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A Digital Echo Integrator for Fish Stock Assessment

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by

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Introduction

During the past few years the technique of Echo Integration has become the most accurate acoustic method of estimating pelagic fish stocks, and the method is now sufficiently well established to be a useful tool for the marine biologist. At the moment it is possible to obtain relative population estimations for any particular area, to a high degree of accuracy, provided that a simple calibration is carried out at regular intervals. Accurate back scattering strength figures can convert relative to real values, and although a great deal of work with fish back scattering strength still remains to be carried out, this work can be carried out independently of the surveying and the results then applied. Thus to enable the development of survey techniques to advance it was decided to design and develop an Echo Integrator. This was to be simple and easy to operate, allowing scientific staff unskilled in electronics to participate more fully in the survey work. To maximise stability in high vibration conditions T.T.L. digital circuitry has been used whenever possible. The analog circuitry has been designed to require the minimum of adjustment once the initial setting up has been completed.

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

a) Signal Processing

The output of the echo sounder should be proportional to acoustic pressure and independent of range. This means that a 20 log R + $2\alpha R$ TVG should have been applied. The schematic circuit shown in Fig 2 shows all the analog circuitry, frequency compensation and decoupling components having been omitted for clarity. The input impedance of 200 k is high enough to avoid loading of most output circuits. The gain is set at the input so that all the other stages then automatically work with optimum signal levels. The detector works over a range of 30kHz to 120kHz; although the gain changes over this range the linearity remains within 0.5 dB over the full 40 dB dynamic range that can be expected from analog TVG amplifiers. The differential amplifier performs the addition to produce full wave detection and a gain correction to match the Sample and Hold and A.D.C. The detector produces a small positive offset but this lies below $\frac{1}{2}$ L.S.B. of the A.D.C. and does not affect the results. The low pass filter removes the ripple on the detected signal to less than $\frac{1}{2}$ L.S.B. The A.D.C. is 8 bit binary with a maximum conversion time of 200 μ sec. Only 7 bits are used for the signal. The sample rate of 0.75 kHz means that the system is suited to pulses of greater than 2.6 millisec. Shorter pulses may be used where higher variances in the results are tolerable or when the total number of samples from the area of interest is large enough to reduce this variance.

The integrator is almost unaffected by noise. For shallow waters where the noise level is high the T.V.G. characteristic does not increase the gain enough to bring peaks of noise up to L.S.B. Using a Simrad EK 38 sounder with a towed body noise is integrated beyond 300 metres but contributes less than 0.5 tonnes/km^2 to an estimate of fish population.

The output of the ADC is proportional to acoustic pressure; to obtain an output proportional to fish density the signal must be squared (Fig 3). The digital signal is fed in parallel to two 7 bit binary rate multipliers in series which are then supplied with a burst of 16384 (2^{14}) pulses at 15 MHz. The output is a train of pulses the number of which is equal to the square of the parallel binary input. The total integral from surface to sea-bed is the sum of all the pulses formed from all the consecutive samples. This can be gated in time to produce integrals from predetermined depth slices.

b) Channel Control and Sea-Bed Following

Fig 4 shows a basic block diagram of this system. The three counters in the centre of the diagram provide all the basic information. The first counter increments starting from zero at the transmit pulse, at 0.75 kHz (1 metre steps) until a bottom pulse is received. The echosounder produces bottom pulses whenever the range corrected signal level exceeds a discriminator setting. It is possible for dense shoals of fish to produce unwanted bottom pulses so once the bottom has been located the distance in metres (the value in the first counter) is stored in the second counter and then updated every transmission. At the start of each transmission this value is loaded into the third counter, which then counts down in synchronism with the first thus arriving at zero where the sea-bed occurred on the previous transmission. From this counter a range gate between plus and minus five metres is generated and only bottom pulses arriving within this range gate are accepted. It has been found that this margin is sufficient to remove most unwanted pulses and still allow the system to follow the sea-bed. Should no bottom pulse occur within the range gate then the content of the store remains unchanged and a warning indicator lights until the start of the next transmission. Should no bottom pulses occur within the range gate for eight consecutive transmissions then the range gate will open downwards. If after a further eight transmissions no sea-bed has been found the system will lock on to an imaginary sea bed at 600 metres. The content of the sea-bed store is displayed and this can be used as a check. All sampling is stopped at the top of the range gate. Should the sea bed rise too rapidly (more than 5 metres between transmissions) then the data will be invalid and the integrator will require resetting.

The channel control pulses are also decoded from this system. Counter one is decoded and used to define two surface referred integrating channels. The third counter is decoded and used for a bottom following channel. For each control pulse three B.C.D. decades are decoded by a set of three 10 line decoders and then passed through two sets of three 'one of ten' selector switches. The outputs of these switches are 'Anded' to produce start or finish pulses and these then set and reset a flip-flop to provide the gating pulse. The three channel control pulses gate the train of pulses provided by the squarer and thus produce three separate pulse-trains. Each channel may be set to any width up to 600 metres and at any position from 0 to 600 metres.

c) Store

The store and data display are in three identical sections, one for each channel. Each section is a nine decade BCD counter of which the seven most significant drive 7 segment L.E.D. displays. To hold the display steady for easy reading the output of the counters are latched and updated at the end of each transmission.

d) Ancillary Counters and Interface Circuits

To enable the operator to assess the validity of the results the M.S.B. of the A.D.C. is used to define an overload and the number of overloaded samples is displayed. When an overload has occurred a warning indicator lights until the start of the next transmission.

The total number of completed transmissions from the start of the integral is displayed. This is required to normalise the integral and to allow the results of adjacent runs to be compared.

The sounder produces a 'transmit' pulse and a 'bottom' pulse. The integrator uses these to derive the basic timing. Both pulses must be long enough to include one complete cycle of the clock (0.13 msec) and the 'transmit' pulse should be long enough to blank the system for the duration of the transmitted pulse.

There are two outputs from the integrator associated with the sounder. One is a marker pulse which marks the paper when a run is started or stopped. The other is a series of pulses which mark the limits of the three channels on the paper. The intensity of the latter may be preset.

The operator controls of the integrator are a start function which clears all the counters and allows the integral to accumulate and a stop function which latches all the displays. There is also an inhibit function which enables the operator to temporarily hold the integral so that any of the settings of the channel selection switches can be changed. These functions only involve the integration and all the timing fuctions continue undisturbed.

Conclusion

This Echo Integrator has been used on three surveys and has performed well on all three. We have at the moment a production order out for four instruments. One will go to the Ministry of Agriculture and Fisheries Laboratory at Lowestoft and it is hoped that a further one will go to UNFAO in Mexico.

I would like to thank all the other members of the design team, in particular Messrs W I Dunn and S T Forbes, and the director of the Marine Laboratory for permission to present this paper.

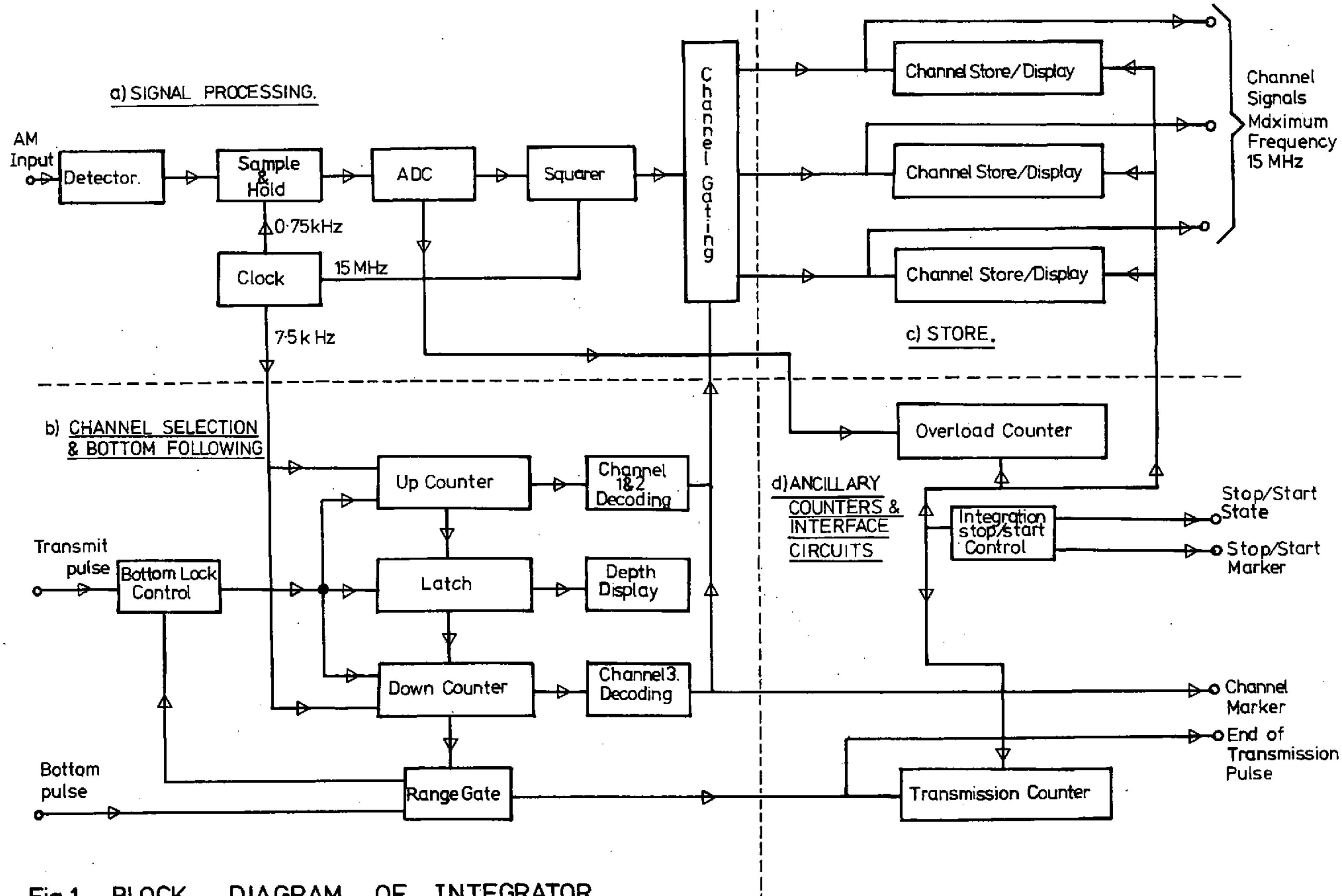

Fig.1 BLOCK DIAGRAM OF INTEGRATOR

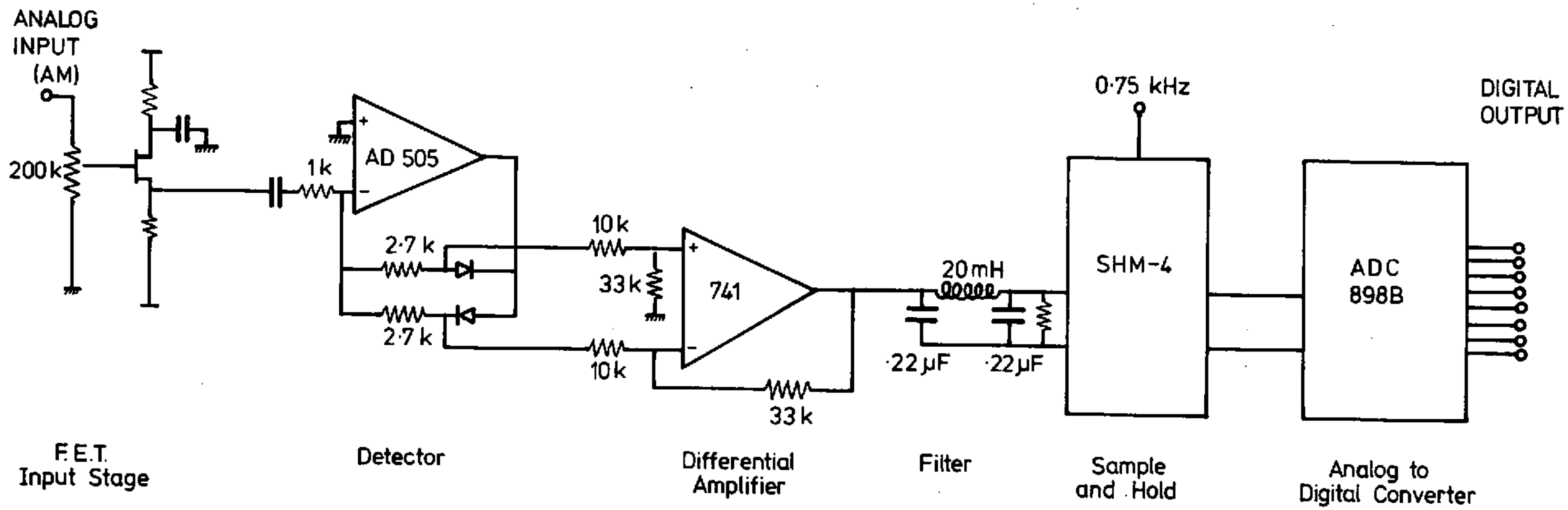

Fig 2 Analog Circuit

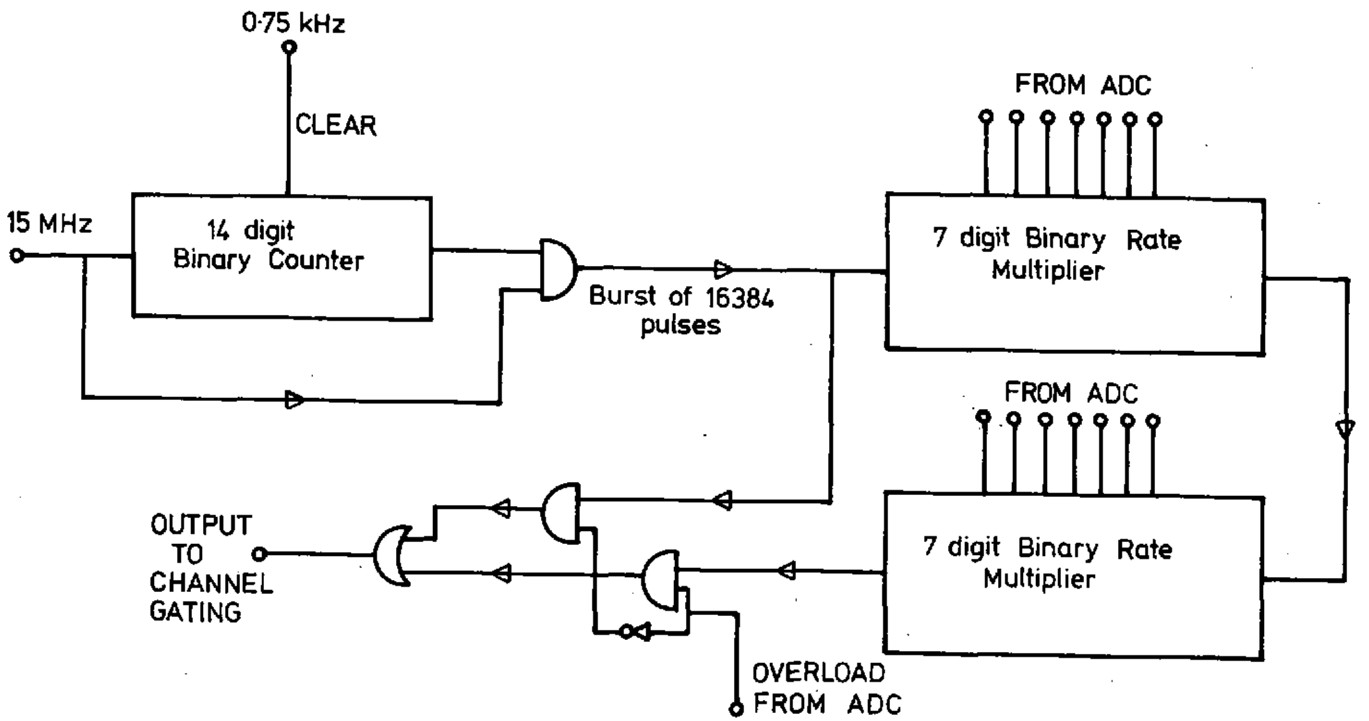

Fig 3 Squarer

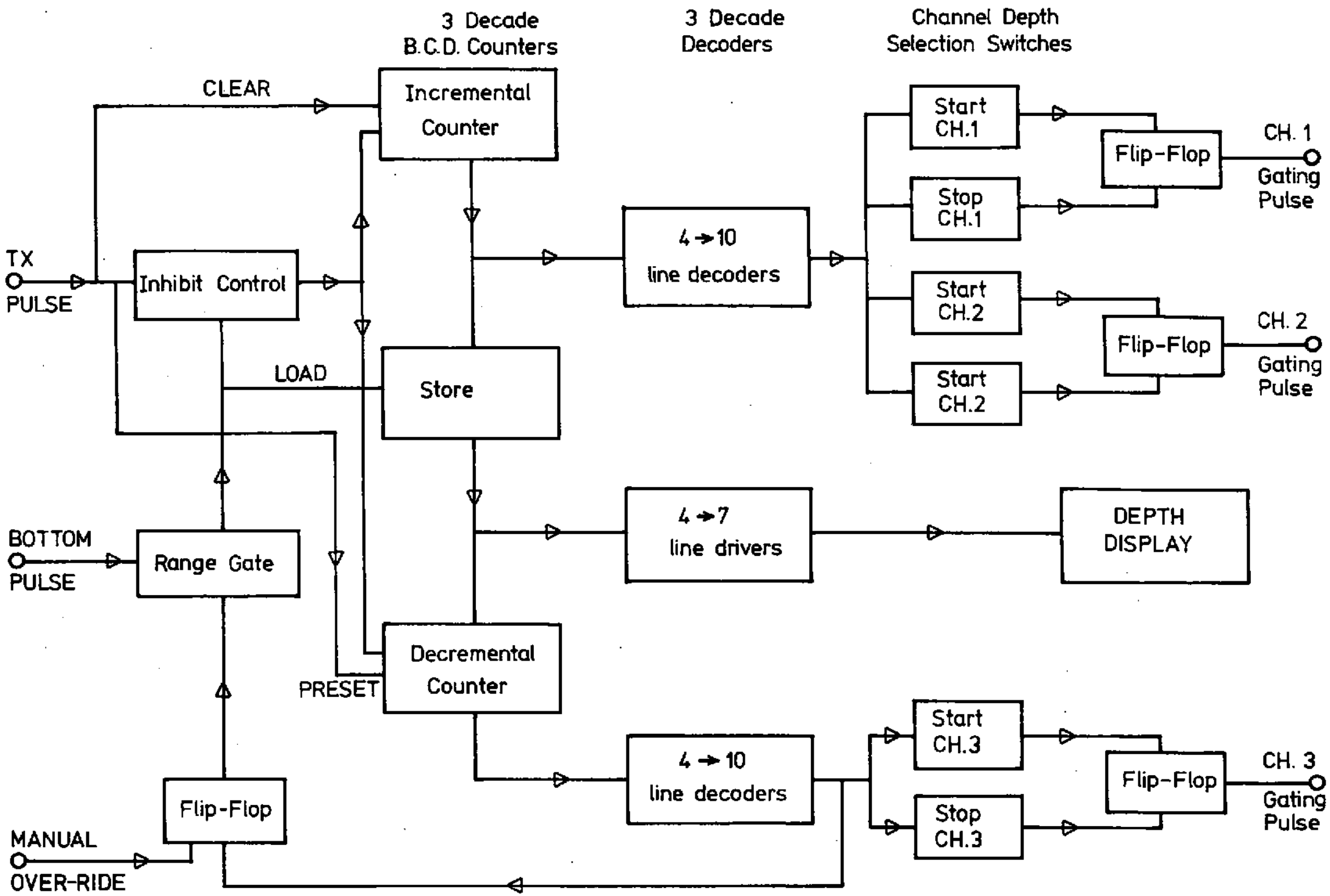

Fig 4 Sea bed following and Channel Selection