is adequate. The worst case error is less than 1% of full scale. The Integrator's 40 dB dynamic range matches the dynamic range of the TVG amplifier for any particular setting of an EK Sounder.

b. Channel Control and Bottom following

This integrator is a three channel instrument. Two of these channels are surface referred with upper and lower limits adjustable in 1 metre steps between the surface and 600 metres. Should the sea-bed occur before 600 metres the depth will be displayed, and the Integrator will gate out the sea-bed echo, using a safety margin of five metres. The third channel is sea-bed referred with only the upper limit adjustable. This channel accumulates data from the distance set above the sea-bed down to five metres above it. If the sea-bed lies below 600 metres Channel 3 will act as though the sea bed lies at 600 metres. There is a bottom lock circuit which enables the Integrator to eliminate the sea-bed echo from the analysis, provided that the sea-bed does not change position by more than five metres between any two transmissions. This safety margin has proved, during two survey trips off the Scottish coast, to be sufficient without being unreasonably large. The bottom lock may be synchronised by operating a front-panel switch for the duration of one transmission. This should be done over an area where fish concentrations are small enough to avoid the production by the echo sounder of spurious "bottom pulses". The system will then accept as fish any target which is shallower than that depth, or any subsequent depth defined by change in terrain. Should the bottom be lost, then after eight consecutive transmissions the integrator will search downwards. If it finds the bottom it will automatically relock. Should it fail to do so after a further eight transmissions, then it will open up to 600 metres. It will then remain in that state unless the bottom rises up through 600 metres. Should the bottom have been lost because it rose too rapidly, the data would already have been completely invalidated, and it would have been obvious to the operator that the integrator required resetting. If the bottom is initially out of range the circuit will automatically lock on to 600 metres

The limits of all three channels are marked automatically on the paper traces so that comparison in later analysis is possible.

c. Store

Each channel is allocated one of three identical store/display units. These have nine decades with the two least significant decades suppressed and the remaining seven displayed. The results appear as accumulating values which are updated once every transmission.

d. Ancillary Counters and Interface Circuits

There are two further stores with displays, one indicating the number of transmissions, and the other the number of overloaded samples. The latter information is a record of the number of times the electronic signal has entered a non linear region within the analysed intervals. This is used as a measure of the validity of the data. Should an overlead occur the full scale value for that sample will be added to the relevant channel stores. There are also two visual warnings, one indicating the prescence of an overload during the transmission under analysis, the other that a bottom pulse has failed to arrive within the range gate.

Operator control functions are:

1. A start function which clears all stores and allows integration to proceed.
2. A stop function which holds all displays constant so that they may be easily read.
3. An inhibit function which must be used should changes in channel depth limits be required during the integration period.

Under normal conditions all displays are updated at the end of each transmission so that they are easily read during analysis.

The integrator has a series of electrical output facilities.

1. Stop-Start lines may be drawn across the sounder paper.
2. Channel position lines may be drawn along the paper.
3. TTL compatible end of transmission pulse.
4. Three channel signals in the form used to drive the stores, These signals consist of trains of TTL pulses with maximum frequency of 15 MHz.
5. A TTL level which defines integrating and stopped states.

These outputs can be used to give real time computer analysis, storage on paper or magnetic tape, or display as a single transmission integral.

Operation

This equipment has performed well on two acoustic surveys, one for Blue Whiting off the western edge of the continental shelf, the other for Sprats to east and west of Orkney. Figure 2 shows an echo trace obtained in an area on the south west of Rosemary Bank during the Blue Whiting survey carried out by FRS 'Explorer' in March and April 1975. Above the trace is the corresponding log sheet. The main fish trace at a depth of 400 metres is Blue Whiting, below which are the two lines indicating the bottom following channel. As can be seen from the log sheet this was set to 50 metres. The upper edge of the white lined sea-bed trace appears 5 metres below the lower limit of the bottom following channel. The line indicating the upper limit of channel 2 appears at 275 metres. The two vertical lines on the left indicate the end of the previous integration period and the start of the current one. The remaining horizontal lines are 100 metre spaced scale marks generated by the sounder. The scattered trace at 100 metres is believed to be Myctophids and Pearlsides.

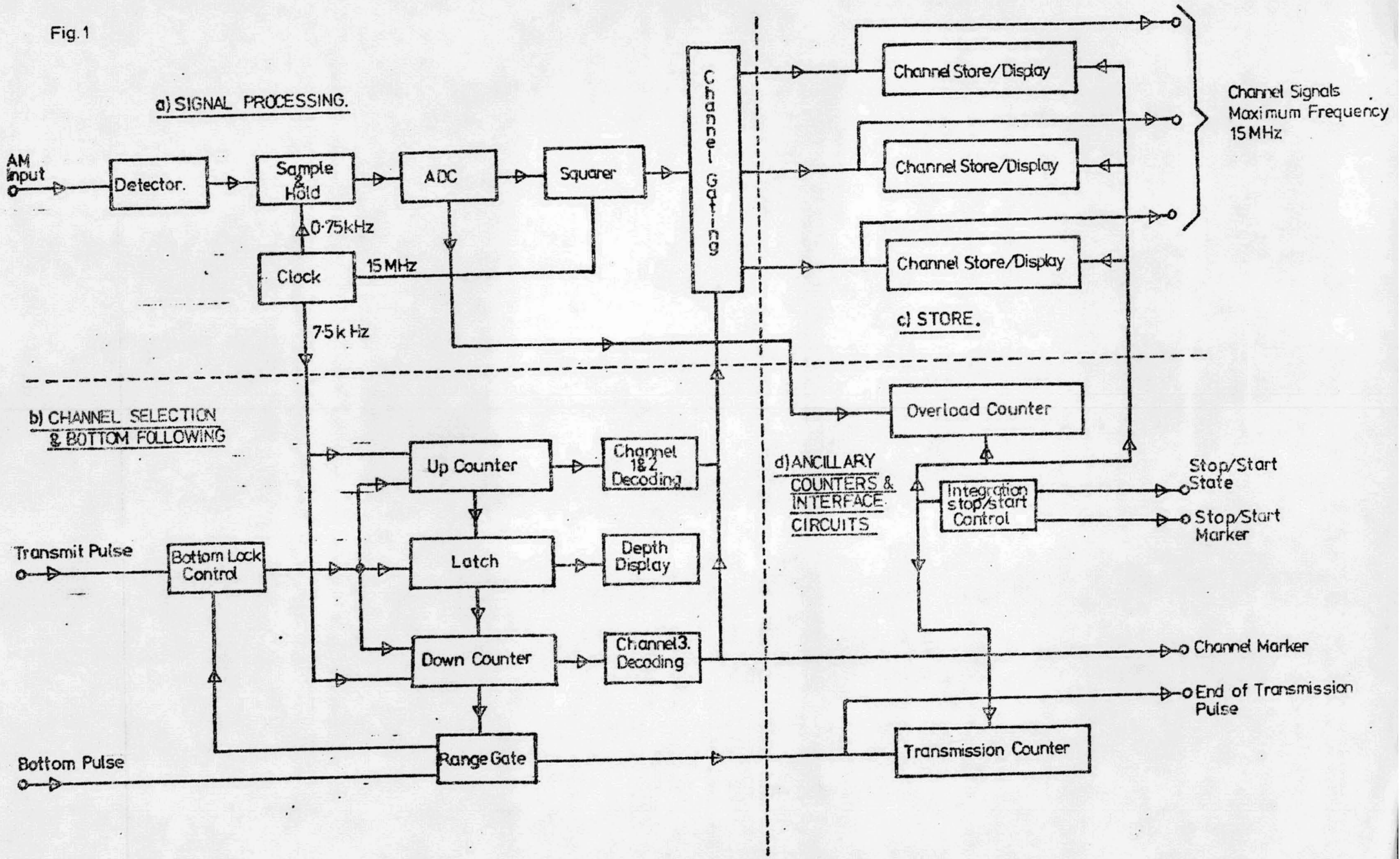
During the survey the assumption was made that all received acoustic intensity from 275 to 600 metres or the sea-bed was Blue Whiting. The data are read from the Integrator at the end of each run and recorded on the log sheets under "Channel Contents", "Trans" (The number of transmissions) and "Overloads" headings. Also recorded are the settings of the EK sounder. To obtain density information or a population estimation from these readings requires only simple arithmetic. The integrator value is divided by the number of transmissions and multiplied by the system constant "K". This gives an average density for the integration period in Tonnes/km^2 of surface area. The constant "K" is obtained from an acoustic calibration of the complete system and a knowledge of target strength for the particular species of interest. The acoustic calibration is carried out several times during a survey to check that the system performance is constant.

The ease of operation of the integrator and the convenient form in which its output is presented have enabled useful results to be produced with the minimum of delay. Circuit stability is such that since initial setting up no adjustments have been necessary over a period of three months. Reliability has also proved to be excellent.

In conclusion this instrument is proving to be a very useful tool in pelagic fish stock assessment.

Thanks in particular to S T Forbes for the bottom following circuit, W I Dunn for the signal processing ideas and R E Craig and J Richards for help with overall function requirements.

Fig. 1


a) SIGNAL PROCESSING.
AM input
Detector.
Sample & Hold
ADC
Squarer
0·75kHz
Clock
15 MHz
7·5 k Hz
Channel Gating
Channel Store/Display
Channel Store/Display
Channel Store/Display
Channel Signals Maximum Frequency 15 MHz
c) STORE.
Overload Counter
b) CHANNEL SELECTION & BOTTOM FOLLOWING
Up Counter
Channel 1&2 Decoding
Latch
Depth Display
Down Counter
Channel 3. Decoding
Transmit Pulse
Bottom Lock Control
Bottom Pulse
Range Gate
d) ANCILLARY COUNTERS & INTERFACE CIRCUITS
Integration stop/start Control
Stop/Start State
Stop/Start Marker
Channel Marker
End of Transmission Pulse
Transmission Counter

ACOUSTIC SURVEY LOG SHEET

VESSEL	DATE	DAY NUMBER	RANGE / PHASE	TVG / GAIN	REC / GAIN	BANDWIDTH / PULSE LENGTH	OUTPUT POWER	K
'Explorer'	6/4/75	96	C/1	20logR/0dB	3	Narrow/4	1/1	6·93

START OF RUN TIME	START OF RUN POSITION	DISTANCE	CHANNEL SETTINGS			CHANNEL CONTENTS "A"	TRANS "B"	OVERLOADS	A/B	TONNES / Km² (A/B x K)	A/B x K x D	COMMENTS
20 00	59° 14'N	5 Nm	CH1	0	600	7491	630	/	11·86	82·18		
			CH2	275	600	7261			11·52	79·83		
	10° 12' W		CH3	50	/	332			0·52	3·6		

Fig. 2